Research Article

Analyzing Students' Perceptions of Collaborative Tools for Automated Assessment of Programming Assignments in Distance Education

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The pandemic situation generated by COVID-19 forced sectors such as education to change how they carry out their activities, moving abruptly from a face-to-face to a fully online model. These online models require the development of constructivist learning environments that contain not only cognitive tools but also conversation and collaboration tools as one of essential components. This experiment, it has designed and developed the integration of an adaptation of Mattermost in combination with DSLab in an e-learning environment in Higher Education. The goals were to facilitate communication between students, collaborating with each other by means of direct messages among students and the teacher, support the creation of public channels where students' questions can be answered by the lecturer or by other students, and encourage spontaneous learning, sending emoticons where students can reflect their moods and other substantial improvements with respect to the traditional virtual campus forum. This study aims to examine the effects of this integration on students' academic performance by enabling the possibilities for collaboration among teachers and students to be expanded and providing improved interactions and student learning. The experiment was carried out on 271 computer and telecommunication engineering students as an important part of the distributed systems subject in the university's virtual campus. The findings suggest an improvement in academic results that there are increases in students' emotional states such as motivation, self-learning and improvement in academic results invite us to think that, beyond a probable novelty effect, these tools have potential as a technological artifact to support learning.

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1. Introduction

The tools available for distance learning expand the possibilities for teaching in today's pandemic environment, where many universities have been forced to adapt to this situation. However, are all available tools suitable for enhancing learning in a distance learning environment?

An automatic assessment tool, named DSLab, has been extensively used as important part of the distributed systems subject in computer and telecommunication engineering degrees (Marquès et al., 2018), providing improved interactions and student learning. In these distributed systems exercises, there are learning processes that can be developed in a collaborative way. This implies that one or more students collaborate with each other to obtain a solution to one of the problems presented by the practical assessment of this subject. Collaboration between students can come from several points, by explicit collaboration (two students form a group to solve the practical) or by collective collaboration in the subject forums. Both options are valid to pass the exercise, and in both cases a specific learning, involvement and motivation is obtained.

The development of Constructivist learning environments (CLE) (Duffy and Jonassen, 1991) requires cognitive tools as well as conversation and collaboration tools as essential components. The studies dedicated to reviewing the improvement of these collaborative tools are diverse and show very positive results in different indicators, especially in terms of collaboration.

There are well-known collaboration-oriented tools in the business environment, such as Slack, which allows versatile communication with work groups and boosts productivity in certain situations (Otero et al., 2013). The introduction of these collaborative tools has a growing trend in education (Delgado et al., 2020). Mattermost (https://mattermost.com) is a collaborative tool similar to Slack, open source whereas it allows free development of its code, customized development in both the frontend and backend as well as adaptation to the needs of the users. This collaborative tool allows the cohesion of the tools previously developed with Mattermost and the IT systems of a university.

The integration of an adaptation of Mattermost into the ecosystem formed by DSLab (Daradoumis, Marquès, Arguedas, Calvet, 2019) and the university's virtual campus enables the possibilities for collaboration between the university's students to be expanded. It may facilitate communication between students by means of direct messages between students and the teacher. It supports the creation of public channels where students' questions can be answered by the lecturer or by other students. It encourages spontaneous learning, collaboration with each other, sending emoticons

where students can reflect their moods and other substantial improvements with respect to the virtual campus forum. This research aims to measure what improvements are produced in the academic performance of students, and in particular, indicators that have to do with collaboration and motivation aspects which are essential to overcome the tasks of Distributed Systems in the field of online teaching. In order to obtain the results reflected in this article, the following points have been worked on:

1. Integration of Mattermost with the automatic assessment tool DSLab.
2. Synchronisation of the students in both systems.
3. Proposing the measurement of indicators that reflect the achievement of measurable results that indicate an increase in emotional states that favour learning.
4. Develop the necessary mechanisms for the collection of these indicators. In the case of this study we have chosen to use questionnaires and log analysis.
5. The last milestone of the study is the actual data collection and data analysis in order to draw the conclusions of the study. The final result of this data collection and analysis is the elaboration of this article.

2. Literature Review

The use of collaborative tools is sufficiently well known in the business environment (Otero et al., 2013) or together with agile methodologies (Calefato et al., 2020). There are also studies referring to the inclusion of these tools in the healthcare environment (Sarkisian and Kagel, 2018) through Slack, or involving patients in health promotion (Pinto, Antunes and Almeida, 2020). In the healthcare area, there are studies with interesting points to highlight, such as the possibility of storing messages and group conversations, documents, and the possibility of using mobile phones (Gofine and Clark, 2017). There are also biomedical research projects that have implemented these tools (Azarova, Hazoglou and Aronoff-Spencer, 2020) from an analytical perspective. There are studies that point out that the possibility of providing opinions and recommendations is an advantage over traditional forums such as Stack Overflow, and that these tools can be a way of disseminating information and as an entry point for chatbot (Chatterjee et al., 2020).

Other studies have focused on compiling a wealth of literature on the use of these tools. The systematic literature review conducted in this direction (Al-Samarraie and Saeed, 2018) provides 29 relevant studies on collaborative tools, many of which are included in this state-of-the-art review

prior to the results of this research. The study categorizes the tools by the following categories, synchronized tools, LMS (university systems like Moodle and Blackboard), Social Networking tools (like Facebook, Twitter, Skype and Whatsapp). It should be noted that neither Mattermost nor Slack appears in this systematic literature review, which points to a gap to be filled by other studies. It highlights the fact that the implementation of these tools provides substantial improvements in student collaboration, through active discussion, sharing and editing of learning resources. Other literature reviews on this topic (Delgado et al., 2020) focuses on higher education and in Spanish-speaking countries highlight the variables of collaborative learning, critical thinking and creativity, but above all an increase in motivation.

There are several studies found on these collaborative tools that emphasize the importance of collaboration and communication in the development of skills and learning (Leo and Neo, 2015). Other studies point to improved academic performance and satisfaction (Koh, Lim, 2012) (Viloria, Lezama, Cabrera, 2020), where more sociable applications allow for a greater sense of teamwork. Emotional traits can affect the implementation of these tools (Venkatesh et al., 2012), and that collaboration is the answer to many of the challenges in education and research, where the importance of managing teamwork in a reflective way stands out (Maican et al., 2019).

Studies on collaborative tools applied to the educational environment cover different stages of the educational process: In childhood (Roschelle et al., 2010) where the importance of prior preparation of the subject to be taught is highlighted; Secondary school (Raman, Sani and Kaur, 2014) where students' experience with this type of tool is noted; Undergraduate student (Duque et al.,2009), (Menzies and Zarb, 2020), (Hart, Bird and Farmer, 2019), (Elmahadi, Osman, 2012) where the improvement in aspects such as motivation is highlighted in general and in postgraduate students (Lopez-Zafra, De Paz-Cobo and Queralt Sánchez, 2020), (Tuhkala and Kärkkäinen, 2018). Some studies have been conducted adapting to the pandemic time (Montrief et al., 2020) to implement these tools. In addition, the most common way to evaluate these tools has been presented through questionnaires to students (Lopez-Zafra, De Paz-Cobo and Queralt Sánchez, 2020), (Menzies and Zarb, 2020).

In general, there is a great predominance of Slack as a tool to be studied (Menzies and Zarb. 2020) or (Montrief et al., 2020) to name a few studies. However, other studies are oriented towards Blackboard Collaborate (Hart, Bird and Farmer, 2019), Facebook (Raman, Sani and Kaur, 2014), Moodle (Elmahadi and Osman, 2012), or a set of them, such as Microssoft Teams among others (Pangestu, Karsen and

Chandra, 2019). Interesting results have been obtained in all of them. Other studies directly analyze the tools that students frequently use for online learning (Wiyono, Wedi and Wahyuni, 2020) showing that Whatsapp, Google search engine and email are the predominant tools. Teachers indicate a moderate commitment to these tools based on aspects such as lack of budgetary support, lack of electronic supplies and their own resistance to change (Wiyono, Wedi and Wahyuni, 2020).

Finally, with regard to Mattermost, there is a small group of studies dealing with this collaborative tool. Some studies place Mattermost as a communication tool at the level of Microsoft Teams, Google Hangouts or Slack (EFSA, 2021). However, other studies highlight that using Mattermost is an interesting research opportunity, thanks to the possibility of adapting it to the educational context (Tuhkala and Kärkkäinen, 2018) despite having used Slack as a collaborative tool in this study. Despite these strengths, there are studies that have seen the opportunity to evaluate the security of Mattermost detecting some design problems, mainly with the abuse of Timestamps (Burkert and Federrath, 2019).

In spite of the large number of collaborative tools and articles published, there are no formal studies of the effectiveness of using Mattermost as a collaborative tool integrated into an automated assessment tool. Previous studies on collaborative tools show an improvement in different indicators, and also point to the need for a design focused on the use of the tool in the subject. All the studies point to evaluating the results by means of questionnaires or by analyzing the conversations that take place in the collaborative tool.

3. Research Aims

3.1. Research Goal

This study aims to examine the effects of an educational tool based on Mattermost in combination with DSLab (Marquès, Calvet, Arguedas, Daradoumis and Mor, 2022) -- a previously developed automated evaluation tool -- on *students' academic performance* in elearning environment in Higher Education. In sum, this study will focus on students' perceptions of the improvement of their learning and the analysis of their interactions with Mattermost.

3.2. Our proposal

Mattermost is a collaborative tool designed for agile and effective teamwork, similar to Slack (Otero et al., 2013). Mattermost is provided with a very powerful API-Rest that allows the creation of Users, Channels and Teams. It works through independent Teams. Each team can be assigned one or more channels and each channel one or more users. Channels can be public, i.e. open to all team members, or private, where access is by invitation only.

When a Team is created with a topic, users who share that topic are added. Mattermost allows the exchange of private messages between users, if they are in the same Team. It also allows the use of emoticons and images as a form of expression by users. It also implements, among other functionalities, the reception and sending of messages by means of user-bots. Some of the most relevant features of Mattermost are:

a. It is open source, so it can be adapted to any system.
b. It is cross-platform, i.e. it works on web, personal computer (PC) and mobile phones.

The software that composes Mattermost is integrated with MySQL and consists of a backend developed in Go, (a programming language inspired by the syntax of C and with a very high performance, similar to C++) and a frontend developed in React (open source Javascript library designed to create user interfaces, with the aim of creating single-page web applications). Currently, the backend and frontend can be adapted independently as two separate projects, which facilitates the parallel development of an own version of Mattermost.

In our version of the tool, we have configured Mattermost with several Teams, where each Team represents a specific classroom. In this way, when students access this environment, they are assigned to a specific Team, i.e. to a virtual classroom of our university. Students have access to the classroom that corresponds to them and can only communicate with students in the same classroom within Mattermost. Under each Team, a number of channels have been configured as shown in Figure 1.

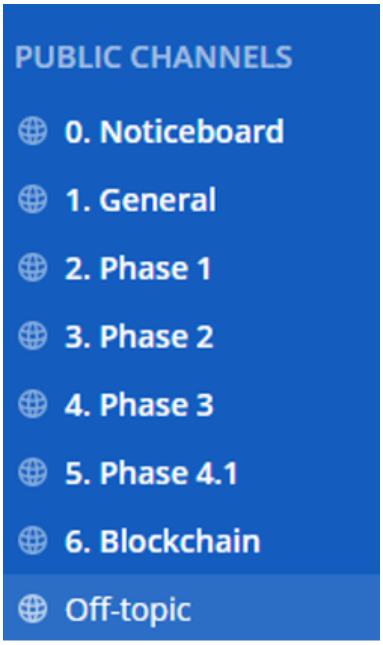

Figure 1. *Channel structure of a Team in our Mattermost configuration*

In an organizative point of view, these channels represent specific topics corresponding to each phase of the practical work that the students must carry out during the course. This division makes it possible to maintain a sequential organization of the practical work where students can raise any doubts they may have about specific aspects of it. Students can consult the questions and answers received from other students in the same class. Generic channels have also been created for them to form groups or raise doubts about the deadlines for delivery of the work carried out in each phase. In this way, we have a channel for each phase of the practical, a channel for blockchain (alternative theoretical-practical part) and two channels for general questions. At the same time, a Team has been set up for the teachers, which functions as a teacher's room, where they can communicate with each other in an agile and comfortable way.

Next, Mattermost has been integrated with the information system that is part of DSlab (Daradoumis, Marquès, Arguedas and Calvet, 2022). This integration has been possible thanks to the fact that Mattermost is open source. For it, both the backend and the frontend have been modified to adapt the authentication by means of oAuth, (open standard for the authorization of APIs, that allows to share information between sites without having to share the identity, in short, a way of authenticating

users) and to add some aesthetic aspects in the welcome page and to be able to use the authentication, respectively. The integration process includes a small utility programmed in Java that allows to detect the students and teachers that are part of a given classroom in DSLab, and to register them in Mattermost through an asynchronous process, which also includes their assignment to a specific classroom. This tool, called Users Utility, is located in the same server where Mattermost and DSLab are installed and running, running in the background and offering the functionality by Remote Method Invocation (RMI - Java API that offers remote connection methods to other applications).

The integration process follows the next sequence:

1. The student or teacher accesses DSLab through the web interface.
2. DSLab informs the Users Utility that a new user has to be created and assigned to a specific Team via RMI.
3. Users Utility makes use of the Mattermost API-REST to register students and professors who have been accessing DSLab. This process has been automated in such a way that student registrations are processed through a queue programmed in the Users Utility application. This ensures that users are registered in Mattermost within a short interval of time and on an individual basis. Each student or teacher will be assigned to a specific Team, corresponding to the class to which he or she belongs.
4. Users Utility checks if the Team exists, if it does not exist, it creates it. Teams are registered with the corresponding classroom code plus the current course.
5. Once the Team is created (or verified to exist), the row of the new user is processed, it is created, it is assigned a random password that it will never use, since it will be authenticated with the oAuth of the university, and it is assigned to the Team in which it should be.
6. Finally, the student or teacher accesses Mattermost in different ways: through the link in DSLab that opens the portal by iframe, through the PC application, through the mobile phone, or through a web browser on any system.

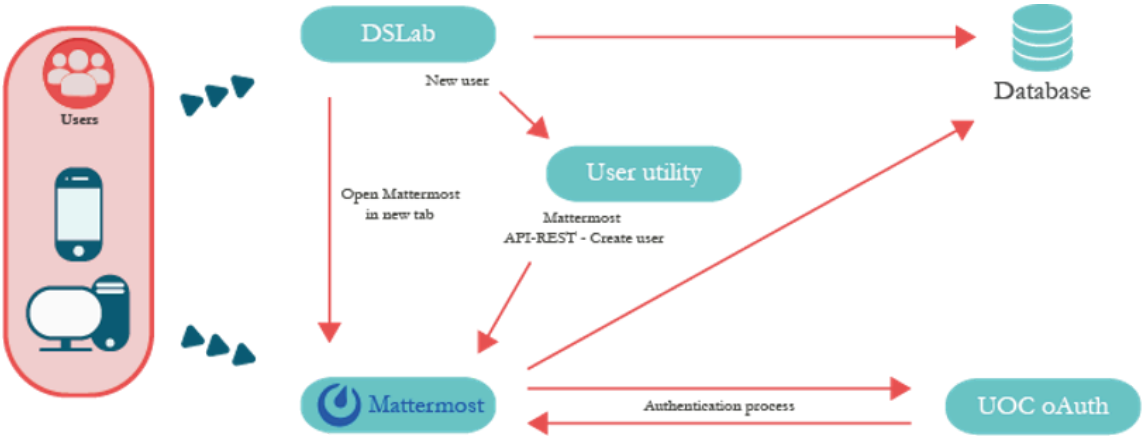

Figure 2. *Mattermost's information system*

Figure 2 shows the integration of Mattermost with the virtual campus of our university allows students to interact with each other in real time, direct communication between them, direct communication with the teachers of the subject, upload documents, and other options that traditional forum does not allow as shown in Table 1.

Functionality	Mattermost	University Forum
Post messages in a Forum	✔	✔
Real-time messaging	✔	-
Private messaging	✔	-
Mobile and Desktop Clients	✔	-
File sharing(figures, pdf, doc)	✔	✔
Private file sharing (figures, pdf, doc)	✔	-
Nailing down relevant comments in channels	✔	-
Installing bots	✔	-
Emoticons in messages	✔	-
Send messages from API REST to channels	✔	-
Allows to change user states	✔	-
Show notifications	✔	-
Allow teachers from other groups to answer questions in public (or private by invitation) channels.	✔	-
Customise tool (css, corporate images)	✔	-

Table 1. Comparison of Possibilities of Mattermost vs Forum

Therefore, this study aims to answer the hypothesis and research questions that it shows in the below subsection.

3.3. Research Hypothesis and Questions

The research hypothesis that we deal in this work is shown below:

- *The use of collaborative tools in online learning environments fulfills a motivating function that improves students' learning process and academic performance, compared to the use of traditional forums.*

The aforementioned hypothesis is specified in the following research questions:

- *RQ1 - To what extend has the use of Mattermost as a collaborative tool improved students' learning process in comparison to the traditional forum?*
- *RQ2 - To what extend has the use of Mattermost as a collaborative tool enhanced students' performance in comparison to the traditional forum?*

To answer the above research questions, we studied the following units of analysis coming, on the one hand, from the questionnaire answered by the students and, on the other hand, from the analysis of the logs yielded by our tool. To analyze and answer RQ1 which involves the more abstract notion of 'students' learning process', we built our questionnaire based on specific indicators identified in previous work, such as *Self-perception of Learning* (Bandura, 1988), *Ease of Communication with Teacher* (Snead & Freiberg, 2019), *Collaboration Improvement* (Doveston & Keenaghan, 2006) and *Tool Utility* (Carbonaro, 2019). These units of analysis, their origin and their relationship with our research questions are shown in Table 2.

	Units' analysis	Source	Research Questions
U1	*The success rate of the students:* The tasks achieved *comparing the experimental versus the control group*.	Log Analysis	RQ2
U2	*The success rate of the groups accomplishing all phases of the assessment comparing the experimental versus the control group.*	Log Analysis	RQ2
U3	*The tasks completed in a group:* Mattermost is a tool that should encourage collaboration in the experimental group. This point can be a factor for academic improvement. The groups are made up of two people in the same classroom.	Log Analysis	RQ2
U4	The time at which each group completes a phase delivery according to the deadline.	Log Analysis	RQ1
U5	The absolute number of errors each group gets and corrects until they achieve a successful submission in the automatic evaluation tool. Errors are the unsuccessful attempts made by students when trying to complete a phase of the project.	Log Analysis	RQ1
U6	*Self-perception of Learning (SL)*	Questionnaires	RQ1
U7	*Ease of Communication with Teacher (CT)*	Questionnaires	RQ1
U8	*Collaboration Improvement (CI)*	Questionnaires	RQ1
U9	*Tool Utility (TU)*	Questionnaires	RQ1

Table 2. The Units of Analysis, Their Origin and Their Relationship to the Research Questions.

4. Methodology / Implementation

This study was carried out with students of the online subject of Distributed Systems belonging to degrees of computer science and telecommunications engineering. We designed an experiment following the control vs. experimental group paradigm.

We applied our integrated approach combining DSLab tool and Mattermost in the experimental group, whereas in the control group students had the traditional forum of the university's virtual campus, where they could send messages to the rest of the students belonging to their group and exchange knowledge with the aim to accomplish each of the project phases performed in the automatic assessment tool DSLab.

The experiment was conducted involving 271 university students with the aim of investigating the effectiveness of our integrated approach. To that end, students must implement a distributed algorithm, the Time-Stamped Anti-Entropy (TSAE) (Golding, 1992) in phases, upload its content and execute it in the DSLab environment (Marquès et al., 2019). During the experiment, our approach was evaluated with the information coming from the logs of the tool during the work of both groups and from the final questionnaire answered by the students of both groups too, with regard to the units of analysis previously established in Section 3.3.

The design of the experiment follows a problem-based learning approach in which students improve their learning skills through critical thinking, communication and collaboration. We divided the experiment into the following phases:

First delivery:

- Phase 1: Students carried out an alternative theoretical-practical work to pass the practical assessment of the course by means of a study on theoretical questions about distributed systems and a practical phase. The practical phase consists of an implementation of some TSAE structures. This is the first part when the students delivered through the automatic assessment tool. If the students do all parts they can, they obtain the maximum grade in the first part.

Second delivery:

- Phase 2: Implementation of reduced version of TSAE (add operation).
- Phase 3: Extension of phase 2, purge log with unsynchronized clocks.
- Phase 4: Evaluation of TSAE protocol and implementation of Remove recipe.

Alternatively, students can carry out an alternative theoretical-practical work to pass the second practical delivery of the course by means of a study on Blockchain.

- Blockchain: It consists of a theoretical-practical delivery on issues related to Blockchain. This practice is not delivered through the automatic assessment tool.

The time interval of the experiment was 8 weeks. The deliverables of first phase must be developed individually. Deliverables of next phases can be implemented individually or in groups. These groups only have two members maximum. Before they started their work each student had to choose if his/her group is individual or in pairs. From that point on, all of them are considered as groups by the DSLab tool. Each delivery attempt of every group in each phase in DSLab produces a set of logs that can be assessed and analyzed, while the Blockchain delivery is unique.

4.1. Participants

Initially, a number of Computer Science and Telecommunications Engineering groups were selected for the experiment. The total number of students enrolled in the course from both degrees was 271 students.

As mentioned before, we established two groups, experimental (EG) and control group (CG). The inclusion of the students in each group was random. One hundred sixty eight adult students agreed to sign a data protection consent form to participate in the experiment, eighty nine belonging to experimental group and seventy nine belonging to control group. The final distribution was as shown in Table 3 and graphically in Table 4.

Studies	**Students enrolled in Distributed Systems subject (Logs analysis)**			**Students who participated in the experiment (Questionnaires)**					
	EG	**CG**	**Total**	**EG**			**CG**		
				Female	**Male**	**Total**	**Female**	**Male**	**Total**
Computer Engineering	119	108	227	21	68	**89**	18	61	**79**
Telecommunications	33	11	44						
Total	152	119	**271**						

Table 3. Distribution of Students by Degree, Group (Experimental and Control) and Gender

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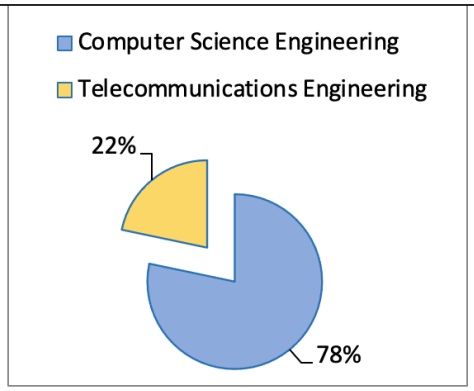
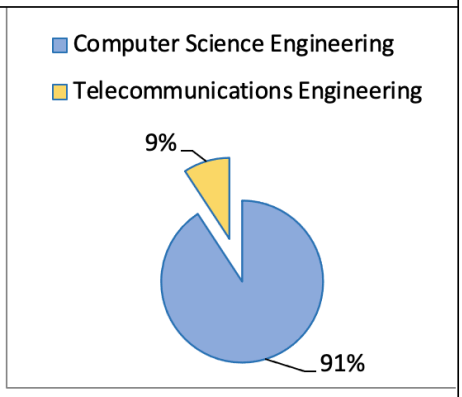
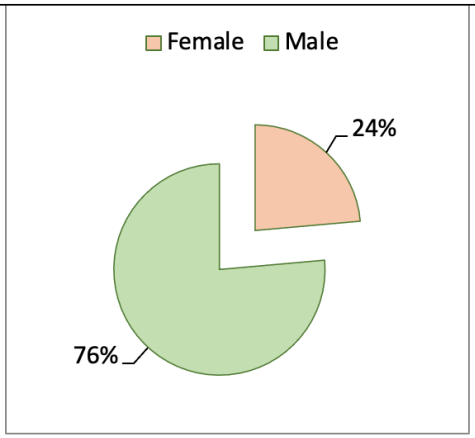
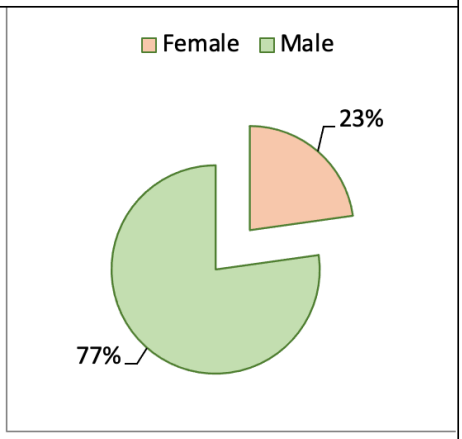
	EXPERIMENTAL GROUP (EG)	CONTROL GROUP (CG)
Students enrolled in Distributed Systems subject for logs analysis		
Students who answered the questionnaire		

Table 4. Graphical Representation of Participants

4.2. Data collection

This study focuses, on the one hand, in a quantitative analysis of the data gathered from the questionnaires completed by the students and, on the other hand, on the analysis of the logs that have been collected in the automatic assessment tool of the subject during the experiment.

4.2.1. Questionnaires

All the students who participated in the experiment were asked to answer the questionnaires anonymously at the end of the evaluation of the online practice on a voluntary basis.

The questionnaire includes 14 items divided into four indicators. These indicators are related to self-perception of Learning (SL) with two items, ease of communication with teacher (CT) with four items, collaboration improvement (CI) with three items, and tool utility (TU) with four items. The dependent

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variable of these questionnaires is Learning Improvement. For these items between question 1 and question 13 a Likert scale of 5 values ranging from Strongly Disagree (1) to Strongly Agree (5) has been used, requiring a quantitative response.

Additionally, a separate item has been included in the questionnaires, which indicates for the experimental group a conditional question with the values YES and NO on whether they would repeat the use of Mattermost versus the traditional forum. For the control group the separate item asks them to choose the forum they already know or a channel-based tool, also with the values YES or NO. The questionnaires are shown in the following Table 5

Experimental Group (EG)		Control Group (CG)	
Self-perception of Learning (SL)		**Self-perception of Learning (SL)**	
EGQ1	The tool has motivated me to improve my work in the subject and to get a better grade	CGQ1	The classroom forum has motivated me to improve my work in the subject and to get a better grade
EGQ2	I have a better understanding of the concepts in practice thanks to the use of Mattermost	CGQ2	I have better understanding of the concepts of practice thanks to the use of the classroom forum
Ease of Communication with Teacher (CT)		**Ease of Communication with Teacher (CT)**	
EGQ3	Communication with teachers has been made easier thanks to the tool	CGQ3	Communication with teachers has been made easier thanks to the classroom forum
EGQ4	Teachers have been able to solve the doubts in a clearer way thanks to Mattermost	CGQ4	Teachers have been able to answer questions in a clearer way thanks to the classroom forum
EGQ5	The doubts have been resolved in a timely manner	CGQ5	The doubts have been resolved in a timely manner
EGQ6	Direct interaction with teachers has encouraged me to ask them more questions during the course	CGQ6	Direct interaction with teachers has encouraged me to ask them more questions during the course
Collaboration Improvement (CI)		**Collaboration Improvement (CI)**	
EGQ7	The tool has made it easier for me to do this practice in a group with another partner	CGQ7	The classroom forum has made it easier for me to carry out this practice in a group with another partner
EGQ8	The discussions on the Mattermost channels of other colleagues' exercises have helped me to make progress in my exercise	CGQ8	Discussions in the classroom forum of other colleagues' exercises have helped me to make progress in my exercise
EGQ9	Collaboration with colleagues has encouraged me to improve my grades in this exercise	CGQ9	Participation with colleagues in the classroom forum has encouraged me to improve my grades in this exercise
Tool Utility (TU)		**Tool Utility (TU)**	

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Experimental Group (EG)		Control Group (CG)	
EGQ10	Mattermost has helped solve my doubts in a more efficient way than the classroom forum	CGQ10	The classroom forum would help to resolve my questions more efficiently if it were a chat tool organized in channels
EGQ11	Sending and receiving messages from different media to Mattermost (web application, desktop application, mobile phone) facilitates communication with other colleagues in the classroom	CGQ11	Sending and receiving messages from different media to the forum (web application, desktop application, mobile phone) would facilitate communication with the rest of the classmates
EGQ12	The fact that Mattermost allows sending and receiving messages from different devices has encouraged me to use it to communicate with my group mate and share my progress (among other things)	CGQ12	If the classroom forum allowed me to send and receive messages from different devices, I would be encouraged to use it to communicate with my group partner
EGQ13	I found Mattermost easy to use	CGQ13	I found it easy to use the classroom forum
Independent Item		**Independent Item**	
EGQ14	Under the same conditions, if you had the option of taking the course using the traditional forum or Mattermost, would you choose Mattermost?	CGQ14	Under the same conditions, if you had the option of taking the course using the traditional forum or a chat tool organized in channels, would you still use the traditional forum?

Table 5. Items Questionnaire Related to Learning Enhancement (LI) in Experimental and Control Groups.

At the end, the questionnaire was completed by 89 students in the experimental group, i.e. 58.55% of the students, and by 79 students in the control group, i.e. 66.38% of the students. Each participant could answer these questionnaires regardless of whether they had completed all the tasks or not.

4.2.2. Log Analysis

As for the log files of the automatic assessment tool, which automatically record the interactions between the tool and the students, they have provided data that serve to study the approach proposed by RQ1 and RQ2. Each time a student uploads a practice through the automatic tool, data related to the upload is recorded together with their code input in the database of the automatic assessment tool. In this case, the analysis has been carried out by querying these tables, by student group and by phase. Data has been collected for all submissions for all phases, including error rates and attempts.

4.3. Data analysis

For this purpose, we have carried out, on the one hand, a quantitative analysis of the data coming from the questionnaires filled in by the students at the end of term and, on the other hand, the analysis of the logs gathered on the automated evaluation tool of the subject during the experiment carried out.

As regard the analysis of the questionnaire data, descriptive statistics, inferential statistics, correlation and variance analysis were used to find relationships between the units of the analysis studied in the experiment and to answer our research question Q1. The reliability of data gathered was ensured by using Cronbach's alpha coefficient. The values obtained are shown in Table 6.A and are higher than 0.70 in both groups, which reinforces the reliability of our indicators. In addition, the Kolmogorov–Smirnov test was also applied to test the normality of the different items in each group due to the size of the sample are higher than 25 (89 in EG and 79 in CG). The confidence level chosen for the different tests was 95%. As shown in Table 6.B, for all unit of analysis, the Kolmogorov–Smirnov normality test was statistically significant, therefore normality was not met. As such, the non-parametric Mann–Whitney U test had to be applied to all comparisons as shown in Table 7. Also we examined the skewness and kurtosis to check the multivariate normality of data. The results showed that data were normally distributed as absolute values of skewness and kurtosis did not exceed the allowed maximum (2.0 for univariate skewness and 7.0 for univariate kurtosis) as shown in Table 6.C.

A. CRONBACH'S ALPHA COEFFICIENT	
Experimental Group (EG)	Control Group (CG)
0,956 (N=13)	0,871 (N=13)

B. MULTIVARIATE NORMALITY OF DATA

EG				CG			
	Skewness	Kurtosis	Min-Max		Skewness	Kurtosis	Min-Max
EGQ1	-0.515	-0.161	1-5	CGQ1	-0.474	0.114	1-5
EGQ2	-0.409	-0.62	1-5	CGQ2	-0.468	-0.597	1-5
EGQ3	-0.887	0.036	1-5	CGQ3	-0.621	0.163	1-5
EGQ4	-0.628	-0.217	1-5	CGQ4	-0.791	-0.054	1-5
EGQ5	-1.008	0.713	1-5	CGQ5	-0.72	-0.302	1-5
EGQ6	-0.614	-0.226	1-5	CGQ6	-0.135	0.238	1-5
EGQ7	-0.058	-0.947	1-5	CGQ7	-0.063	-0.535	1-5
EGQ8	-0.684	-0.685	1-5	CGQ8	-1.049	0.37	1-5
EGQ9	-0.437	-0.712	1-5	CGQ9	-0.241	-0.658	1-5
EGQ10	-0.632	-0.693	1-5	CGQ10	-0.613	-0.169	1-5
EGQ11	-0.764	-0.322	1-5	CGQ11	-1.375	2.736	1-5
EGQ12	-0.206	-0.666	1-5	CGQ12	-1.062	0.686	1-5
EGQ13	-1.21	0.893	1-5	CGQ13	-1.098	1.274	1-5

C. THE KOLMOGOROV-SMIRNOV TEST

EG (n=89)		CG (n=79)	
	p_value		p_value
EGQ1	<0.001	CGQ1	<0.001
EGQ2	<0.001	CGQ2	<0.001
EGQ3	<0.001	CGQ3	<0.001
EGQ4	<0.001	CGQ4	<0.001
EGQ5	<0.001	CGQ5	<0.001
EGQ6	<0.001	CGQ6	<0.001
EGQ7	<0.001	CGQ7	<0.001
EGQ8	<0.001	CGQ8	<0.001
EGQ9	<0.001	CGQ9	<0.001
EGQ10	<0.001	CGQ10	<0.001
EGQ11	<0.001	CGQ11	<0.001
EGQ12	<0.001	CGQ12	<0.001
EGQ13	<0.001	CGQ13	<0.001

(*) The Kolmogorov-Smirnov Test was used to verify the normality of the sample

Table 6. Descriptive Statistic Measures and the Kolmogorov-Smirnov Test of Experimental and Control Group

5. Results

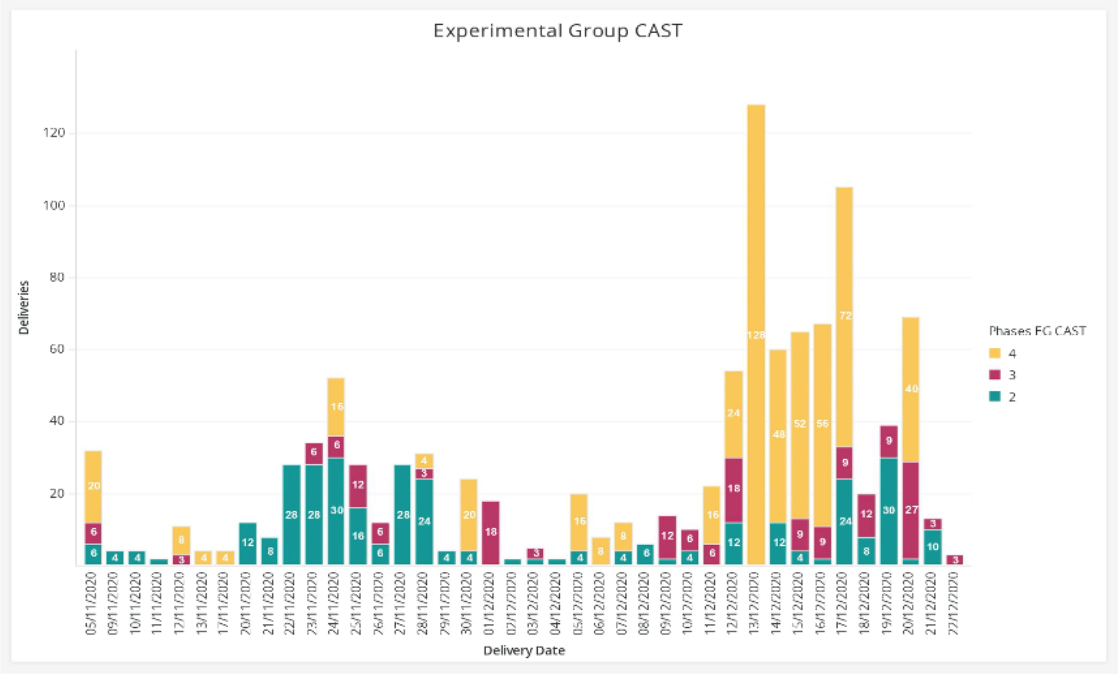
In this study we provide a statistical analysis as deep as possible in a gradual, progressive and cumulative manner. As such, the purpose of Subsection 5.1 is to present the results, grouped by unit of analysis, as for our first research question. The results to the second research question are provided in detail in Subsection 5.2.

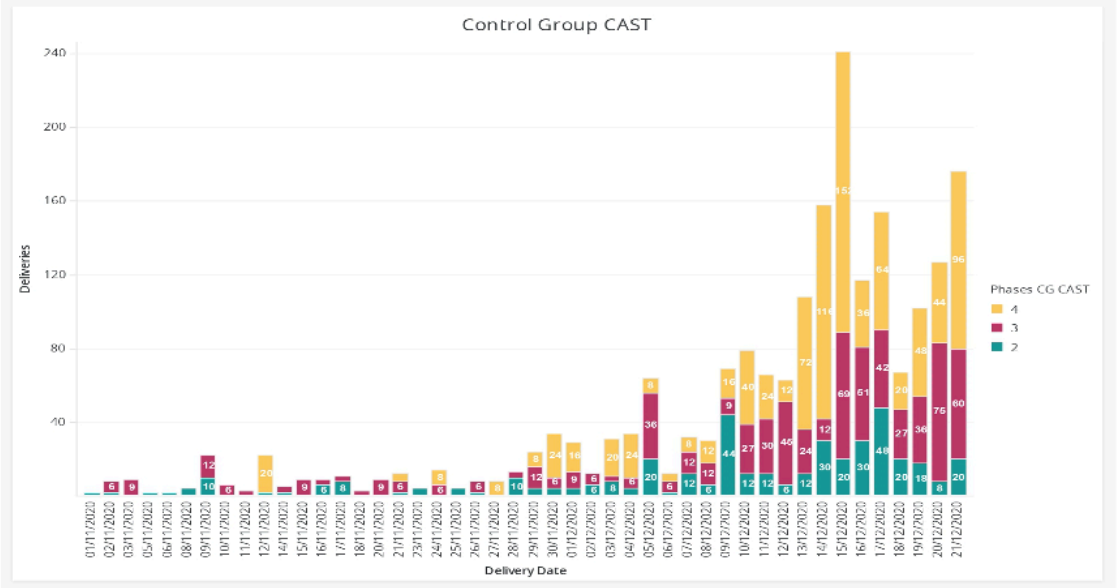
5.1. The results with regard to RQ1

5.1.1. *Results of units* ***U4*** *(the time at which each group completes a phase delivery according to the deadline) and* ***U5*** *(the absolute number of errors each group gets and corrects until they achieve a successful submission in the automatic evaluation tool.*

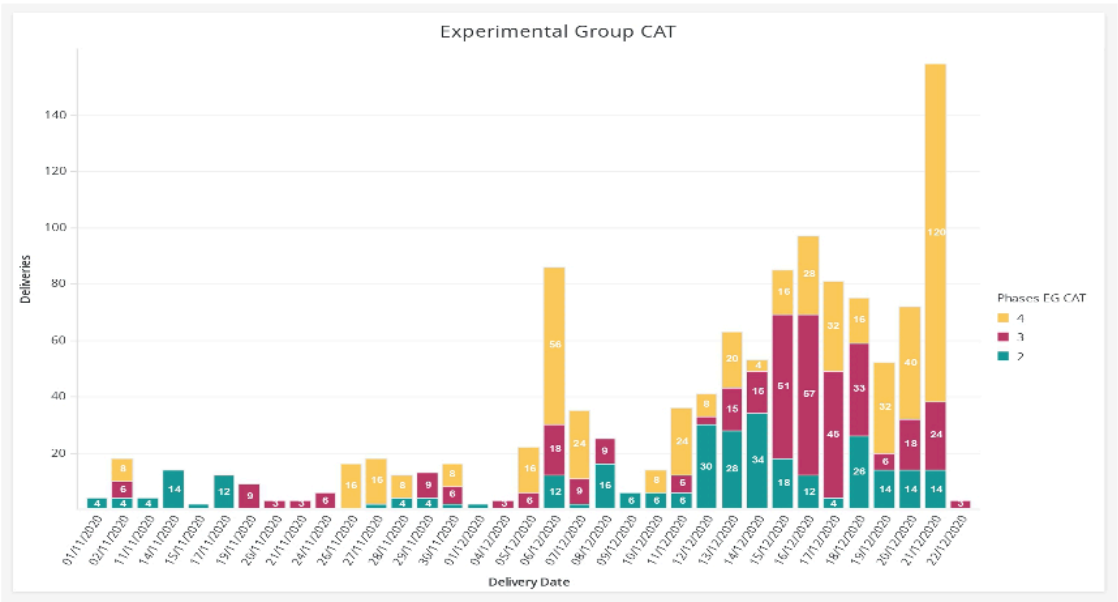
Errors are the unsuccessful attempts made by students when trying to complete a phase of the project) come ***from analyzing the logs of the tool***

As regard U4, the separate group deliveries show a higher volume of phase 4 deliveries in the experimental groups compared to the deliveries made by the control group. There is no clear trend with respect to starting practice development earlier in the experimental groups, nor in the control groups. However, in line with what is shown by the data collected in the log analysis, there is a greater sample of phases 3 and 4 in the graphs, which indicates an increase in the marks obtained, as shown in Table 7.





doi.org/10.32388/SXFME3



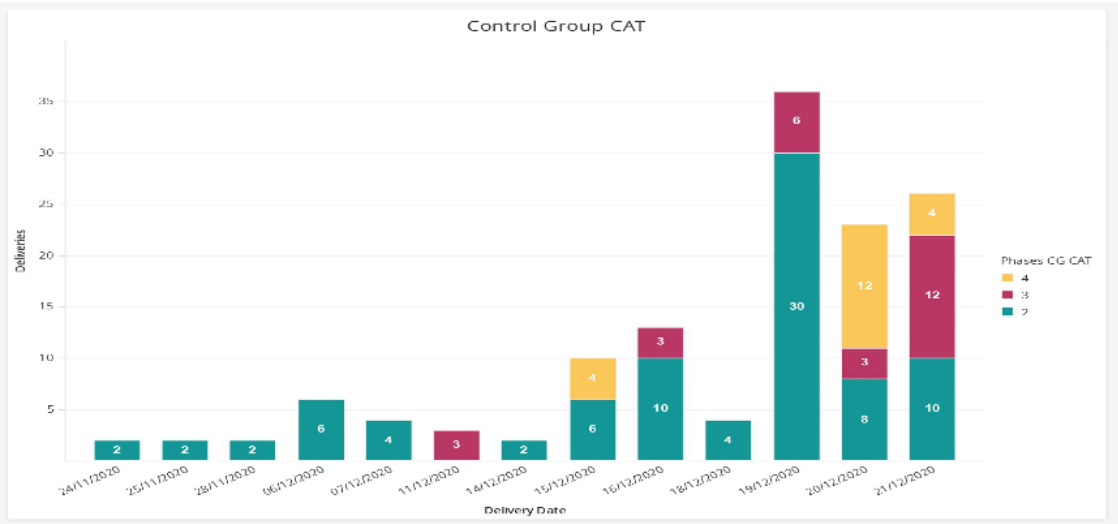


Table 7. Results Obtained for the Time at Which Each Group Completes a Phase Delivery According to the Deadline: Indicator 4 (RQ2I4): Trend in Deliveries by Each Group.

Regarding U5, the highest volume of errors in the experimental group is concentrated during phase 2, this also occurs in the control group. In absolute numbers there is a big difference in the number of

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wrong attempts in the experimental group. While we have an error rate in phase 2 of 3.94 errors per learner in the experimental group, in the control group we have a rate of 2.52 errors per learner. In other word, in phase 2 which is necessary to pass the practical, students in the experimental group attempt more submissions than those in the control group. This may be due to various factors, but if we analyze the results of the previous indicators, the rate of students in the experimental group who pass phase 2 is higher, therefore **they try more times to pass phase 2 in the experimental group, and less in the rest**. It should be noted that the practice is passed by passing phase 2.

Group	Total Submissions (All The Phases)	Submissions Experiment Phases 2. 3. 4	Errors (All The Phases)	% Errors Experiment Phases 2. 3. 4			
				Phase 2	Phase 3	Phase 4	Total
EG	1235	1031	**760**	**308 (42.77%)**	**199 (27.63%)**	**213 (29.58%)**	**720**
CG	596	451	**383**	**121 (36.33%)**	**98 (29.42%)**	**114 (34.23%)**	**333**

Table 8. Results Obtained for the Absolute Number of Errors Each Group Gets and Corrects Until They Achieve a Successful Submission in the Automatic Evaluation Tool. Errors Are the Unsuccessful Attempts Made by Students When Trying to Complete a Phase of the Project Indicator 5 (RQ2I5): Mean Errors for Each Group

5.1.2. Results of units U6 (Self-perception of Learning (SL)), U7 (Ease of Communication with Teacher (CT)), U8 (Collaboration Improvement (CI)) and U9 (Tool Utility (TU)) from the questionnaires

As mentioned before, we use descriptive and inferential statistics measures for comparing the two groups (control vs. experimental), thus evaluating the effectiveness of possibilities of Mattermost with respect to the ones offered by *the traditional forum*. As a consequence, we focus the analysis on making comparisons between the two group's scores and p-values to know if there were statistically significant differences in the effects of the units of analysis from U6 to U9 between the two groups to answer our first research question.

I. Descriptive statistic measures in control and experimental groups

First, we examine the mean values of U6 Self-perception of Learning (SL), U7 Ease of Communication with Teacher (CT), U8 Collaboration Improvement (CI) and U9 Tool Utility (TU) shown in Table 9.

	Control Group (N=79)			Experimental Group (N=89)			
Self-perception of Learning (SL)	**Mean(SD[a])**	**Median(IR[b])**	**Min-Max**	**Mean(SD[a])**	**Median(IR[b])**	**Min-Max**	**p-value (*)**
Q1	3.23(0.88)	3.00(1.00)	1 - 5	3.25(1.14)	3.00(1.00)	1 - 5	0.674
Q2	3.26(1.19)	3.00(1.25)	1 - 5	3.26(1.24)	3.00(1.00)	1 - 5	0.985
Ease of Communication with Teacher (CT)							
Q3	3.73(0.98)	4.00(1.00)	1 - 5	3.70(1.21)	4.00(2.00)	1 - 5	0.704
Q4	3.81(1.11)	4.00(2.00)	1 - 5	3.70(1.11)	4.00(2.00)	1 - 5	0.485
Q5	3.76(1.13)	4.00(2.00)	1 - 5	3.91(1.10)	4.00(2.00)	1 - 5	0.381
Q6	3.26(0.92)	3.00(1.00)	1 - 5	3.51(1.20)	4.00(1.00)	1 - 5	**0.051**
Collaboration Improvement (CI)							
Q7	2.97(1.13)	3.00(2.00)	1 - 5	2.91(1.29)	3.00(2.00)	1 - 5	0.797
Q8	3.83(1.19)	4.00(2.00)	1 - 5	3.75(1.29)	4.00(2.00)	1 - 5	0.818
Q9	3.27(1.15)	3.00(1.50)	1 - 5	3.54(1.19)	4.00(2.00)	1 - 5	0.131
Tool Utility (TU)							
Q10	3.78(1.04)	4.00(2.00)	1 - 5	3.52(1.33)	4.00(2.00)	1 - 5	0.341
Q11	4.31(0.81)	4.00(1.00)	1 - 5	3.67(1.27)	4.00(2.00)	1 - 5	**0.001**
Q12	3.97(1.07)	4.00(2.00)	1 - 5	3.18(1.23)	3.00(1.00)	1 - 5	**0.000**
Q13	4.09(0.96)	4.00(1.00)	1 - 5	4.20(1.02)	5.00(1.00)	1 - 5	0.289
(*) The Non Parametric Mann-Whitney U test was used to compare group [a] Standard Deviation; [b] Interquartile Range							

Table 9. Results of Self-Perception of Learning (SL), U7 Ease of Communication With Teacher (CT), U8 Collaboration Improvement (CI) and U9 Tool Utility (TU) in Control and Experimental Groups.

Self-perception of Learning (SL): In both group, the mean exceed the value of three (3.0) in two items. This indicates that students in both groups experienced a rather positive interaction either with

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traditional forum (CG) or with Mattermost (EG). However, SL.Q1 (The tool has motivated me to improve my work in the subject and to get a better grade) had a major effect on EG students. As long as, SL.Q2 (I have a better understanding of the concepts in practice thanks to the use of Mattermost/traditional forum) both groups had the same perception, i.e. in both groups the tools (Mattermost (EG) / Traditional Forum (CG)) helped them to better understand the concepts of the activity.

Ease of Communication with Teacher (CT): In both group, the mean exceed the value of three (3.0) in all items. This indicates that students in both groups experienced a rather positive communication with both tools. However, CT.Q5 (The doubts have been resolved in a timely manner) and CT.Q6 (Direct interaction with teachers has encouraged me to ask them more questions during the course) were more useful on EG students. Instead, CT.Q3 (Communication with teachers has been made easier thanks to the tool) and CT.Q4 (Teachers have been able to solve the doubts in a clearer way thanks to traditional forum) proved to be more useful to CG students.

Collaboration Improvement (CI): However, not all items had the same effect in both groups. CI.Q9 (Collaboration with colleagues has encouraged me to improve my grades in this exercise) had a major effect on EG students. Instead, CI.Q7 (The tool has made it easier for me to do this practice in a group with another partner) and CI.Q8 (The discussions on the Mattermost channels of other colleagues' exercises have helped me to make progress in my exercise) proved to be more useful to CG students.

Tool Utility (TU): In both group, the mean exceed the value of three (3.0) in all items. This indicates that students in both groups experienced a rather positive usefulness with both tools. However, not all items had the same effect in both groups. TU.Q13 (I found Mattermost easy to use) was more useful on EG. Instead, TU.Q10 (The classroom forum would help to resolve my questions more efficiently if it were a chat tool organized in channels), TU.Q11 (Sending and receiving messages from different media to the forum (web application, desktop application, mobile phone) would facilitate communication with the rest of the classmates) and TU.Q12 (If the classroom forum allowed me to send and receive messages from different devices, I would be encouraged to use it to communicate with my group partner) proved to be more useful to CG students.

II. The non-parametric Mann–Whitney U test

Subsequently, the non-parametric Mann–Whitney U test was used to compare group and perform a bivariate comparison between both groups. Table 7 shows the mean, standard deviation, median and

interquartile range (P75–P25), as well as the p-value of the nonparametric contrast (its significance). This value has been highlighted in bold and highlight in yellow when it is significant (≤0.05).

Table 9 shows that there are significant differences between the control and experimental groups in CT.Q6, TU.Q.11 and TU.Q12 with significantly higher values for TU.Q11 and TU.Q12 in the control group. Additionally, it is noted that CT.Q6, does not move away from the critical point 0.05, taking higher values in the experimental group. Probably, with a larger number of participants, more conclusive results could be obtained.

III. Bivariate and multivariate analysis

Below, for the experimental group (EG) we analyze the relationship between Self-perception of Learning (SL), Ease of Communication with Teacher (CT), Collaboration Improvement (CI) and Tool Utility (TU). This analysis was carried out from a bivariate and multivariate point of view.

From the bivariate point of view, the Pearson correlation coefficient among the variables is calculated. This analysis is extended with a multivariate approach by performing an exploratory factor analysis, so that to present an overall view of the relationship between the set of items of the units of analysis.

A. Bivariate analysis.

The Pearson correlations among the units of analysis measuring are presented in Table 10. All items belonging to each units of analysis has been correlated with each other's items of the rest units of analysis. In this sense, Table 10.a) shows the Pearson correlation among SL's items on the one hand and CT, CI and TU items on the other, Table 10.b) shows the correlation among CT's items on the one hand and CI and TU items on the other and finally, Table 10.c shows the correlation between CI's items and TU' items.

The measures show that all Coefficients are significant at 99 %(**). Significant implies that they are significantly different from zero, but this association can be weak or strong, depending on the value of the coefficient. The correlation coefficient measures the degree of association between variables. Since this coefficient ranges between -1 and 1, a value close to 1 or -1 indicates a strong positive (high values of one variable correspond to high values in the other variable) or negative (high values of one variable correspond to low values in the other variable) relationship between the two variables, respectively.

In our case, given that the strong correlations among all items, we have taken as strong correlation the values higher or equal than 0.7, highlight in blue and as moderate correlation the

values higher or equal than 0.6, highlight in green.

Among SL and CT, CI and TU there is a high significant correlation between SL.Q1 and CT.Q3; SL.Q1 and CT.Q4; SL.Q1 and TU.Q10; SL.Q1 and TU.Q11; SL.Q2 and CT.Q3; SL.Q2 and CT.Q4; SL.Q2 and CT.Q6; SL.Q2 and TU.Q10; SL.Q2 and TU.Q12. Likewise, there is a moderate significant correlation between SL.Q1 and CT.Q6; SL.Q1 and CI.Q8; SL.Q1 and TU.Q12; SL.Q2 and CT.Q5; SL.Q2 and CI.Q9; SL.Q2 and TU.Q11.

Among CT and CI and TU there is a high significant correlation between CT.Q3 and TU.Q10; CT.Q3 and TU.Q11; CT.Q4 and TU.Q10; CT.Q4 and TU.Q11; CT.Q6 and TU.Q10; CT.Q6 and TU.Q11; CT.Q6 and TU.Q12. Likewise, there is a moderate significant correlation between CT.Q3 and CI.Q8; CT.Q3 and CI.Q9; CT.Q3 and TU.Q12; CT.Q3 and TU.Q13; CT.Q4 and CI.Q8; CT.Q4 and TU.Q12; CT.Q5 and TU.Q13; CT.Q6 and CI.Q9;

Between CI and TU there is a moderate significant correlation between CI.Q7 and TU.Q12; CI.Q8 and TU.Q10; CI.Q8 and TU.Q11; CI.Q8 and TU.Q12; CI.Q9 and TU.Q10; CI.Q9 and TU.Q11; CI.Q9 and TU.Q12.

a) Pearson correlation among Self-perception of Learning (SL) and Ease of Communication with Teacher (CT), Collaboration Improvement (CI) and Tool Utility (TU)

		Ease of Communication with Teacher (CT)				Collaboration Improvement (CI)			Tool Utility (TU)			
		Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
Self-perception of Learning (SL)	Q1	.702**	.765**	.529**	.652**	.402**	.652**	.591**	.763**	.730**	.689**	.525*
	Q2	.756**	.782**	.607**	.736**	.494**	.595**	.626**	.761**	.696**	.701**	.499*

b) Pearson correlation among Ease of Communication with Teacher (CT) and Collaboration Improvement (CI) and Tool Utility (TU)

		Collaboration Improvement (CI)			Tool Utility (TU)			
		Q7	Q8	Q9	Q10	Q11	Q12	Q13
Ease of Communication with Teacher (CT)	Q3	.503**	.645**	.622**	.748**	.749**	.609**	.649**
	Q4	.451**	.662**	.563**	.752**	.718**	.647**	.534**
	Q5	.430**	.486**	.467**	.568**	.561**	.498**	.609**
	Q6	.579**	.573**	.646**	.746**	.721**	.759**	.573**

c) Pearson correlation between Collaboration Improvement (CI) and Tool Utility (TU)

		Tool Utility (TU)			
		Q10	Q11	Q12	Q13
Collaboration Improvement (CI)	Q7	.510**	.554**	.658**	.278**
	Q8	.683**	.658**	.642**	.410**
	Q9	.638**	.635**	.649**	.439**

Table 10. Pearson Correlations Between Self-Perception of Learning (SL), Ease of Communication With Teacher (CT), Collaboration Improvement (CI) and Tool Utility (TU) in the Experimental Group (EG, N=89)

B. Multivariate analysis.

In order to summarize the information, a multivariate analysis will be carried out; more specifically, a factor analysis of the items will be presented,

We carried out a multivariate analysis consisting in a factor analysis of the items with the aim to reduce the number of dimensions and identify factors common to the variables by examining whether these factors are sufficient to explain the results of the units of analysis studied.

The Kaiser–Meyer–Olkin index (KMO) measures the adequacy of the sample and indicates that it is appropriate the application of Factor Analysis when values between 0.5 and 1 are obtained. In

our analysis, we obtained a value of 0.917 which is acceptable.

Barlett's test of sphericity has also been performed. In our specific case, the analysis was significant with a pvalue of 0.000; therefore, the null hypothesis that they are not correlated is rejected. Hence, there is correlation between the variables. The principal component analysis (PCA) method was used to extract the factors and the Varimax rotation method was applied. Table 11 shows the factor weighting matrix. The variables with the highest weights are highlighted in each factor. For a better interpretation, only factor scores greater than 0.6 are displayed.

		Factors	
		1	2
U1	EGQ1 (SL)	0,625	
	EGQ2 (SL)	0,639	
U2	EGQ3 (CT)		0,754
	EGQ4 (CT)		0,708
	EGQ5 (CT)		0,800
	EGQ6 (CT)	0,650	
U3	EGQ7 (CI)	0,730	
	EGQ8 (CI)	0,753	
	EGQ9 (CI)	0,738	
U4	EGQ10 (TU)	0,702	
	EGQ11 (TU)	0,737	
	EGQ12 (TU)	0,845	
	EGQ13 (TU)		0,838

Table 11. Factorial Multivariate Analysis Between Self-Perception of Learning (SL), Ease of Communication With Teacher (CT), Collaboration Improvement (CI) and Tool Utility (TU) in the Experimental Group (EG, N=89)

Factor 1: In this factor all items of U3 (Collaboration Improvement (CI)) and items TU.Q10, TU.Q11 and TU.Q12 of U2 have high weights together with all items of U1 (Self-perception of Learning) and item

CT.Q6 of U2.

Factor 2: In this factor items CT.Q3, CT.Q4 and CT.Q5 of U2 have high weights together with TU.Q13 of U4, in order of weighting.

5.2. The results with regard to the RQ2

In sum, the following general results were obtained for the log analysis, covering phases 2. 3 and 4 of the experiment (see Table 12).

Group	Total Submissions (All Phases)	Total Submissions Experiment (Phases 2. 3 and 4)	Total Students
EG	1235	1031	152
CG	596	451	119

Table 12. General Log Analysis Data

Table 13 shows the percentage of students participating in the experiment (51.31%) is significantly higher than the percentage of students in the control group (38.65%) who take part in phases 2. 3 and 4 of the experiment a difference of 12.66%. which compared to the difference in phase 1. which is not included in the experiment. is 7.8%. It is an objective fact that more students in the experimental group participate in the DSLab phases than in the control group. The number of successful submissions in the experimental group is 311 compared to 118 in the control group. If we weight the results of the successful submissions per student of both groups we have the following result: 3.98 successful submissions per student of the experimental group versus 2.56 successful submissions per student. That is**, the number of successful deliveries in the experimental group is proportionally better than in the control group**.

Group	TPID* Total	TPID* Experiment (Phases 2. 3 y 4)	Distinct Students (All phases)	Distinct Students Experiment (Phases 2. 3 y 4)
EG	475	311	100 (65.78%)	78 (51.31%)
CG	213	118	69 (57.98%)	46 (38.65%)

Table 13. Results Obtained for the Tasks Achieved Comparing the Experimental Versus the Control Group: Indicador 1 (RQ2I1): The Tasks Passed of Experimental (EG) vs Control (CG) Group

(*) TPID: Task Passed in DSLAB

Despite the number of students participating in the experiment, there are not a large number of groups formed. There are certain conditioning factors that may affect the creation of group, such as time availability, affinity between students, different time zones affecting students from different countries, to give some examples. In any case, the results show a higher proportion of groups in the experimental group than in the control group. The ratio is 9.75 students for each group compared to 11.5 students per group in the control group (see Table 14).

Group	Groups (1 Student)	Groups (2 Students)
EG	194	8
CG	130	4

Table 14. Results Obtained for the Success Rate of the Groups Accomplishing All Phases of the Assessment Comparing the Experimental Versus the Control Group: Indicador 2 (RQ2I2): Groups Formed in Both Experimental (EG) and Control (CG) Group

The results obtained for this indicator show that the trained groups have a higher percentage of success in passing all the phases than those who try to approach the practice individually, both for the experimental group and the control group. Analyzing the results, 37.5% of the formed groups in the experimental group pass all the phases and therefore obtain the maximum mark in the practical, while 35.89% of the students who attempt to pass the practical individually in the experimental group pass

the practical. This difference is greater in the control group, where 10.86% of the students who attempt to pass the practical individually do so, compared to 25% of the students who pass the practical as a group. There are also differences between the experimental group and the control group in terms of the percentages of students who pass the stages. This passing of stages is directly related to the grade obtained in the practical, since the more stages passed, the higher the final grade. These results suggest that there is a higher probability of success in passing all the stages if they are done as a group (see Table 15).

Group	Individual pass all phases	Groups of 2 pass all phases	Individual pass phases 2. 3	Groups of 2 pass phases 2. 3	Individual pass phase 2	Groups of 2 pass Phase 2
EG	28 (35.89%)	3 (37.5%)	42 (53.84%)	7 (87.5%)	58 (74.35%)	8 (100%)
CG	7 (15.21%)	1 (25%)	19 (41.30%)	2 (50%)	38 (82.60%)	3 (75%)

Table 15. Results Obtained for the the Tasks Completed in a Group: Indicador 3 (RQ2I3): Groups That Pass All Phases in the Experimental Group Versus Those That Succeed in the Control Group.

6. Discussion

6.1. Students' perception of learning improvement (RQ1)

The findings found in the analysis of the data collected from the questionnaires showed that our integrated approach with Mattermost motivated mostly to experimental group students to improve their work in the subject and to get a better grade increase the *self-perception of their Learning* ***(U6)*** (Delgado et al., 2020). Likewise, it helped them to better understand the concepts of the activity though the traditional forum had the same effect in the in control group students.

According to study carried out by Chatterjee et al., (2020), our model improved the communication with the teachers **(U7)** by resolving doubts and offering recommendations in a timely manner that all the students in experimental group could consult at any time and through a direct interaction with teachers what they encouraged to ask them more questions and show them their opinions during the course. Although, the traditional forum.

Despite we did not found studies related to the use of Mattermost as collaborative tool **(U8)** (Al-Samarraie and Saeed, 2018), our research explored whether the collaboration during the development of the all phases improved. In this sense, the findings showed that the use of our model encouraged to the students' experimental group to improve their grades in the exercise. Though, also, the use of traditional forum made it easier to do their practice in a group with another partners to the students' control group.

Regarding to the utility of Mattemost together with DSLab as collaborative tool designed for agile and effective teamwork in classroom (U9), students' experimental group reported that it was easy to use (Otero et al., 2013). Moreover, students' control group expressed in this regard that they would rather (a) a chat tool organized in channels which they would help to resolve their questions more efficiently, (b) sending and receiving messages from different media (web application, desktop application, and mobile phone) would facilitate communication with the rest of the classmates.

6.2. The relationship between students' perceived online interaction via Mattermost and academic performance

The results obtained from the log analysis show improvements in all the indicators in the experimental group compared to the control group. There is a general improvement in the grades obtained by the students taking the practical in the experimental group, there is an increase in the creation of groups in the experimental group, and there are more stages passed and a higher volume of final stages passed in the experimental group. This leads to an improvement in the academic performance of the experimental group, which obtains better grades in practice than the control group. The study suggests that this improvement in academic performance is in line with other similar studies (Menzies and Zarb, 2020). The improvement in academic performance noted in other studies (Pangestu, Karsen and Chandra, 2019) may come from factors including good planning of the experiment, as has been the case her, where careful planning of the design of the experience has been undertaken. This fact was already pointed out in other studies with collaborative tools (Roschelle et al., 2010) where it is precisely indicated that good experiment planning is important to obtain good results. The improvement in learning may be due to increased communication and socialization, as indicated by other similar studies (Leo and Neo, 2015). On the increase in group creation, the improvement in communication and collaboration has already been referred to by similar studies

(Duque et al., 2009) (Al-Samarraie and Saeed, 2018) (Koh and Lim, 2012), therefore this log analysis goes in this direction.

7. Conclusion, Limitations and future work

The conclusions drawn from this study with respect to log analysis suggest that there is an increase in student collaboration, and improvements in motivation. This leads to an improvement in the academic results of the students in the experimental group compared to the control group. The factors mentioned in other studies are aligned with the results obtained in this study, relating the improvement in motivation and collaboration, and whose results obtained are an improvement in the grades obtained, and as a final conclusion, an improvement in academic performance. However, there are some limitations to mention regarding these results. There is a novelty factor that needs to be properly studied, as students may increase their motivation when moving from a traditional forum system to the use of Mattermost. This study has required a technological development to integrate Mattermost with the automatic assessment tool and a planning of the experiment. Finally, there are factors that can influence the improvement of the collaborative tool that can affect motivation, for example, the creation of different public or private channels that affect the separation imposed by classes.

With regard to future lines of research, there are three lines that can go together or separately:

- As mentioned in other studies (Chatterjee et al., 2020), the inclusion of chatbots in Mattermost to support practice development can improve learning outcomes.
- Integration with the automated assessment tool can go a step further and display notifications and assessment results in Mattermost, give advice on how to improve delivery in a personalized way and display other information, taking steps towards a gamified system.
- A contrast study on the effectiveness of different of these tools can be a powerful alternative line of research.

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Informed consent: This article does not contain any studies with human participants or animals performed by any of the authors. Human participants (university students) have merely answered an accorded questionnaire anonymously. That is, no participants' personal data were used or recorded.

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