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Learning Analytics for Formative Assessment in Engineering Education*

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The development of skills in the engineering education is one of the issues that generate greater interest at present. Thanks to Learning Analytics, we found an excellent opportunity to offer a quality competence assessment of our engineering students. Research in Learning Analytics currently focuses on applying these techniques to find out how the student learns and to improve teaching/learning processes. A key aspect in improving these processes is the assessment of general competences, which constitutes key learning in engineering students and has thus been identified as a need that can be met by Learning Analytics. This article presents two related studies conducted at the University of Deusto. The first study wants to show that it is possible to carry out an assessment of the project management competence through the analysis of the data that is obtained when the students interact with certain tools for the management of projects. In this sense, in the first study conducted with 93 students in the academic year 2014–2015, it compares the automatic assessment performed with Learning Analytics and the manual assessment carried out by the teacher. Another objective of this first study is to compare the validity at the time to assess the project management competence of the three technological tools used in the study. In the second study conducted with 227 students in the academic year 2015–2016, an assessment model is designed based on analytical data that is extracted from even more complex technological tools. In this second study the objective is to demonstrate that the use of Learning Analytics assessment to carry out continuous monitoring and provide feedback to the students, directly influences their capacity to manage a project and therefore, leads to an improvement in their results. The model designed in both studies for analysis is described in this paper, in addition to the methodology and research carried out.

Keywords: learning analytics; project management; formative assessment; competence assessment; engineering education; self-regulated learning

1. Introduction

Currently, degree titles adapted to the European Higher Education Area must integrate into their programs a training profile in transversal and specific competences. In addition, European quality standards stipulate that students should be clearly informed about the assessment methods and criteria that will be used to assess their performance. In this sense, it is a clear challenge to define systems that consistently evaluate the development of these competences [1]. This is the starting point for the assessment of competences in one of the main focuses of attention of the higher education centres. In addition, competence assessment is not only a fundamental dimension in student learning, but also, from an institutional point of view, the competence assessment is associated with the extent to which the university manages to get its graduates to be proficient in its training profile and offers indicators of the returns of the efficiency of the training processes. Therefore, there is a high level of interest among teachers who need competence assessment systems to evaluate the performance of their students and even more among the institutions that see an important quality indicator in the results of their assessment of student competences. More specifically, on engineering degree courses special attention is paid to general competences such as time management, teamwork and project management. These competences are the ones that will enable the student to stand out over others in their future careers and obtain greater success [2]. In many engineering jobs, what counts most is not just the knowledge gained but also which competences students have acquired or what work experience they have when overseeing projects, working in multidisciplinary teams and planning in order to achieve certain objectives.

Thanks to new areas of research such as Learning Analytics (LA), a clear opportunity has been identified to transfer to assessment the benefits provided by other studies carried out such as data analysis in the field of education. LA started off being an area of academic data exploitation that tended to focus more on student participation, the use they make of certain resources and access to online Moodle-style platforms [2–4]. In a second phase, LA evolved into other uses that focused more on ascertaining how students learn, and new applications are currently being discovered by means of which knowledge may be obtained via LA in order to improve students'

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learning process [5, 6]. In this sense, it provides an excellent opportunity if these same LA techniques are applied to student assessment, especially in assessing the development of transversal competences. LA offers institutions the opportunity to enrich training processes by personalizing them [7]. One way of personalizing these processes is to optimize the assessment systems by offering tools that support teachers in monitoring their students, and the students themselves in knowing how to improve and regulate their own learning; and this can be done by optimizing digital environments with the tools of LA [8]. This is the main objective pursued by this research, designing competence assessment models based on the integration of LA tools in the learning environments of engineering programs.

Within the engineering programs, regardless of the specialty, students must acquire a series of competences and demonstrate their mastery in the development of different tasks. One of these tasks, which occupy a great part of student performance in engineering, is project management. In project management the student can demonstrate the dominance of various competences such as planning, resource utilization, information search, teamwork etc. Currently there are several technological tools that facilitate the task of the students in project management, but there are no assessment systems or tools that supervise the students' work, which show their mastery of competences and, in short, that provide information about their learning.

In order to assess competences, teachers need to control many variables, not just the acquisition of knowledge. Rubrics-based systems are incomplete when it comes to evaluating all the learning objectives, and if they have to be complemented with other traditional methods, it is very laborious for teachers when they have a class of more than 30 students. To cover the detected need, during the academic year 2014–2015, a study was carried out that focused on assessment of the project management competence on five degree groups from the Engineering Faculty at the University of Deusto. To this end, a series of technological tools were proposed that will be described later in this paper, and an analysis taken from student interaction with these tools was carried out using LA techniques. This data was used and subsequently contrasted using a rubric-based assessment system. The research question we are concerned with in this study (RQ1) is: *Can LA techniques support to the teacher in assessing the project management competence from data obtained from students' interaction with technologies?*

Later, during the academic year 2015–2016, another study was carried out with 7 other groups from different degrees and faculties of the University of Deusto. In this second study, LA techniques were again used for evaluating the project management competence by analyzing the data extracted from various tools and a further step was taken by adding a continuous assessment system with feedback for students. The research question in this second study (RQ2) is: *Does facilitating continuous assessment of competences through LA techniques, positively influence obtaining better levels of competence development?*

In Section 2, we analyse previous studies in the area of interest that we consider as reference points when defining the LA model for competence assessment. The methodology, the sample of each study and the LA techniques are described in Section 3. Section 4 shows the results obtained from both studies, with a discussion about these results provided in Section 5. Lastly, Section 6 contains the conclusions drawn from the study together with future lines of work that remain open for subsequent studies.

2. Background and related work

Once the new learning model based on the acquisition of competences came into force, all university degree syllabuses were readapted, with new teacher and student concerns thus arising. Teaching staff demand new teaching and assessment methods which are adapted to this new system, while students demand more specific criteria that enable them to know how they are going to be assessed in their learning. In 2005, the OECD defined competence as referring to a combination of inter-related practical and cognitive skills, including emotions and other special aspects, that may make it easier for citizens to contribute to the knowledge society [9]. This new concept of competence focuses on learning outcomes, on what the student is capable of doing on completion of a training process, and on procedures that will enable them to continue learning independently throughout their life. Thus, an individual will be deemed competent if they are able to put their knowledge, skills and experiences into practice when faced with a new situation or dispute and successfully deal with it [10, 11]. A great variety of subjects are taught on the different engineering degree courses which in one way or another seek to achieve this same objective. However, the mere acquisition of knowledge does not ensure that the student is prepared to face certain challenges within a professional environment.

Apart from being duty bound to adapt their syllabuses, higher educational centres must also be equipped with procedures that enable them to ascertain whether the ultimate goal of the actions they embark on is to favour student learning [12]. In this sense, assessment procedures also need adapted. Assessment is defined as a system comprising processes that gather, analyse and interpret valid and reliable information, which in comparison to a reference or criterion, enables us to reach a decision that favours improvement of the subject being assessed [13]. More specifically, competence assessment implies generating relevant information and using a tool that enables us to manage the integrated acquisition of knowledge [14]. Competence assessment in higher education should at least include the following features [15]: they should be *valid*, to measure the evidence of achieving the learning outcomes as specifically as possible; *reliable*, to guarantee that marking criteria are designed with a sufficient degree of accuracy; *demanding*, to guarantee that the performance standards required are maintained; and *efficient*, the time set aside for correction by teaching staff must be more or less in proportion to the importance of the work within the syllabus.

Several authors coincide in maintaining that competence assessment needs to be of a formative, procedural nature and based on evidence [16, 17]. Thus, the most common methods that have tended to be used to assess competences have been the portfolio, observation protocols and rubrics [18, 19]. Based on these assumptions, the rubric is taken as a reference in the assessment of the studies in this investigation, and in the second study a model of formative assessment of LA is proposed, which integrates internal feedback reports for the students.

Formative assessment has the function of informing the student and the teacher [20]. The information provided with the formative assessment is especially useful when it is available before or during the learning process. In defining a formative assessment, if the focus of attention is placed on the student himself, and not so much on obtaining indicators of progress for the teacher's supervision, can generate enriching experiences of self-regulation of learning. Self-regulation is defined as an active process in which subjects establish the objectives that guide their learning by trying to monitor, regulate and control their cognitions, motivations and behaviours with the intention of achieving these objectives [21]. Feedback plays a crucial role in regulating learning processes. When feedback is well formulated it can help students to be aware of their thinking, to be strategic and to direct their motivation towards goals [22–24]. The fact that a student actively engages in learning or opts to dissociate or abandon the task is governed by motivation, which is a self-regulatory choice. Several studies conducted on feedback in virtual learning environments have shown that the way students receive feedback is one of the most important factors in improving learning experiences [23–25]. There are even studies that have shown prediction rates for declining school performance thanks to continuous assessment systems in LMS environments [26]. In this sense, the greater or lesser success of a feedback system based on data analytics, will depend on the prediction capacity of the data, the relevance of the information and the perception of the student of such information. There are several authors who are committed to using LA techniques to facilitate feedback to students, since they see improvements in learning processes and since they can predict patterns of success in learning [27].

Effective feedback should provide sufficient detail, it should be focused on the performance of students and not on their personal characteristics, and it should be given at a point in time when the students are still working on carrying out the activity, so that they have time to realize where they are failing and can receive help from the teacher to improve [28].

2.1 The project management competence

The project management competence is defined as the planning, management, leadership, coordination, programming and control of all resources (individuals, materials, machines and method) needed to comply with the technique, costs, time and quality-related factors of a given project [29]. This is an essential competence in engineering syllabuses, given that it is related to other competences and skills such as teamwork and problem-solving, and that it forms part of the typical work carried out by an engineer [30]. According to ABET criteria, students who complete engineering need to be equipped with certain skills, such as being able to design processes that meet certain needs, working in multidisciplinary teams and identifying and dealing with problems [31]. These skills form part of the very definition of the project management competence. Organisations demand engineers with the competences required to identify strategic projects by exploiting resources and opportunities, identifying needs and participating effectively in multidisciplinary teams. Universities therefore seek to equip new engineers with the skills needed to enable them to design, plan, implement, administer and run strategic projects [2].

When assessing this competence, it is important to ascertain what the currently valid conceptual frameworks are with regard to project management, given that the indicators deemed relevant for assessment purposes are going to be established. In this sense, we currently have at our disposal two frameworks that can be considered reference points in project management at an international level: on the one hand, the PMBooK® Guide, (A Guide to the Project Management Body of Knowledge) which was first published in 1987 by the PMI® (Project Management Institute) [32]; and on the other, the ICB 3.0 (IPMA Competence Baseline 3.0) published by the IPMA (International Project Management Association), which was defined in 2009 [33]. Both theoretical frameworks define the areas of knowledge, levels of performance, competences and skills with which a good project manager needs to be equipped.

2.2 Learning analytics

Thanks to the use of ICTs and virtual learning environments, a large amount of data is being generated about student performance, their interactions, relations and the processes they carry out. The application of LA methods to analyse and process this data offers new opportunities for improving assessment processes. LA involves using data about the student's activity which, via certain analytical models, enables us to discover information about their social relations, predict learning outcomes and advise about such learning [34–36]. There are several definitions of LA, though all of them coincide in using data from the educational context in order to find out more about, understand and improve learning/teaching processes.

There has been wide-ranging research into the area of LA, covering applications such as learning about the preferences of students in choosing a Learning Management System (LMS) [3] and student satisfaction based on their interactions [4], adapting learning behaviour-based training courses in order to identify students at-risk, i.e., students who require temporary or ongoing intervention in order to succeed academically [37], and ascertaining how students interact with the materials used on a course and guiding them via reminders and notifications [38, 39]. In the field of assessment, there are LA-based systems that provide immediate feedback to students about their answers to a questionnaire with a view to improving their motivation regarding the activity and learning [40], systems that analyse and assess how students learn in the programming subject [41], and there are also some prior experiences of LA being used to assess the general teamwork competence based on contributions made to forums [41–43]. There are few cases of work involving LA being used to assess general competences, and one of the main limitations of this type of study is the difficulty faced when defining indicators and objective criteria to parameterize students' skills. In this study we focus precisely on this work that involves defining specific descriptors for different mastery levels of each indicator of the competence in question and transforming them into data analysis.

This research work has been designed taking as reference the theories of competence assessment and self-regulating learning, the models that are international benchmarks in the definition of the project management competence, the LA techniques for processing and studying the data, and the technological tools in common use among university students. The challenge facing this work involves demonstrating the fact that the use of technological tools to develop a project—whether of an individual or group nature—generates data regarding student interaction which, once processed and analysed using LA techniques, enables us to obtain information about the level of competence development based on the project management competence and, therefore, may help the teacher to obtain objective indicators for such competence development. And on the other hand, demonstrating that training assessment based on the provision of intermediate feedback reports to the student on their level of competence development, obtained through data analysis, gives them a better mastery of the competence.

3. Empirical studies

This article presents two related studies that seek to verify how to provide an assessment of the competence-based development of project management through the data provided by technological tools. The first study presents an assessment model based on the use of a technological tool for the design of Gantt charts within engineering projects. In this first study a comparison is made between three technological tools used by students in the design of Gantt charts, and a contrast is also made between the assessment obtained by the LA model automatically and the assessment carried out manually by teaching staff.

The results of the first study have motivated the development of the second research study. In fact, he comparative analysis of the 3 tools has been made to know what tool is the most appropriate for carrying out an analysis more advanced of the competence assessment. Therefore, the tool used in the second study is Gantter. In addition, in the second study there is extended the number of indicators of the competence and will take into account data from two complementary tools used by the student to the planning and development of the project.

In the second study, an assessment model is designed based on analytical data that is extracted from even more complex technological tools. The unique feature of the second study is that data are taken from several tools for the assessment of the same student. Normally several tools are used for the development of a project, all of which provide relevant information about how students manage a project, so it is essential to capture that information and take it into account in the assessment. In this second study, a different objective is sought: that is, to demonstrate that the use of LA assessment to carry out continuous monitoring and provide feedback to the students, directly influences their capacity to manage a project and therefore, leads to an improvement in their results.

3.1 Study 1: Comparison between teacher assessment and Learning Analytics assessment

3.1.1 Research design

In the first study the research question (RQ1) is: *Can LA techniques support to the teacher in assessing the project management competence from data obtained from students' interaction with technologies?* The methodological approach of this research is a mixed approach due to the objectives raised and the nature of the data. On the one hand the study is carried out from a quantitative approach to carry out the analysis of the data and to validate and to observe the competence assessment from the data. And on the other hand, a qualitative and interpretive approach appears at the time of knowing how the teachers value the use of LA for the competence assessment.

3.1.2 Population and sample

The sample of the research is a non-probabilistic sample and with regard to the purposes and the needs of the study. In the first study, a sample consisting of five groups of students and five teachers was selected, with a total participation of 98 people in the study. All the groups of students belong to the Faculty of Engineering of the University of Deusto. The sample has been selected according to the requirements of the study, that is, groups of students have been selected whose degree programs include the project management competence at Levels 1 and 2. Therefore the sample consists of 93 students, 5 teachers and 43 projects. The students are aged between 18 and 21 years old. The population of this study are all university students enrolled in some degree of an engineering faculty.

3.1.3 Variables and measure instruments

In the first study the independent variable is the agent assessor of the competence, that is to say if the assessment is realized by LA or by the teacher. Another independent variable in this first study is the type of technological tool used that can be: Gantter, MS Project or Google Calendar. The dependent variables are the grades of the final assessment and the grade of each one of the indicators of the competence in the rubric.

For the design of the assessment model in both studies, we have taken as reference the framework of competences of Aurelio Villa and Manuel Poblete [45], since this is the theoretical framework that is implemented in the University of Deusto, besides being aligned with the specifications of the Tuning project; and other international reference models such as PMBook and ICB3 [32, 33]. Based on these reference models, an assessment rubric is designed with 5 indicators and 3 levels of mastery for the first study.

Table 1. Rubric of Study 1

Level of mastery 1			
Indicators	**1**	**2**	**3**
1. Defining actions.	Specifies actions without establishing who is in charge.	Specifies actions and assigns those in charge.	Specifies actions and sub-actions and assigns those in charge.
2. Planning.	Foresees the approximate time required.	Plans the time required for actions in detail.	Includes a forecast of additional time for unforeseen circumstances.
Level of mastery 2			
Indicators	**1**	**2**	**3**
3. Exploitation of resources.	Does not specify which resources are used.	Integrates available resources.	Rates the efficiency of the resources used.
4. Monitoring mechanisms.	Makes no mention of monitoring mechanisms.	Partially plans monitoring mechanisms.	Plans by whom, when and how the monitoring will be undertaken.
5. Foreseeing risks.	Existence of risks not taken into consideration.	Recognizes possible risks without specifying when or how to deal with them.	Identifies possible risks, foresees their impact and proposes measures.

3.1.4 Procedure

Phase 1: Teacher training

In the first place we organize with the teachers how the student's work is going to be. The teacher is responsible for providing the students with an informed consent document, which they must collect after it has been signed by the students, and another one containing instructions for the activity.

It is essential to describe a pattern of activity that allows the same guidelines to be followed in each group of students, in order to guarantee validity and consistency in the research. For this an activity model is defined with a series of specific guidelines for each type of tool: one for Gantter, one for Google Calendar and one for Microsoft Project.

Phase 2: Assessment by Teachers

Once the teachers know the activity and have all the instructions to carry it out in class, they are provided with a tool to perform the assessment, consisting of an Excel file with different sheets or tabs. Each tab corresponds to a project, since what is going to be evaluated are the projects. In the Excel file, the teachers have a simplified rubric for each project of their class and they have to use that template to evaluate their students and give them a 1, 2 or 3 according to which descriptor of the indicator best reflects the work they have done. Thus, the data recorded by the teacher in this template can be compared via the data extracted from LA.

Phase 3: Final questionnaire for teachers

The objective of this questionnaire is mainly to find out whether teachers value LA as a resource to facilitate the competence assessment in the classroom. It also helps us to know whether the teachers have previously used these technological tools to work on the project management competence in the classroom and whether they would use it again. It consists of an open-ended question form, closed questions and questions for assessment via scales from 1 to 4. The questionnaire has 12 items of which the first 6 are control questions to guarantee the data of the sample, i.e., questions related to the tool used, the subject and the number of students.

3.1.5 Data analyse using learning analytics

The general phases of an LA-based research methodology are: data collection, filtering of the most significant data, data analysis and decision-making based on the data analysed [26]. Therefore, a main phase in the application of LA methodologies for competence assessment involves mining all the data attached to the student's activity and selecting the most significant data that may help us to obtain evidence about each competence indicator.

The process of analysing data for learning has been different in each study, but in both cases the different phases of the process have been respected: data collection, filtering of the most significant data, data analysis and decision making based on the data analysed. In the first study, the data are aggregated, cleaned and normalized, eliminating the data that do not provide information about the study. Subsequently, the Pentaho-Kettle Data Integration System is used, integrating the data and conducting a series of consultations based on competence indicators.

An example of guidelines for one of the competence indicators is shown below. There are no guidelines or filtering for descriptor 1 of each indicator, given that the data does not comply with the rules for descriptors 2 and 3, and so these automatically go on to form part of descriptor 1.

For instance, the following would be guidelines for filtering of indicator 2 *Planning and timing*:

- Descriptor 1: Foresees the approximate time required.
- Descriptor 2: Plans the time required for actions in detail.
  In the case of Gantter and Microsoft Project, those groups are filtered with a number of tasks with a different start and end date greater than the minimum established value. In the case of Google Calendar, groups are filtered with a number of events with a different start and end date greater than the minimum established value (summary + end data time + start data time).
- Descriptor 3: Includes a forecast of additional time for unforeseen circumstances.
  In the case of Gantter and Microsoft Project, those groups are filtered with a number of events with a different start and end date greater than the minimum established value, and who also contain the key word unforeseen in the name of the task. In the case of Gantter and Microsoft Project, those groups are filtered with a number of events with a different start and end date greater than the minimum established value, and who also contain the key word unforeseen in the description or title of the task (summary + end date time + start date time + description).

Another type of data was taken into consideration for the remaining indicators, and searches were conducted according to key words when trying to establish whether possible risks or monitoring mechanisms had been foreseen. To do this, each teacher defines a set of keywords related to monitoring mechanisms or risk forecasting. Thus, searches are made for generic keywords and also for more specific keywords in each area. The use of this type of technique tends to be referred to as text analytics and tends to be used in those in which there is unstructured content, such as in the analysis of blogs, forums and emails [44].

Filtering via the Kettle system is then carried out using these guidelines, which is known as data processing. The logical system in Kettle for conducting searches or filters involves asking questions via formulas OR and AND. For instance, with the assigned resources variable: if assigned resources IS NOT NULL, OR predecessor IS NOT NULL. In this way, we ask for a list of the projects they have or for assigned resources or predecessors in some of their actions to be mined, and from this data filtering is obtained that corresponds to descriptor 2 of the indicator Exploitation of Resources. In the case of indicator 3, questions are asked about the type of resources.

The final step in the data analysis is the display. Kettle provides you with a data file with the filter applied to each descriptor and each indicator. The result of searches is thus quickly observed. All filtering is then unified in a single data file and from this we obtain what would be the assessment of each project via LA. This assessment is the one that is subsequently compared statistically to the assessment made by teaching staff.

3.2 Study 2: Formative assessment using LA

3.2.1 Research design

In the second study the research question (RQ2) is: *Does facilitating continuous assessment of competences through LA techniques, positively influence obtaining better levels of competence development?* A mixed approach is also used in the second study. The objective of this mixed methodology is to obtain inferences from all the information gathered to achieve a greater understanding of the phenomenon under study.

3.2.2 Population and sample

In the second study also is used a non-probabilistic sample. The sample has been selected consisting of seven groups of students, totalling 227 students. The groups of students belong to different faculties of the University of Deusto, allowing us to make a comparison between the level of development of the project management competence between the degrees of the Faculty of Engineering and other degrees of other faculties of the university. In this case, groups of students have been selected whose degree programs include the project management competence at Levels 1 and 2. The population of this second study are all university students, not just those enrolled in engineering school.

3.2.3 Variables and measure instruments

In the second study the independent variable is the type of assessment received, i.e., the students who have received an intermediate feedback and the final assessment and the students who have only received the final assessment. The dependent variables are the grades of the final assessment and the grade of each one of the indicators of the competence in the rubric. Based on the reference models, the assessment rubric for the second study is designed with 7 indicators and 3 levels of mastery.

3.2.4 Procedure

Phase 1: Previous interview and preparation with teachers
To carry out the study, an initial interview with the teachers is held to find out how they normally evaluate the project management competence with their students. In the interview they explain what the project consists of that they are going to work on with their students, and we propose the research methodology. The proposed methodology is to suggest that students use Gantter as a technological tool for the management of the project and Google Docs as a program for editing the work collaboratively. In the interview, the teacher explains which indicators of the competence he or she takes into account in their assessment. In some cases, "risk forecasting and contingency plan proposal" is not marked as a learning target.

Phase 2: Training session with students
In the training session the researcher gives the students a brief tutorial on how to use the Gantter tool and the Google Docs tool. Also, in the training session they are reminded of the suggested dates for continuous assessment. It is very important to make the students understand that the objective of the study is not to monitor their work, but to help them in the process so that they understand at all times how to improve. It is essential not to give students the feeling of being watched. In addition, two documents are provided in this session: the informed consent form and the instruction document.

Phase 3: Issuing assessment reports
During the development of the project by the student, follow-up reports are produced. Before making such reports, it is important to verify that all the working groups have shared their projects with the teacher and the responsible investigator. To carry out the follow-up reports, the day after the date agreed with the students and the teacher, all the data from the tools are extracted and an objective assessment is made of each project group and each

Table 2. Rubric of Study 2

	Level 1	Level 2	Level 3
Indicator 1: Defining targets	Does not set the objectives of the project, nor involves the team in defining the project objectives.	Sets clear objectives for the project. Does not involve the whole team in defining the project objectives.	Sets clear objectives for the project. The objectives of the project involve the whole team.
Indicator 2: Task definition	Defines general tasks for project achievement.	Defines general and specific tasks to achieve the project.	Defines tasks with a high level of detail to achieve the project. Evenly distributes the workload among team members.
Indicator 3: Temporal planning	Tasks are not well sequenced temporally.	Anticipates and assigns times for the achievement of each task. Task planning is not sequenced according to the different levels of development.	Anticipates and assigns times for the achievement of each task. The different levels of tasks are well sequenced temporally.
Indicator 4: Resource management	Does not assign responsibility for project tasks nor specifies which material resources will be needed to achieve the project.	Assigns responsibility to each task. Does not specify which material resources will be needed to achieve the project.	Assigns responsibility to each task. Takes advantage of all the resources available. Complements the project with all the information that is relevant.
Indicator 5: Risk forecasting	Does not anticipate the possible risks that may occur during the course of the project.	Identifies possible risks inherent in the project but does not assess their impact and probability in the development of the project.	Identifies possible risks inherent in the project. Estimates the probability and impact of potential risks. Keeps track of the anticipated risks.
Indicator 6: Change control	Does not keep track of the project implementation.	Performs continued monitoring of project implementation. Does not adapt actions and resources to the incidents and to the changes that arise.	Plans tracking mechanisms. Adapts actions and resources to the incidents and changes that arise. Performs continued implementation tracking.
Indicator 7: Communication and collaboration	Does not form a project team or establish communication channels between the team members.	Forms a project team but communication and collaboration between the members of the project is not sufficiently empowered.	Forms a project team. Plans communications management. Establishes mechanisms and systems of collaboration.

individual. Follow-up reports are sent to each student 1 or 2 days after the date indicated, and in this report, they receive information about their individual performance, the performance of their group and the performance of their group with respect to the entire class. Teachers do not receive these intermediates; they are only informed in the event that some group has done nothing. Teachers only receive the final report after they have issued their final grade for the course, so that the assessments do not affect the student's final grade.

3.2.5 Data analyse using learning analytics

In the second study the data are collected through the technological tools themselves (Gantter and Google Docs) and are integrated into a large database. Data extraction in Google Docs uses a data analytics plugin called "Revision History Analytics" that extracts relevant data for the study: Total interactions by user, total edits by user, total comments by user, and total words by user. Once the data is integrated into the database, the data that will not be used in the analysis is cleaned and the resulting data format is standardized. With the complete database of each group of students, a complex series of algorithms is applied that allow evaluating the level of competence development of each student and working group in relation to each indicator of the competence. For this purpose the laborious task of relating data types with indicators has been carried out, taking as reference the definition of the indicators in the theoretical frameworks of reference [32, 33, 42].

For example, to assess the first indicator "Defining targets", the system analyses the name of each task and searches for unnamed tasks, studies the project document and analyses the number of comments, the number of reviews, or the number of words written in the document by each member of the group. In the case of indicator 3 "Temporal planning", the system analyses the number of tasks, the number of tasks with different start and end dates, the number of tasks at level 2 and level 3 that refers to whether the student has defined tasks and sub-tasks, etc.

A fundamental part of the design of the algorithms of the assessment model is negotiation with the teachers of each group, who define a series of constants that will be the limit values to make the decisions between one level of competence or another. For example, some of the negotiations to be taken together with the teaching staff would be:

Table 3. Coinciding and non-coinciding assessments for each competence indicator

	Coinciding assessment		**Non-coinciding assessment**	
	N	**%**	**N**	**%**
IND1: Defining objectives	40	93.03	3	6.97
IND2: Planning	35	81.4	8	18.6
IND3: Exploitation of resources	35	81.4	8	18.6
IND4: Monitoring mechanisms	41	95.3	2	4.7
IND5: Foreseeing risks	41	95.3	2	4.7

Table 4. Coinciding assessments for each indicator and for each tool

	MS Project		**Gantter**		**Google Calendar**	
	C.P.	**%**	**C.P.**	**%**	**C.P.**	**%**
IND1	2	66.6	23	100	15	88.2
IND2	3	100	19	82.6	13	76.5
IND3	1	33.3	19	82.6	15	88.2
IND4	3	100	23	100	15	82.2
IND5	2	66.6	22	95.6	17	100

the assessment ranges for the number of tasks defined, the average duration of a long task and a short task, the number of words, of revisions, of Level 2 tasks, etc. These constants serve to define the negotiating rules that will be used to carry out the assessment of the data. The matrix of relationships between data and indicators is shown below, and some negotiating rules are defined for each of the indicators:

4. Results

The results obtained in each of the research studies are shown below. First, we show the results referring to the first study, with the assessment of 5 groups from Engineering who have managed a project via 3 different tools: Gantter, Microsoft Project and Google Calendar. In this first study the objective is to compare the automatic assessment facilitated by LA with the assessment by the teaching staff, and also to find out the opinion of the teachers in relation to the use of this type of assessment systems with LA.

In the second study we observe the results of the formative assessment with LA compared with the results of a summative or final assessment also carried out with LA. What is intended with this second study is to demonstrate that the use of LA to issue intermediate follow-up reports for the students positively influences the improvement of the final results and therefore the development of higher levels of mastery of the project management competence.

4.1 Results of the effectiveness of Learning Analytics for competence assessment

The first analysis involved studying the effectiveness of LA for assessment of each competence indicator.

Table 5. Total coinciding and non–coinciding assessments

	Coinciding assessment		**Non-coinciding assessment**	
	N	**%**	**N**	**%**
MS Project	11	73.33%	4	26.66%
Gantter	106	92.17%	9	7.83%
Google Calendar	75	88.24%	10	11.76
Total	192	89.3%	23	10.7%

The Table 3 contains the results obtained for each indicator. The indicators in which the teacher assessment and LA assessment coincide most closely were Defining objectives (IND1) with 93.03%, and Monitoring mechanisms (IND4) and Foreseeing risks (IND5) with 95.3%.

Data were also obtained about the effectiveness of LA for the assessment of competence indicators according to the technological tools used, as shown in the following Table 4.

And lastly, the overall result of the study can be observed by analysing the total number of coinciding assessments among the five indicators, and with which technological tool the greatest similarity between assessments was noted. This is shown in the following Table 5.

According to the data gathered, the percentage similarity between teacher and LA assessments is 89.3%, with only 23 non-coinciding assessments out of 215 in total. And among the tools, the greatest incidence of similarity between assessments is in the case of Gantter, with 92.1%, putting MS in last place with 73.33%.

4.2 Results of teaching staff ratings about the use of Learning Analytics in competence assessment

A questionnaire was passed on to five teachers (one for each sample group) to find out how they rate the application or the use of LA techniques to facilitate competence assessment techniques. The result of the analysis confirms that teaching staff who took part in the study positively rate LA's effectiveness in facilitating assessment. As one of the teachers states in their answer: "Yes, it can facilitate work when you have a lot of students or projects to assess. It also helps to always assess students' work in accordance with common criteria." The relationship between the content analysis categories would also suggest that teachers recognise its validity in assisting or complementing teacher assessment, although it should not be considered as a replacement, and that teachers appreciate the automatic nature of processes and objectivity in terms of competence assessment. One example of the answers that back up this stance would be: "Yes, I think it would be very interesting to make advances in this sense and to facilitate assessment via automatic processes that might be enriched by teacher assessment." They were also asked what they miss when assessing competences, and the teachers demand good competence descriptors, systems that can automate the process and systems that can integrate several documents or works in order to assess a single competence. This shows that LA is in line with what teachers are seeking.

4.3 Results on the impact of formative assessment with feedback through LA

First we obtain a distribution of the sample and see that there are 3 distinct groups, on the one hand students who have received one intermediate follow-up with feedback (130 students), another group who have received two intermediate follow-ups with feedback (12 students) and finally, the sample of students who have not had intermediate feedback and therefore only have the final assessment (76 students).

In the following histograms we can see the difference in the grades of the sample groups (142 students) in the intermediate follow-up and in the final assessment. And we can even see the last histogram with the difference between the intermediate and final assessments of the sample groups. In this last histogram we can appreciate the improvement between the assessments. According to this last graph, is most frequent to get small improvements. This is because the grading rank is between 1 and 3, so there is less margin for improvement.

The relation between the intermediate follow-up and the final average grade of the sample group is analysed. We take as a null hypothesis that the intermediate follow-up does not improve the results of the final assessment and we assume a 5% level of statistical significance. Below we can see, according to the results of the statistical analysis, in which indicators there has been a greater effect of the process of formative assessment.

If we look at the ranks between the grades of the groups that have only had one final assessment and those that have had one intermediate assessment plus the final one, in most case indicators there is an improvement of results in the groups with intermediate assessment provided by LA. This improvement has not been observed in indicators 2 and 4 (Task definition and Resource management). However, these indicators have high scores, especially in indicator 2 (Task definition) that has an average score of 2.75, therefore there is less margin for improvement in these groups.

According to the results of statistical significance, the impact obtained in the final assessment through the intermediate assessment can be generalized in the case of the following indicators: Defining targets (1), Task definition (2), Resource management (4) and Communication and collaboration (7). However, although in indicators 5 and 6 (Risk forecast-

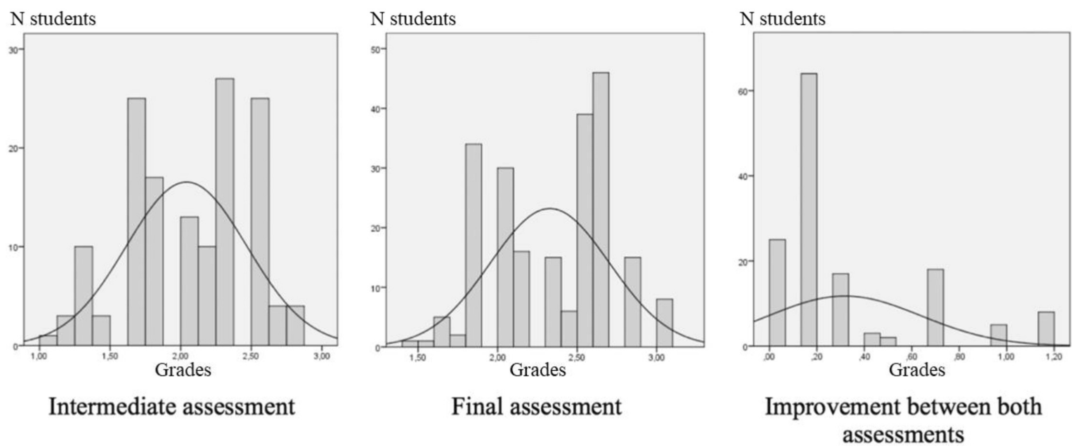

Fig. 1. Histograms of the intermediate and the final assessment

Table 6. Table of ranges, mean differences, significance and effect size between each indicator and the formative assessment

		Rank average	Mean	N	Std. Deviation	Sig.	Effect
Ind. 1: Defining targets	Final assessment	68.74	2.44	57	0.627	0.000	0.90
	1+2 assessment	104.63	2.89	114	0.308		
	1+2+3 assessment	82.50	2.58	12	0.669		
	Total		2.73	183	0.502		
Ind. 2: Task definition	Final assessment	137.80	2.75	75	0.438	0.000	0.78
	1+2 assessment	94.95	2.23	130	0.721		
	1+2+3 assessment	81.25	2.17	12	0.389		
	Total		2.41	217	0.668		
Ind. 3: Temporary planning	Final assessment	104.04	2.01	76	0.887	0.491	0.17
	1+2 assessment	113.42	2.15	130	0.762		
	1+2+3 assessment	101.63	2.00	12	0.739		
	Total		2.10	218	0.806		
Ind. 4: Resource management	Final assessment	114.66	2.11	76	0.309	0.000	0.06
	1+2 assessment	113.28	2.08	130	0.571		
	1+2+3 assessment	35.88	1.25	12	0.452		
	Total		2.05	218	0.524		
Ind. 5: Risk forecasting	Final assessment	20.00	1.00	19	0.000	0.420	0.55
	1+2 assessment	26.88	1.31	16	0.479		
	1+2+3 assessment	26.50	1.50	12	0.905		
	Total		1.23	47	0.560		
Ind. 6: Change control	Final assessment	102.34	2.47	76	0.774	0.310	0.31
	1+2 assessment	113.61	2.67	30	0.562		
	1+2+3 assessment	110.33	2.67	12	0.492		
	Total		2.60	218	0.645		
Ind. 7: Communication and collaboration	Final assessment	89.75	2.35	57	0.481	0.000	0.35
	1+2 assessment	109.59	2.58	130	0.649		
	1+2+3 assessment	44.79	1.58	12	0.793		
	Total		2.42	199	0.653		

Table 7. Comparative table of data between engineering groups and the rest of groups of other faculties

	Workload	Assigned work days	N reviews	N commets	N answers	N words	N task	N long task	N short task	Days of project	Resources	Risks
Average	0.88	11.09	16.11	1.07	0.34	1397	10.65	1.49	7.85	29.69	0.68	0.01
Engineering groups—average	0.15	10.74	21.48	2.96	0.96	2677	11.60	2.72	7.23	30.79	1.30	0.00

ing and Change control), the statistic indicates that the relationship is not significant, the size of the effect on these two indicators is medium (greater than 0.2), which is why the relationship between the formative assessment provided by LA and the final grades is relevant.

Finally, relevant results are included in the study on some performance data of the competence that have been used in the evaluation of the indicators. The following Table 7 highlights the most relevant values from the point of view of training in engineering degrees, such as: task definition, number of revisions, task fulfilment update, project duration, risk definition, or resource definition.

As can be observed in the data, the workload in the engineering groups is better distributed, the number of revisions in the document is greater, as well as the number of answers, the number of words, the number of tasks, the project duration or the use of resources.

5. Discussion

In relation to the first research question (RQ1): *Can LA techniques support to the teacher in assessing the project management competence from data obtained from students' interaction with technologies?* The data gathered showed a high degree of similarity between the assessments made by teaching staff manually and those generated via the application of LA automatically. Likewise, instances of discrepancies between assessments might be resolved if a more rigorous way of defining assessment criteria and data filtering conditions were established. The subjectivity factor inherent in individuals should also be taken into account, and this has indeed been analysed in previous studies. The use of LA techniques exceeds these limitations of human assessment, given that the data cleaning and filtering system is governed by common, objective criteria.

The three tools proved suitable for assessing the project management competence, with Gantter being the tool that showed the most similarity between LA and teacher assessments. We understand that Gantter and Microsoft Project coincide more, given that they are tools specifically designed for project management, unlike Google Calendar, which is more of a time management tool. Between Gantter and Microsoft Project, we consider the way in which the information is structured to be a determining factor as the metadata that classifies the information is what subsequently facilitates filtering and analysis. However, the MS Project sample is not large enough to obtain conclusions from.

Another relevant fact we noted following the study is that in cases of non-coincidence, the assessment made automatically via LA tended to drop below that made by the teacher. This may be due to the fact that the decision-making criteria and filtering established using LA were more demanding than teacher criteria. It is therefore very important to properly define what is understood by a low, average or high level of performance in both assessments, i.e., the automatic one using LA and that of the teacher.

As for teaching staff, they rated the contributions that LA can make in the area of competences very highly. Likewise, they confirmed their concern with and interest in learning about new processes for assessing competences, and also stated that for specific tasks and for large groups of students in which individual assessment may prove tedious, this type of assessment system may facilitate this work to a large extent. Objectivity, the presence of indicators that can be measured and the automatic nature of competence assessment processes feature among the aspects rated by teachers when improving such processes. An obvious link exists between teachers' needs and what LA contributes to this research.

Surpassing a first challenge by validating the competence assessment through LA techniques through comparison of the results with the assessments of the teachers in the first study, a new challenge is addressed by proposing new formulas of continuous competence assessment through techniques of LA. In the field of engineering there are many educational contexts with the presence of technological tools, so it is an important contribution to define systems of assessment extensible to other contexts and other tools that allow an automatic and continuous assessment to be carried out.

In relation to the second research question (RQ2): *Does facilitating continuous assessment of competences through LA techniques, positively influence obtaining better levels of competence development?* Data from the second study have shown a significant improvement in the results of assessment of the project management competence in those groups that have received intermediate feedback reports. These reports have allowed the students to know their level of performance at each assessment interval and to establish improvement strategies or to seek motivation towards the achievement of higher-level objectives. These are the objectives pursued by self-regulating learning, and thanks to LA, we have been able to design a system of competence assessment focused on student learning and on self-regulation of learning.

Not only is it relevant to demonstrate the improvement of the final results thanks to formative assessment, it is equally interesting to see the amount of information that can be obtained thanks to data analysis. This is one of the keys that the teachers have highlighted in the final interviews. All the teachers agreed on the usefulness and impact of having access to all this amount of information on the ordinary assessment of engineering projects, for example in GFRs. Thanks to LA, teachers have access to a lot of information that they cannot get at first sight, for example, the number of revisions by each member of a working group in a shared document, the management of the change in tasks or the distribution of resources during the course of a project, the actual contributions of each member of the group etc. All this amount of new information that is revealed to the teaching staff, together with the opportunity for an automatic continuous assessment tool, are the main contribution of LA to the field of competence assessment.

In summary, this research using LA for competence assessment has shown that conclusions can be reached about the level of a student's competence development based on data mined via the use of a technological tool, and that it is possible to provide feedback to students regarding their level of competence, thus influencing an improvement of their final level of competence development. From the research standpoint in the area of LA, we consider the main contribution made by this model to be the combination of an automatic analysis and exploratory techniques to facilitate the formative assessment of transversal competences and self-regulated learning in the field of engineering. The results of the study represent a step forward from previous research in the area of competence assessment through Learning Analytics [27, 41–43]. It has also been corroborated with the study that the formative assessment process through feedback to students helps them redefine their strategies towards the achievement of learning objectives [24, 25, 28].

6. Conclusions and future work

The conclusion we draw from the study is that the main keys to assessing competences via LA techniques are the selection of technological tools that enable data about the student's activity to be properly mined and that they be equipped with a data structure to facilitate their subsequent analysis. Also required, for the most accurate possible rubric-based assessment, is that it should not give rise to confusing interpretations and that it should coincide with the teacher's assessment criteria. Lastly, it is important for students to be fully aware of and consent to the fact that all their activity is being observed and may be subject to assessment.

Another decisive factor in the design of continuous assessment systems by means of LA is negotiating assessment criteria with teachers. This factor is both an advantage and a limitation. It assumes a strength of the model since it can be customized to different subjects and groups of students. And on the other hand, it is a limitation, because in extrapolating this model to other contexts, it cannot easily be replicated without defining or altering some algorithms of the analysis model.

Another interesting aspect of this study was that the assessment model taken into consideration was integrated naturally into the teachers' and student's ordinary activity, i.e., it did not involve any extra work for them, nor any modification to their habits. This is an advantage when trying to implement the model in other groups, as it is only necessary to select a technological tool that enables projects to be managed and adapts filtering criteria to its data structure in order to analyse competence indicators. Indeed, the main limitation of the research has been the complexity of the data structure attached to each technological tool and the lack of format standardisation in the data, as this complicates comparison work. Fortunately, several initiatives exist regarding standardisation of such data. Linked to this lack of standardisation, we come up against another limitation of this project, which is the difficulty faced in replicating the study with any other technological tool. However, this will be easily overcome as a result of the work that is currently being carried out on format standardisation.

In future research it would be interesting to extend the assessment scale of headings to 5 levels of mastery to achieve greater accuracy in assessments. As an advance in the research area of LA it would be interesting to design a model of continuous assessment of competences with LA that includes several moments of feedback, and after each moment of feedback, to facilitate a teacher-student meeting, either face-to-face or virtual, to be able to correct mistaken uses or jointly rethink strategies for improvement. It would also be interesting to incorporate data from new complementary resources present in the common management of projects among engineering students. This study has incorporated data from two common tools but there are more tools that could complement the profile of the competence of students in project management.

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