Advancing Chemical Engineering Education: Amplifying Active Learning with Wooclap's Innovative Pedagogical Techniques

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Abstract

The integration of Information and Communication Technologies (ICT) into university education has evolved into Learning and Knowledge Technologies (LKT), enhancing teaching and learning practices. In this scenario, Audience Response Systems (ARS), such as Wooclap, are effective tools for fostering student engagement through interactive methods like real-time questions, surveys, and games. In this study, Wooclap was implemented in 12 Chemical Engineering courses from 7 different degree programs, with a potential audience of 629 students. A total of 277 students (44% response rate) and 10 instructors participated in the evaluation, which measured perceptions through a questionnaire and comparative academic performance. The results indicated that 68% of students had never used Wooclap before, highlighting the innovative aspect of this work. Both students and educators reported that Wooclap improved the three pillars of the Engaged Learning Index, particularly enhancing behavioural and cognitive engagement. Moreover, 84% of respondents recommended the use of this application in other courses, especially in theoretical ones. Educators found it easy to use, effective in boosting participation, and helpful in facilitating a deeper understanding of complex concepts. Importantly, Wooclap use led to an improvement in student performance, highlighting its potential as a valuable catalyst for active learning in higher education.

Keywords

Active Learning, Learning and Knowledge Technologies (LKT), Audience Response Systems, Wooclap, Chemical Engineering

1. Introduction

As Bruner posted in the 1960s, "Effective learning occurs through a spiral-like process rather than linearly" (Bruner, 1960). Consequently, educators should frequently revisit and reinforce previously introduced concepts to enhance student retention and strengthen the learning process (Hattie and Yates, 2013; Rosenshine, 2012). In this context, Information and Communication Technologies (ICT) emerge as viable means to facilitate this spiral approach to learning. ICT refers to the integrated set of digital tools and resources—such as computers, smartphones, the Internet, and specialized software—that facilitate communication, collaboration, and access to information. Some scholars have characterized ICT resources employed in education as e-learning or Learning Knowledge Technologies (LKT) (Beetham and Sharpe, 2019; Garrison, 2011). Examples of LKTs include e-learning platforms (LearnChemE); digital libraries (PubChem or Compendex), simulation software (ChemCAD or Aspen HYSYS), and virtual laboratories (Virtual Labs or LearnChemE). These technologies enable a student-centered approach by allowing learners to access educational materials at their own pace, engage actively in problem-solving, and collaborate with peers, thereby personalizing the learning experience (Bates, 2019; Bennett et al., 2008; Godsk and Møller, 2024; Prensky, 2001). LKT not only enables online learning but also allows for a student-centered approach, empowering learners to set their own pace and take control of their educational journey. These e-learning tools have become increasingly essential in academic literature, particularly as educators face a generation of students born in the internet era. Among the myriad software and applications developed for LKT, a subset known as Audience Response Systems (ARS) has gained prominence.

Audience Response Systems (ARS) have gained widespread adoption across various disciplines in higher education, primarily due to their ability to enhance instructor-student interaction, particularly in large-scale courses (Caldwell, 2007; Kay and LeSage, 2009). These systems have demonstrated several key benefits, including increased student engagement and interest (Mayer et al., 2009; Pradipta and Arini, 2025), early identification of at-risk students through performance analysis (Lantz, 2010), provision of immediate feedback (Diaz et al., 2024; Heaslip et al., 2014), and promotion of collaborative learning environments (Blasco-Arcas et al., 2013; Hunsu et al., 2016). The effectiveness of ARS in improving classroom dynamics has been well-documented in numerous studies across diverse academic fields (Keough, 2012). Particularly, some authors (Monot et al, 2020; Koretsky, 2022) highlighted the following specific learning outcomes that are critical in chemical engineering education: Enhanced conceptual understanding, Improved problem-solving skills, Increased student engagement and Better retention of complex material.

In recent years, the field of Audience Response Systems (ARS) has seen a proliferation of commercial applications, including popular platforms such as Kahoot!, Socrative, Moodle, and Wooclap (Awedh et al., 2014; Costa et al., 2012; Martín-Sómer et al., 2024; Wang and Tahir, 2020). This study focuses specifically on the Wooclap application, chosen for its capacity to facilitate real-time interaction between instructors and students in both face-to-face and remote learning environments (Walther, 2025 and Molina-Rodríguez et al., 2023). Wooclap's versatility in adapting to various educational settings aligns with the growing need for flexible learning tools in higher education (Marin et al., 2021). Moreover, Wooclap offers a unique approach to addressing the perennial challenge of distraction caused by smartphones and tablets in classrooms by repurposing these devices as interactive learning tools (Braçe-Diko and Garrido-Cumbrera, 2022). The integration of such technology not only enhances classroom dynamics but also provides educators with valuable real-time feedback on student understanding and engagement (Moreno-Medina et al., 2023)

Wooclap, an interactive learning platform, has garnered significant attention in educational research, with several studies evaluating its impact on student learning processes (Grzych and Schraen-Maschke, 2019). The versatility of Wooclap is evident in its wide-ranging applications across diverse academic disciplines, including chemical engineering and also medicine, economics, geology, biology, computer science, and journalism (Braçe-Diko and Garrido-Cumbrera, 2022; Catala Estada et al., 2024; Catalina-García and Galera, 2022; Marin et al., 2021; Moreno-Medina et al., 2023; Rodriguez Calzada, 2021; Sanz Alvarez et al., 2020). This broad applicability underscores the platform's adaptability to various fields, spanning both scientific, engineering and humanities subjects. A key advantage of Wooclap is its user-friendly interface and the absence of any required app installation, enhancing its accessibility (Braçe-Diko and Garrido-Cumbrera, 2022; Rodriguez Calzada, 2021).

The platform offers flexibility in implementation, allowing educators to engage students at various points during the learning process. It can be utilised in a flipped-classroom approach, employed at the beginning of a session to pique interest, during the lecture to assess concept comprehension, or at the conclusion to evaluate overall understanding (Catala Estada et al., 2024; Catalina-García and Galera, 2022; Poulain et al., 2023). Moreover, Wooclap's innovative "confusion button" feature enables real-time feedback from students, allowing instructors to adapt their explanations dynamically, thereby facilitating more effective concept assimilation. This adaptability and immediate feedback mechanism align well with the active learning and student engagement (Braçe-Diko and Garrido-Cumbrera, 2022; Rodriguez Calzada, 2021). Wooclap offers a diverse array of question types, including multiple-choice, open-ended questions, word clouds, and image identification, which enhances its versatility in various educational contexts (Braçe-Diko and Garrido-Cumbrera, 2022). This diversity in assessment methods has been shown to improve concept understanding and promote active student participation significantly (Grzych and Schraen-Maschke, 2019; Rodriguez Calzada, 2021). Therefore, Wooclap effectively shifts the focus of the learning process from an instructor-centered to a student-centered approach (Heaslip et al., 2014), aligning with contemporary pedagogical theories that emphasize active learning and student engagement. Some current pedagogical theories in this line are the Constructivism, Socio-Constructivism or Inquiry-based learning, which encourage students to take an active role in their learning process (Engqvist Boman et al., 2022; M. José Francisco Amador et al., 2023; Shroff et al., 2021)

Recent studies have demonstrated that the implementation of Wooclap in educational settings leads to increased student engagement, more effective feedback mechanisms, and enhanced concentration in the classroom (Aldalur and Perez, 2023; Catalina-García and Galera, 2022; Moreno-Medina et al., 2023). Furthermore, the platform has been noted to facilitate the introduction of debate and collective reflection, (Marin et al., 2021; Sanz Alvarez et al., 2020). Therefore, Wooclap's design principles are congruent with the four pillars of learning as defined by Stanislas Dehaene: attention, active engagement, error feedback, and consolidation (Stanislas Dehaene, 2020). This alignment is particularly significant as it corresponds with the four modes of engagement outlined in Chi and Wylie's ICAP (Interactive, Constructive, Active, Passive) framework (Chi and Wylie, 2014). The integration of these theoretical foundations into Wooclap's functionality suggests its potential to enhance cognitive processes and learning outcomes. Recent neuroeducation research further supports the efficacy of such interactive learning tools in promoting deep learning and long-term retention (Breitwieser and Brod, 2021; van Merriënboer and Kirschner, 2017).

Previous studies on the implementation of Wooclap have primarily focused on its application within single courses (Aldalur and Perez, 2023; Grzych and Schraen-Maschke, 2019; Rodriguez

Calzada, 2021), across different degrees within the same course (Braçe-Diko and Garrido-Cumbrera, 2022), or in various courses within a single degree program under a common theme (Catala Estada et al., 2024; Catalina-García and Galera, 2022). However, there is a notable gap in the literature regarding comprehensive, cross-disciplinary analyses of Wooclap's effectiveness across multiple courses and degree programs within a specific field of study. While previous studies have primarily focused on individual courses or degree programs, a cross-disciplinary approach within chemical engineering is particularly valuable. This perspective allows for a deeper understanding of how Wooclap can be implemented across different specializations within the field, providing insights into how its effectiveness might vary depending on course content, student level, and specific degree programs. Such an analysis can highlight the platform's adaptability and potential for fostering active learning across diverse contexts within the same discipline. The present research aims to address this gap by conducting a comparative analysis of Wooclap's implementation across 12 distinct courses in the field of chemical engineering, spanning seven undergraduate degree programs and one master's program conducted within the Chemical Engineering Department at the Universitat de València, seeks to provide a holistic perspective on the utilization and acceptance of Wooclap as an innovative pedagogical too.

Chemical engineering is a discipline characterized by complex theoretical concepts, mathematical modelling, and the integration of practical laboratory work. These aspects of the field often present challenges for students in terms of comprehension and application. ARS platforms like Wooclap can be particularly beneficial in this context, as they foster active engagement, provide immediate feedback, and allow for real-time interaction, which can help students better grasp complex ideas and reinforce the connection between theory and practice. l. By expanding the scope of analysis beyond previous studies, this research contributes to the growing body of literature on ARS in higher education. Furthermore, it offers a unique opportunity to examine the versatility and efficacy of Wooclap across varied educational contexts within the chemical engineering discipline.. In summary, the current research would try to answer the following question: *To what extent does the integration of Wooclap enhance student engagement and academic performance in chemical engineering courses?*' To assess that, the learning outcomes will be evaluated according to ICAP framework, student and teachers experiences and courses qualifications.(Catala Estada et al., 2024; Catalina-García and Galera, 2022).

2. Methodology

2.1 Academic Context

The academic context in this work involved students of 12 different courses in the field of Chemical Engineering taught in 7 degrees at the University of València (UV), with a potential impact on 629 students, whose main characteristics are presented in **Table 1**. All the subjects, presenting different learning outcomes and dynamics, and were given by 10 different instructors. This generates a heterogeneous sample of students and instructors that permits to determine the homogeneity in the use of ARS in higher education or finding out the possible differences between courses.

Table 1. Main characteristics of the courses. Note: "A" and "B" represent the semester in which the course is taught. "A" corresponds to the first semester, while "B" corresponds to the second semester.

Course	Degree	Course and semester	ECTS and typology	Students		
				Enrolled	Average Attending	Participant
Energetic Technologies	Chemical Engineering	4th B	4.5 Elective	26	18	9

Industrial Security	Chemical Engineering	4th B	4.5 Elective	29	19	13
Process Engineering I	Chemical Engineering	3rd B	4.5 Mandatory	66	44	25
Chemical Reaction Engineering I	Chemical Engineering	2nd B	6 Mandatory	73	51	15
Ambiental Contamination Engineering	Chemical Engineering	3rd B	6 Mandatory	70	52	43
Projects in Chemistry	Chemistry	4th A	6 Mandatory	74	52	54
Ambiental Engineering	Environmental Sciences	2nd B	4.5 Mandatory	74	63	16
Basic Operations in Bioprocesses	Biotechnology	3rd B	6 Mandatory	72	61	42
Mechanisms Design	Electronic Engineering	2nd B	6 Mandatory	65	39	22
Quality Management	Food and Science Technology	3rd B	4.5 Mandatory	44	22	12
Applied Electrochemical Technology	Master in Chemical Engineering	1st B	3 Elective	14	13	9
Polymer Science and Technology	Master in Chemical Engineering	1st B	3 Elective	22	20	17
			Total	**629**	**454**	**277**

It is worth noting that there is a difference between the total enrolled students and those who attended the lessons. There are some cases where attendance is close to, only, 50% due to the high rate of absenteeism. The causes of the absenteeism are usually related to a high rate of repeaters and students who are in part-time jobs, which difficult for them to attend lessons. In this work, the participation rate was obtained from the students who actively participated in Wooclap during the course and, among them, the ones that answered the user experience survey.

2.2 Implementation of Wooclap

In all the courses, Wooclap was integrated into the teaching methodology in several ways to enhance student engagement and facilitate learning. During lessons, Wooclap was used to ask questions that were directly related to the content being presented. These questions were posed throughout the lessons to assess comprehension in real-time and encourage active participation. At the end of each lesson, Wooclap was also employed to provide a brief review of the key concepts covered, reinforcing the material learned. In addition, Wooclap served as a self-evaluation tool, allowing students to test their own understanding of the content outside of class time. This multifaceted approach to using Wooclap ensured that it was an interactive and integral part of both in-class and independent learning experiences.

To favor students' participation, the results of these questions did not weigh on students' assessment, according to previous works (Catala Estada et al., 2024; Wood and Shirazi, 2020). This design decision was intentionally made to remove any potential bias, ensuring that students could provide candid responses without the fear of their performance influencing their grades. By decoupling assessment and feedback, we aimed to foster a more open and meaningful evaluation

of the learning tools, which is particularly important in studies exploring new pedagogical approaches.(Catala Estada et al., 2024; Wood and Shirazi, 2020).

Regarding Wooclap characteristics, it must be emphasized that it provides a variety of interactive tools. While some advanced features require a paid subscription, the free version offers essential functionalities such as multiple-choice questions, polls, and word clouds ("Wooclap," 2025). This ensures that educators can integrate Wooclap into their courses without financial constraints. As for the time investment for Wooclap implementation, educators reported that while an initial learning curve exists when first using the tool, the time investment required for creating questions and setting up activities is relatively low once familiarized with the platform. Instructors found that the increased student engagement and real-time feedback provided by Wooclap made the preparation effort worthwhile, reinforcing its value as a tool for active learning in chemical engineering education.

2.3 Student's Questionnaire

The student's perspective on the use of Wooclap was evaluated by conducting surveys through a questionnaire. Surveys can be considered as data collection tools that allow extracting the required information by asking questions. In addition, they permit a quick and economical collection of data that is, usually, facile to manage (Catala Estada et al., 2024).

The student survey was structured with the aim to answer the research question: *To what extent does the integration of Wooclap enhance student engagement and academic performance in chemical engineering courses?* This survey was structured into eight different questions, the first of which (Q1) was a control question about their genre. The other questions, except Q3 explained afterwards, were nominal (where the Likert scale is replaced with sentences) and dealt with the application frequency of use (Q2), the time dedicated to Wooclap (Q4), the implementation satisfaction (Q5), the recommendation in other courses (Q6) and the overall rating (Q7). Q3 is an evaluation of the main Wooclap advantages, such as enhancing attention, consolidating concepts, identifying doubts, etc. on a Likert scale from 1 to 5 based on previous studies (Catala Estada et al., 2024; Catalina-García and Galera, 2022; Moreno-Medina et al., 2023)Q3 is based on the Engaged Learning Index, which considers the psychological dimensions of engagement in learning, that is meaningful processing of information (cognitive engagement), focused attention on the course (affective engagement), and active participation during the course (behavioural engagement) (Michinov and Hutain, 2023; Schreiner and Louis, 2011). The last question (Q8) is an open-ended request to provide their opinion about the use of the app. This kind of question allows a greater depth and variety of responses from the audience, improving the results (Catala Estada et al., 2024)Except for Q1 and Q3, the other questions about the tool's use were conducted to help improve the application's use.

The surveys were carried out during the middle of the course (1^{st} - 2^{nd} March week 2024), except for the projects in chemistry subject, which were realised at the end of the 1^{st} semester (last week December 2024). The questionnaire was answered by a total of 277 students, involving a participation rate of 61%, considering the population as the Wooclap users. **Table 2** gathers the description of the student's perception questionnaire.

Table 2. Student's perception questionnaire.

Question	Text	Answers	Type
Q1	What is your gender?	- Male. - Female. - Fluid.	Nominal (five levels)

		- Other. - Don't want to answer.	
Q2	Did you use Wooclap previously?	- Never used it before. - Punctually used. - Other teachers employ it usually.	Nominal (three levels)
Q3	Rate the following characteristics of Wooclap on a scale of 1 to 5 (1 implies a strong disagreement and 5 strong agreement)	- Improve the concept understanding. - Present a direct application of theory. - Facilitates the memorization. - Favours the emergence of doubts. - Facilitates the doubts resolution. - Increase the interaction with the lecturer. - Increases participation in the course. - Encourage class attendance.	Likert Scale (five levels)
Q4	Has Wooclap been correctly integrated into the course?	- It has been integrated disastrously. - It has been completed with difficulties. - It has integrated well in some points and badly in others. - It has integrated well. - It has been integrated harmoniously.	Nominal (five levels)
Q5	The time employed during the course to Wooclap was, from your point of view	- Excessive. - A lot. - Adequate. - Little. - Insufficient.	Nominal (five levels)
Q6	What is the general assessment of the use of Wooclap in the subject?	- Excellent. - Good. - Adequate. - Bad. - Unpleasant.	Nominal (five levels)
Q7	Would you use Wooclap in other subjects?	- Yes, in all of them. - Yes, but only in theoretical courses. - Yes, but only in practical subjects. - No.	Nominal (four levels)
Q8	Have you any comments or suggestions about the use of Wooclap?		Open question

2.4 Instructor's Questionnaire

The 10 instructors involved in this work were all from the Chemical Engineering Department of the University of València. They formed part of the innovative teaching project *TAC(IQ): Knowledge and Learning technologies in Chemical Engineering* and participated voluntarily in the use of Wooclap in their courses. This project carried out formative actions during the first 2023/24 semester in the use of the application for all the instructors involved, a caption of the presentation carried out together with the link to it could be found in the **SF1**.

The instructor's perspective after the implantation of Wooclap was assessed through a questionnaire structured into eight different questions. First, a polar question about the previous experience with audience response tools the first question was asked (Q1), with the possibility of selecting the previously used audience response tools (Q2). Shared with the student's questionnaire, the main Wooclap advantages were evaluated (Q3) on a Likert scale from 1 to 5,

according to the formerly mentioned Engaged Learning Index. Subsequently, the moment when it was used Wooclap (Q4) and the frequency of use (Q5) were evaluated. Then, some of the characteristics of Wooclap related to its implementation (Q6) were assessed on a Likert scale from 1 to 5. Also shared with the student's evaluation, the recommendation in other courses was requested (Q7). Finally, an open-ended question (Q8) requested inconveniences experienced during the use of the app and other comments. These questions helped to know how the use of Wooclap could improve the learning experience of the students involved from the instructors point of view. All the teaching staff answered the questionnaire, which is gathered in **Table S1** of the **Supplementary Material**.

2.5 Academic Performance

Student performance was evaluated by comparing the grades of the 2022-23 academic season with those of the 2023-24 season. The analysis focused on categorizing students' final grades into four groups: "fail", "pass", "good", and "excellent". The distribution of students across these categories was examined before and after the implementation of Wooclap, in order to assess any potential impact on academic performance. The proportion of students in each grade category was compared between the two seasons, and statistical analysis was performed to determine if any significant changes occurred, particularly in the percentage of students moving from failing or passing categories to higher grades (good or excellent).

2.6 Statistical Evaluation

To determine the homogeneity of the responses obtained among the different groups, involving the mentioned degrees and courses, the Pearson chi-square test was applied (Catala Estada et al., 2024). This statistical method was specifically chosen to examine whether the heterogeneity in our sample affected the results obtained by testing differences between the course (with 12 categories) and each of the questions (nominal variables with 3 to 5 levels). In the nominal variables, the percentage of answers for each response was evaluated.(Catala Estada et al., 2024).

To evaluate the perceptions of teachers and students regarding the use of Wooclap, data from surveys assessing various aspects such as participation, interaction, concept understanding, and doubt resolution were collected. Descriptive statistics were used to summarize the responses, followed by independent sample t-tests to compare the mean scores between teachers and students for each evaluated characteristic. Differences between the two groups were considered statistically significant if the *p*-value was less than 0.05. This analysis helped assess how teachers and students perceived Wooclap's effectiveness in enhancing learning engagement and outcomes.

For the analysis of academic performance, a comparison of the proportions of students in different grade categories (failing, passing, good, and excellent) before and after the use of Wooclap was conducted. The significance of the changes in student grades was evaluated using chi-square tests, with a significance level of $p < 0.05$. This statistical test helped determine whether the use of Wooclap had a significant impact on students' academic performance, particularly in terms of grade improvements.

2.7 Ethical Considerations

The study was conducted in accordance with institutional guidelines of the Universitat de València, ensuring that all data were analysed in an aggregated and anonymized manner. Since the study focused on general educational practices without collecting personal or sensitive information, no specific consent procedures were required.

3. Results and discussion

3.1 Student's Evaluation

The student's evaluation was firstly discussed in terms of (*i*) frequency of previous use, (*ii*) dedicated time to the use of Wooclap, (*iii*) implementation satisfaction, and (*iv*) recommendation in other subjects, which individual (per course), and overall results are presented in **Figure 1**. These questions do not answer our learning outcome but help to give a framework for the whole study.

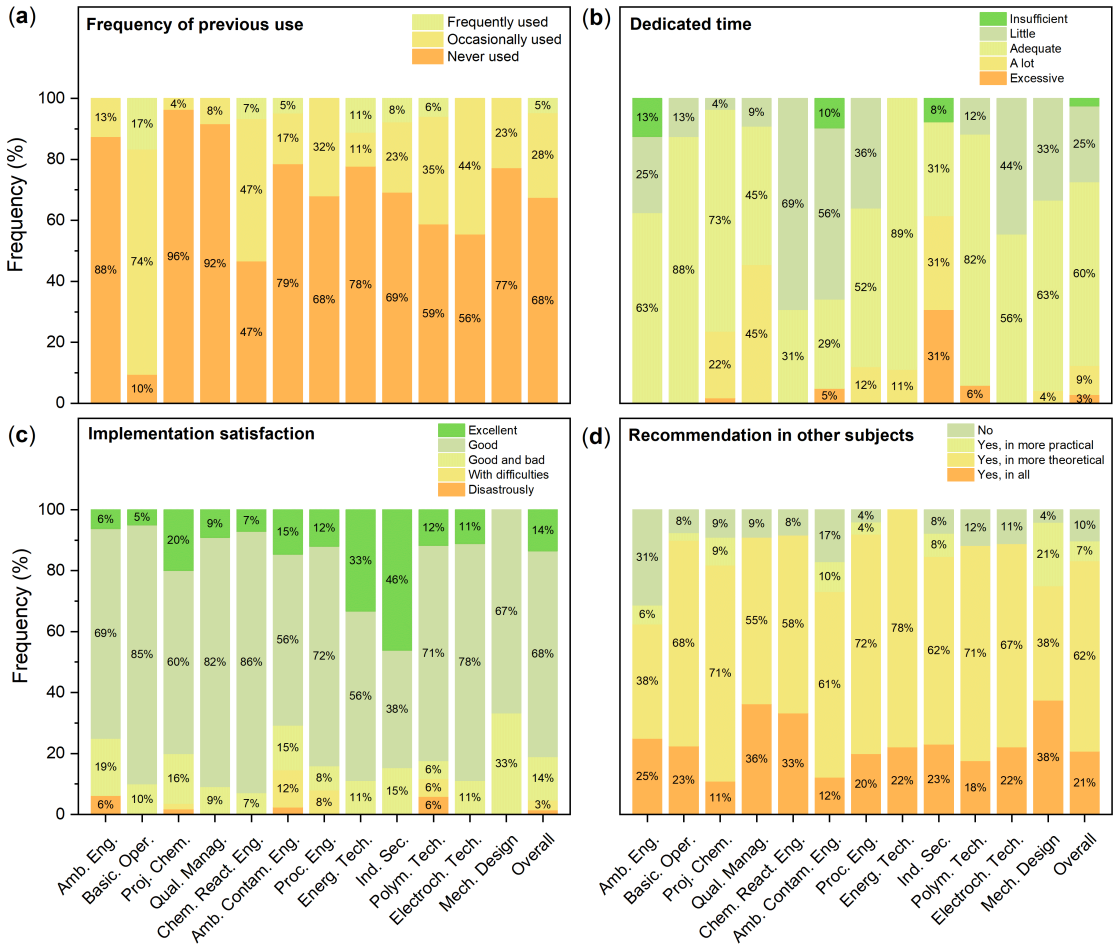

Figure 1. Results for the student evaluation about the (a) frequency of use, (b) dedicated time, (c) implementation satisfaction and (d) recommendation in other subjects.

Because of the differences observed between marks of the different courses, the Pearson chi-square test must be applied to verify whether these responses' diversity is the result of random variability, or it is significant (Catala Estada et al., 2024). The possibility of no correlation between course, teaching methodology, students' diversity and their choice in the answers is the null hypothesis. The Pearson test was then applied to the frequencies of each answer in each course, obtaining the chi-square value. This value was compared with the critical one corresponding to a confidence level of 95%. For the obtained data, **Table S2** of the **Supplementary Material** gathers the Pearson Chi-square test results for the student's response. This test concluded that no relationship between the course the students were listed and the answer to the questions they provided was detected in the whole survey. Therefore, the analysis of overall results could provide valid information about Wooclap implementation.

Results show that Wooclap remains unknown in the degrees where the Chemical Engineering department (from the UV) participates as 95% of the respondents have never or only punctually

used it (**Figure 1a**). It is worth noting that Wooclap seems to be often employed in the chemical engineering degree as they show a slightly higher trend. An exception is *Basic Operations in Bioprocesses* subject, where most students have occasionally used Wooclap before. This is the only data that presented a chi-square higher than the critical value, indicating some kind of relationship between course and answers. Investigating this result, it was found that in the *Biotechnology* degree, some instructors employed Wooclap occasionally during the first course. Despite this, general results highlight the novelty of this tool in the Chemical Engineering UV related courses.

Regarding the time dedicated to Wooclap activities (**Figure 1b**), the variety of courses, degrees, dynamics, students, and, especially, the instructor using Wooclap as it will be shown below (**Table S2**), generated a wide spectrum of answers. However, the samples were consistent and showed no relationship between the course and the answer according to the Pearson test, where the values of chi-square were close but lower than the critical value. In general terms, more than 60% of students thought that Wooclap was correctly integrated with time dedication. Therefore, future work will be carried out to address the courses where the application was under or overused.

According to the satisfaction about the implementation of activities in Wooclap (**Figure 1c**), students think that instructors correctly employed the application. The worst results showed a minority of ~30% of students indicating that the activities could be bitterly implemented in the courses of *Ambiental Contamination Engineering* and *Mechanism Design*. Despite these singularities, the Pearson test showed no influence on the response. Individual and general results depicted that more than 70% of students were satisfied with the implementation of Wooclap. Català *et al.* also noted a positive student reception of Wooclap's integration into their courses (Catala Estada et al., 2024).

Finally, 90% of students indicated that they would recommend the implementation of Wooclap in other courses (**Figure 1 d**), especially in theoretical subjects with more than 60% of answers. The only exception to this trend is observed in the *Ambiental Engineering* course where 31% of respondents marked that they will not use Wooclap in other courses. The recommendation of Wooclap use in theoretical subjects, where maintaining attention and active participation can be more challenging, has been previously observed in the literature (Jailani et al., 2023; Martín-Alguacil and Avedillo, 2024). Satisfaction and recommendation results are useful because if students strongly agrees with the use of the application and it boosts their learning experience, Wooclap use will be maintained and expanded to other courses to help students acquire all the knowledge and skills they should.

The student's perception was further evaluated with the evaluation of the Engage Learning Index (Schreiner and Louis, 2011), where the real effectiveness of the application is evaluated. **Table 2** and **Figure 2** present the obtained individual (per course), and overall qualifications, respectively. Behavioural engagement is represented by the three first items (attendance, participation, and interaction), while the cognitive one is related to the following three (memorization, doubt resolution and concept understanding). Finally, affective engagement is associated with the last two items (concept application, doubt arise). In general terms, students agree with the improvement in all the items presented as all the values are above 3 on the Likert scale. The mean value is 3.62, indicating that most students consider that Wooclap is enhancing their learning experience.

Table 3. Results for the engaged learning index ascribed to cognitive, affective and behavioural engagement in the Likert scale (1-5) obtained in the different courses. Colour scale is orange (2.0-2.9), yellow (3.0-3.9), and green (4.0-4.9).

Course	Attendance	Participation	Interaction	Memorization	Concept understanding	Doubt resolution	Doubt arise	Concept application
Energetic Technologies	4.1	4.3	4.2	3.8	4.1	3.6	3.4	3.9
Industrial Security	4.1	4.2	4.3	4.0	3.8	3.9	3.8	4.3
Process Engineering I	3.0	4.0	4.0	3.1	3.5	3.6	3.6	3.8
Chemical Reaction Engineering I	3.5	3.9	3.9	3.4	3.4	3.6	4.1	3.7
Ambiental Contamination Engineering	2.6	3.1	3.0	3.3	3.5	3.2	2.8	3.5
Projects in Chemistry	3.4	4.2	4.2	3.6	4.0	3.9	3.9	4.1
Ambiental Engineering	2.6	3.3	3.3	3.4	3.3	3.2	3.2	3.5
Basic Operations in Bioprocesses	3.4	3.6	3.7	3.6	3.3	3.5	3.3	4.0
Mechanisms Design	3.5	4.3	4.5	4.1	4.1	4.1	4.2	4.2
Quality Management	2.3	3.3	3.8	3.6	3.7	4.0	3.5	3.5
Applied Electrochemical Technology	2.9	3.8	3.8	4.0	3.9	3.7	3.6	4.3
Polymer Science and Technology	2.6	3.1	3.3	3.6	3.6	3.8	3.3	3.8

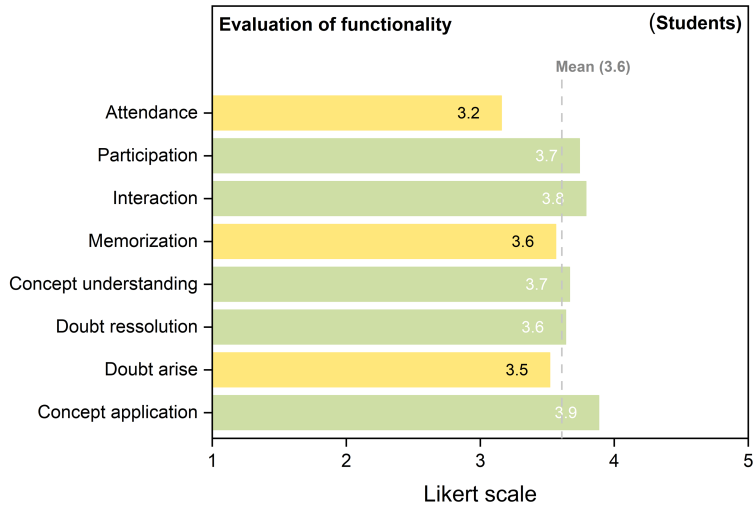

Figure 2. Student's evaluation of functionality, aligned with the engage learning index ascribed to cognitive, affective and behavioural engagement.

The items with the highest consideration are the increase in their participation (3.7) and interaction with the instructor (3.8) and an improvement in their course understanding by the direct application of concepts (3.9) shown in the theory, which corresponds to the behavioural and affective engagement, respectively. These results are expected for an ARS where the questions can be placed directly after the concept explanation. Furthermore, the possibility of answering anonymously helps to break the wall between instructors and students (Heaslip et al., 2014; Latham and Hill, 2014; Yu and Liu, 2009). These results are in concordance with those presented

in the previous literature (Araújo et al., 2013; Lours and Sujobert, 2018; Voelkel and Bennett, 2014; Zhang et al., 2020).

Two more items presented values higher than the mean, the improvement in concepts understanding (3.7) and doubts resolution (3.6), both corresponding to cognitive engagement. Both items are directly related to the results previously mentioned, as a direct application of the theoretical concepts facilitates their understanding. Furthermore, instructors generally used instantaneous feedback from Wooclap to explain the common failure reasons or how to differentiate true from bad answers. Previous works observed similar trends during the use of various ARS. For instance, Voelkel *et al.* noted that the use of ARS encourages deeper cognitive processing of the material presented (Voelkel and Bennett, 2014). The work of Arujo *et al.*, on the other hand, marked that ARS enhanced the understanding among students (Araújo et al., 2013). Lours *et al.* highlighted that instant feedback allows instructors to offer alternative explanations for concepts that students struggle with (Lours and Sujobert, 2018).

As for items lower than the mean, memorization (3.6) and doubt arise (3.5), both correspond to cognitive and affective engagement, respectively. These results could be associated with the date of the survey, one month before exams. Then, some doubts will arise during exams preparation. Furthermore, research suggests that questions often do not emerge spontaneously from students (Burgh et al., 2018). On the other hand, the lowest value is for the promotion of student attendance thanks to the use of Wooclap, with a value of 3.2, which remains slightly higher than the neutral value, meaning that respondents felt the courses were a little bit attractive. Other authors like Santos *et al.*, linked the capacity of asking questions not only to address misconceptions but also to enhance memorization thanks to the ARS use (Santos et al., 2019). On the other hand, Goyal *et al.* indicates that the improvement in student participation and engagement using ARS led to better memorization (Goyal et al., 2023). Finally, Fitzpatrick *et al.* related the use of an ARS to the attendance improvement (FitzPatrick et al., 2011).Haga clic o pulse aquí para escribir texto.

Although the Pearson test shows no relationship between the course and the punctuation of each item, the statistical analysis of the data coming from **Table 3** shows three concepts with a high standard deviation: *interaction*, the *doubt resolution* and *attendance* to the courses topics. This variability could be associated with the dissimilar use of Wooclap by the instructors, since the frequency of use, the kind of questions, etc, were not normalized as will be further discussed in section 3.2.

Regarding the general experience of the students using the Wooclap application, it can be appreciated in **Figure 3** that 74% of respondents rated their experience as good or excellent. On the other hand, 24% expressed that their experience was adequate, while less than 2% presented a bad or unpleasant experience. This good perception has been observed in other degrees and universities in the Chemical Engineering Degree in the Faculty of Sciences of the *Universidad Autónoma de Madrid* (Moreno-Medina et al., 2023)(Moreno-Medina et al., 2023), Economic courses in the *Universitat de València* and *Universidad Rey Juan Carlos I* (Catala Estada et al., 2024; Rodriguez Calzada, 2021), the Faculty of Veterinary Medicine of *Universidad Complutense de Madrid* (Martín-Alguacil and Avedillo, 2024). Consequently, Wooclap seems like an unknown tool in the UV that charms students and aids them within the Engagement Learning Indexes, making their learning process easier by promoting more active learning. According to the students perception, Wooclap enhances their learning process. In future sections, the instructors view and the analysis of the students performance would also be evaluated.

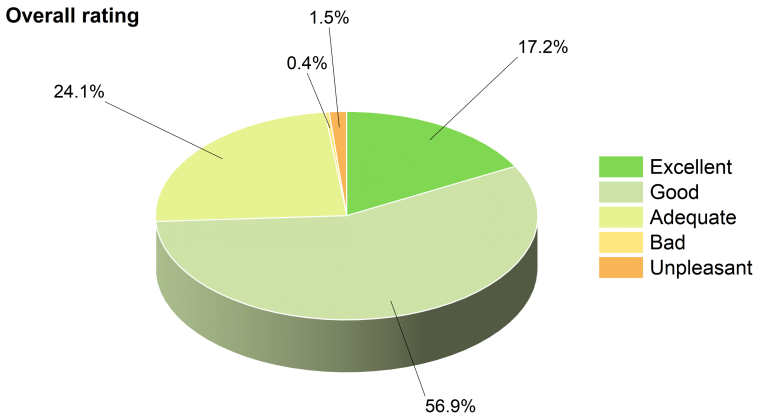

Figure 3. Results for the general experience and overall rating of Wooclap.

Q8 was an open-ended question that generated a wide range of responses. Nevertheless, results can be classified in some topics according to their similar nature. Briefly, most students (190) directly did not answer the question or responded with "nothing to add". 38 students, on the other hand, were thankful for the dynamization of the course thanks to the use of Wooclap, which explains the high mark obtained by the items corresponding to behavioral engagement. Moreover, 33 students pointed out that the use of Wooclap helped them to pay more attention to the courses, which are related to punctuation in affective engagement. Finally, a notable concern raised by 13 students was the "filling the gap" questions, where incorrect answers could be marked due to minor discrepancies in wording. This issue led to a sense of frustration, with some students expressing that these questions were wasted time. These negative experiences highlight the need for further refinement in the design of question formats to better align with student expectations and reduce potential confusion. It is essential to ensure that students' engagement does not lead to frustration, which could impact their learning experience. Thus, while the overall student perception was largely positive, these points of feedback provide valuable insight into areas where the application of Wooclap could be improved for future use.

3.2 Instructor's Evaluation

The teaching staff participating in this work answered the survey described in the supplementary materials section (**Table S1**). Regarding their previous use of any ARS, 90% of instructors have previously employed, at least, one of them, pointing to Socrative and Kahoot as the most used. All respondents marked that they used Wooclap during the lessons, but 30% also employed it at the end of the course and another 30% as a self-evaluation tool. This points out the predisposition of the teaching staff to the application of a tool like Wooclap and, on the other hand, the Wooclap's versatility of use.

As done by the students, the instructor's application evaluation was carried out with the assessment of the Engage Learning Index (Schreiner and Louis, 2011), according to a Likert scale, considering behavioral (attendance, participation, and interaction), cognitive (memorization, doubt resolution and concept understanding) and affective engagement (concept application, doubt arise). The overall qualifications are shown in **Figure 4a**.

The perceptions of Wooclap functionality were compared between instructors and students to understand the differences in their evaluations of the tool. The mean differences in their ratings across several dimensions were found to be statistically significant, as evidenced by a *t-statistic* of 6.36 (p = 0.00038). This indicates a clear disparity in how teachers and students perceive the effectiveness of the tool. In general, teachers rated the tool significantly higher than students did.

On average, teachers provided a mean score of 4.24 across the assessed characteristics, while students rated Wooclap at 3.62 on average, resulting in a mean difference of 0.62 points. This suggests that instructors tend to have a more favourable view of the tool's functionalities compared to students. Specifically, teachers particularly valued Wooclap's ability to increase participation (4.4) and interaction (4.5), both of which correlate strongly with behavioural engagement (Araújo et al., 2013; Lours and Sujobert, 2018; Voelkel and Bennett, 2014; Zhang et al., 2020). Interestingly, teachers also appreciated Wooclap's role in generating doubts (4.6) and aiding in doubt resolution (4.3), aspects that were not as highly rated by students. This disparity may reflect differences in perspective: teachers, with a broader view of the course and students' challenges, see Wooclap as a relevant tool in addressing conceptual difficulties and engaging students in real-time. On the other hand, students might not always be aware of the role that Wooclap plays in fostering doubt or guiding them towards better conceptual understanding.(Araújo et al., 2013; Lours and Sujobert, 2018; Voelkel and Bennett, 2014; Zhang et al., 2020).

Furthermore, students rated the tool less favorably in terms of memorization (3.6) and attendance (3.2), suggesting that they did not perceive Wooclap as a major influence on these aspects. This lower evaluation could indicate that students may not associate the tool with these outcomes as strongly as they do with concept understanding or participation. The statistical analysis confirms these differences and highlights the importance of understanding both teacher and student perspectives when evaluating educational tools. Teachers' higher ratings (3.6 and 3.4 in memorization and attendance) can be attributed to their ability to observe the tool's long-term effects on student behaviour and learning outcomes. In contrast, students, in their more immediate experience with the tool, might not fully recognize its influence on their learning process, especially in aspects like doubt generation and resolution.

The findings suggest that Wooclap's potential for increasing participation and interaction, along with its capability to help resolve doubts and improve understanding, are more fully recognized by instructors, who use the tool with a holistic view of its impact on the learning environment. In contrast, students may not be fully aware of these benefits, which could explain the lower observed ratings. The statistically significant difference in ratings suggests that instructors might see the tool as an indispensable teaching aid while students may view it as just one of many tools without fully appreciating its impact on their learning. This difference in perspective may also be linked to the role each group plays in the learning process. Instructors have a broader overview of the course and are likely to perceive the tool's benefits in facilitating engagement and concept mastery, whereas students may focus more on the immediate effects of the tool, such as participation during the session. Additionally, students' lower ratings on memorization and attendance highlight potential areas for further development. Wooclap could be enhanced to emphasize these features, perhaps through more targeted activities that encourage recall or greater integration into course materials designed to improve attendance rates.

Overall, the statistical analysis underscores the value of Wooclap from an instructor's viewpoint, particularly in enhancing participation, interaction, and concept understanding. The significant differences in the perception of the tool between instructors and students suggest that both groups may benefit from additional training or support to recognize the full potential of Wooclap in improving the learning experience. Instructors could benefit from more targeted training on integrating Wooclap's features, while students might benefit from more exposure to how the tool aids in conceptual development and doubt resolution, which could further enhance their

engagement with the platform.(Araújo et al., 2013; Lours and Sujobert, 2018; Voelkel and Bennett, 2014; Zhang et al., 2020)Subsequently, the teaching characteristics of Wooclap were analysed by instructor mainly based on the capability to give instant feedback, the allowance of complex questions, the integration within presentations, the question type variety and the overall simplicity, which results can be found in **Figure 4b**.

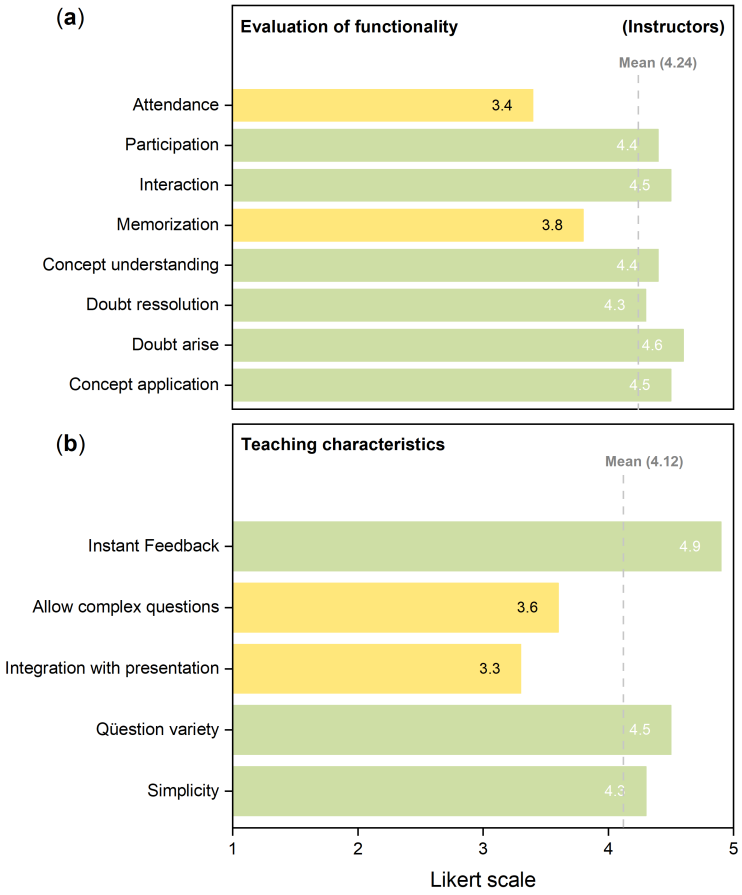

Figure 4. (a) Instructor perception of Wooclap's impact on engagement, and (b) Instructor perception of Wooclap's utility in fostering student interaction.

The instructors' most valued characteristic of Wooclap was the instantaneous feedback given by Wooclap (4.9). Having the possibility to corroborate or disprove the students' response with the immediacy that the tool provides is greatly valued by the instructor. As mentioned before, instant feedback allows educators to offer alternative explanations for concepts that students struggle with (Lours and Sujobert, 2018). Subsequently, the wide variety of types of questions that Wooclap offers was gently valued by instructors (4.5), which enhances student engagement and participation (Braçe-Diko and Garrido-Cumbrera, 2022). The most used types include multiple choice, word clouds, polls (rating or ranking), open-ended questions, and fill-in-the-blanks. Other options like image-based questions, matching, and brainstorming further diversify the learning experience. These tools allow educators to assess understanding, spark discussions, and encourage active learning in real-time, making Wooclap a versatile platform for interactive teaching (Rodriguez Calzada, 2021)(Rodriguez Calzada, 2021)(Rodriguez Calzada, 2021)(Rodriguez Calzada, 2021). In addition, instructors valued the simplicity of Wooclap (4.3), offering an intuitive and user-friendly interface that allows both instructors and students to engage with ease, without the need for extensive training. However, the allowance of complex questions

(3.6) and integration with presentations (3.3) were valued by instructors below the mean. The low rating of these features may be linked to insufficient practice among the instructors. While Wooclap's wide variety of question types enables managing complex topics through thoughtful selection of the most appropriate format, it also offers seamless integration with platforms like Microsoft PowerPoint and Moodle. Given these advantages, more practice in these areas could lead to a higher evaluation from instructors, as they would better understand how to fully leverage the platform's capabilities.

On the other hand, the instructor evaluated the frequency of use, and recommended implementation in other subjects. **Figure 5** shows a heterogeneous response about the frequency of use by the different instructors. While 50% reported minor use, 12.5% and 12.5% answered medium and major use, and 25% used Wooclap in virtually all the sessions. These results can be correlated with the perception of the dedicated time given by students of the different courses shown in previous sections. Regarding the future implementation of Wooclap in other subjects, the instructors coincide with students. All of them would be in favour of using Wooclap in other courses, especially in those with more theoretical contents, according to other studies in the literature (Jailani et al., 2023; Martín-Alguacil and Avedillo, 2024). Using Wooclap in more theoretical subjects is encouraged because it promotes active learning and enhances student engagement with complex concepts. By incorporating interactive features such as real-time questions, polls, and open-ended discussions, Wooclap helps break down abstract or dense material, making it more accessible and easier to understand. This interaction encourages reflection, critical thinking, and immediate feedback, all of which are crucial for deepening comprehension of theoretical subjects. Additionally, it fosters greater participation, turning passive lectures into dynamic learning experiences.(Jailani et al., 2023; Martín-Alguacil and Avedillo, 2024).

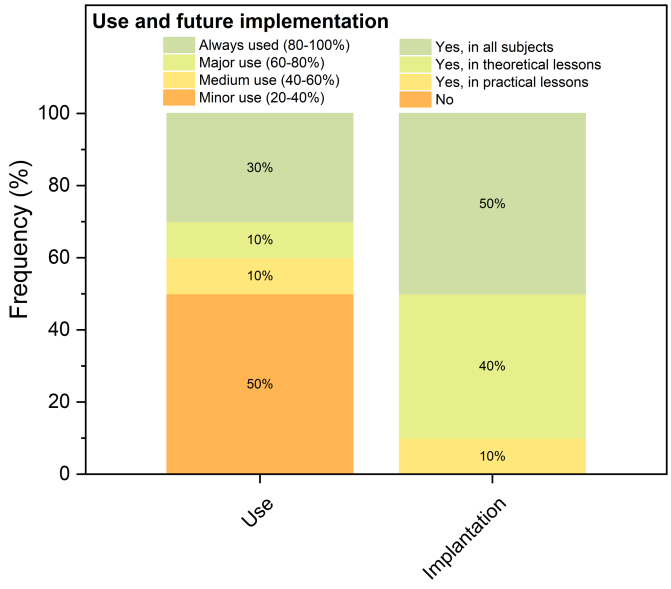

Figure 5. Results for the instructor evaluation about the frequency of use, and recommendation for implantation in other subjects.

Finally, the open question shows some concerns of educators. In general, there were no problems during Wooclap use (6 instructors did not remark anything). However, an instructor found problems with the format of the slides when implementing the presentation. In this sense, another professor marked that the integration of Wooclap was not easy enough. Finally, an educator highlighted that students' participation in Wooclap events must be improved, which is in

concordance with the results observed during the application use. The integration of a true-false question type was also indicated by another colleague.

3.3 Academic Performance

An analysis of the academic qualifications obtained by the students in the different courses is presented in **Figure 6**. There was no statistically significant difference between the number of students failing the courses after the application of Wooclap ($p > 0.05$). Several hypotheses could explain these results. First, as aforementioned, there is absenteeism of approximately 20%. Additionally, not all students attending the courses participated in all the Wooclap activities, some only answered the questions they considered easier or simpler to do, not the ones that required a higher effort (intellectual and/or time commitment). On average, only 60-80% of students participated in all the questions. As a result, the percentage of students failing the course could be inside these two groups: the ones not using the tool or the absentees.

Regarding the percentage of students who just passed the courses, there was a decrease of 9.4% but, as mentioned earlier, this decrease did not correspond to an increase in failing students. Instead, the increase was observed in the group with good grades, as almost 8.7% of students improved their grades from “pass” to “good”. This change was statistically significant ($p = 0.03$), suggesting a positive effect of using Wooclap on the student’s learning. In contrast, the increase in students achieving “excellent” qualifications was not significant, with a 1.2% increase ($p = 0.15$), which suggests that Wooclap’s impact might be more pronounced on mid-range performers rather than top achievers.

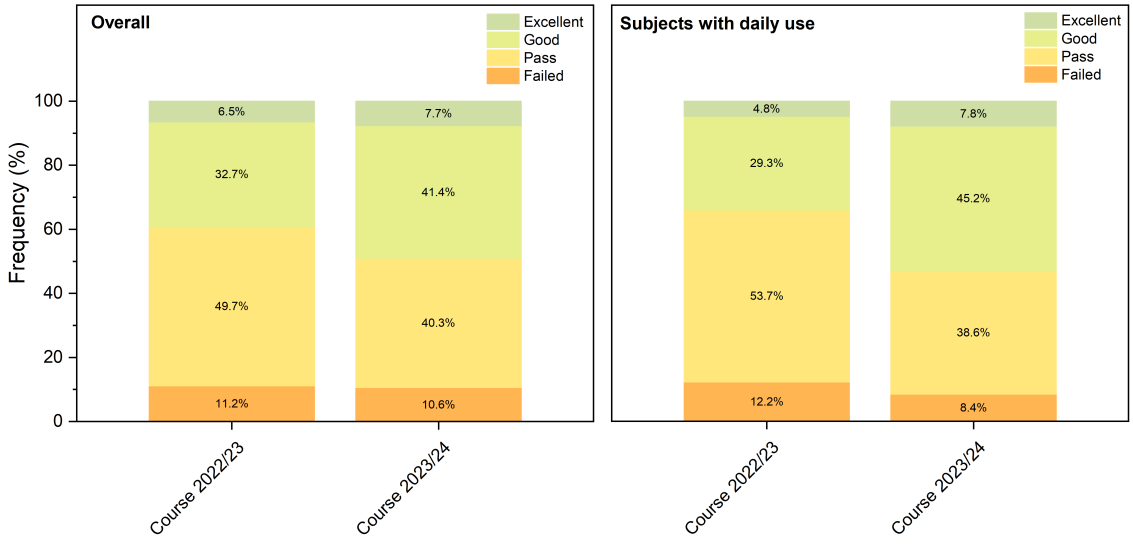

Figure 6. Academic performance of students for courses 2023/24 and 2022/23 in the overall subjects where Wooclap was applied (left) and those subjects with daily use (right).

Additionally, a positive correlation ($r = 0.72$, $p = 0.01$) was found between the frequency of Wooclap usage and the improvement in student qualifications. Specifically, in courses where Wooclap was used intensively, i.e., employed at least once per session (*Projects in Chemistry*, *Quality Control*, *Environmental Engineering*), there was a 3.8% reduction in failing students, coupled with a 15.2% decrease in students achieving a "pass" grade. This reduction in students with lower qualifications corresponded to a significant increase of 15.9% in "good" qualifications and a modest 3.1% rise in "excellent" qualifications. These results were statistically significant ($p < 0.05$) for both "good" and "excellent" categories. Other works have also reported similar findings. For example, Moreno *et al.* observed that while the average student’s mark did not

change significantly, the number of students passing the course increased (Moreno-Medina et al., 2023). Rodríguez-Calzada *et al.* showed a slight increase in the average mark along with an increase in the number of students passing the course (Rodriguez Calzada, 2021). Martín *et al.* also observed similar results when using learning tools (Martín-Sómer et al., 2024).

The results highlight that not only the use of a tool like Wooclap but also its frequency plays a crucial role in determining its effectiveness. A more intensive implementation, where Wooclap was used in every session, was associated with a notable improvement in student performance. Specifically, courses with higher Wooclap usage showed a reduction in the percentage of failing students and those with minimal passing grades, with a corresponding increase in students achieving good and excellent grades. This suggests that consistent engagement with interactive tools fosters a more active learning process, reinforcing key concepts and enhancing knowledge retention. Future research could further explore this correlation, considering additional factors such as the type of questions used, student motivation, and engagement levels. Considering the research question, Wooclap seems to help students to increase their marks in the courses where it was implemented, which had a major impact where the use was more intensive.

Altogether, the findings suggest that the use of Wooclap had a positive impact on student engagement and academic performance, particularly in terms of increased participation and improved grades. However, it is important to acknowledge potential confounding factors that may have influenced these results. One key factor is the variation in how instructors integrated Wooclap into their courses. While the tool was generally used to support lesson content, the frequency and depth of its implementation likely varied among instructors and courses. Some instructors may have used Wooclap more consistently and in a more structured manner, leading to differences in student engagement and perceived usefulness. Another factor to consider is the students' pre-existing motivation and study habits. More engaged students may have been naturally inclined to participate in Wooclap activities, leading to an overestimation of their impact. Additionally, while a correlation was observed between frequent Wooclap use and improved grades, this does not establish a direct causal relationship. Other instructional strategies, assessment methods, or external factors such as student workload and course difficulty could have contributed to the observed improvements. Furthermore, the study did not control differences between theoretical and practical courses, as instructors had the flexibility to incorporate Wooclap in both types of settings. Future studies could examine whether the impact of Wooclap varies depending on course format, as well as the influence of other pedagogical elements that may interact with ARS tools to enhance the learning outcomes. Despite these limitations, the results align with previous research indicating that ARS tools can increase student participation and positively influence learning. The findings support the idea that both the use and frequency of ARS applications should be considered when evaluating their effectiveness in educational settings.

4. Conclusions

The increase in the use and affinity of new technologies by students is a fact that should be considered to transform potential distractions, such as mobile phones or tablets, into potential interactive learning tools. Wooclap exemplifies this by offering a simple yet highly effective audience response tool, which has garnered positive feedback from both students and teachers. Its intuitive design and easy integration make it an accessible solution for increasing student engagement and facilitating meaningful interaction between students and instructors. Wooclap's ability to provide real-time feedback and display direct examples enables a deeper understanding of complex concepts, which is particularly beneficial in more theoretical subjects. Both students

and educators marked the benefits of employing Wooclap in the 3 Engagement Learning Indexes. As a result, both students and faculty strongly recommend its wider use across different courses, independently of the degree and especially to face the theoretical content.

However, the study has several limitations that should be considered. First, the sample size was limited to specific courses, which may not be representative of all educational contexts. Additionally, the use of Wooclap was not uniform across all courses, potentially influencing the consistency of results, although the pearson test shown no significance in the differences observed among courses.

The impact of Wooclap on student performance is significant, with higher grades observed among students who passed, highlighting its potential as a catalyst for active learning. By promoting both cognitive and behavioural engagement, Wooclap enhances the overall educational experience, fostering a more interactive, student-centred learning environment. Consequently, the research question: "*To what extent does the integration of Wooclap enhance student engagement and academic performance in chemical engineering courses?*' has been correctly faced among the manuscript, describing the positive Wooclap use effects on student engagement and academic performance.

In terms of implementation, educators should consider integrating Wooclap gradually into their teaching methods, starting with specific activities that require student interaction and feedback. Clear guidelines should be provided to instructors to maximize the tool's effectiveness and ensure its alignment with learning objectives. Moreover, it would be beneficial to offer students opportunities to familiarize themselves with the platform before incorporating it into high-stakes assessments.

Future work will involve expanding the implementation of Wooclap across a broader range of courses, with a more homogeneous approach, to assess its impact on diverse types of subjects. A comprehensive evaluation of academic performance across different subject areas will provide a clearer understanding of its effectiveness in enhancing student outcomes. Additionally, future research should explore the long-term impact of interactive technologies on student engagement and performance, including how these tools influence retention rates and overall student satisfaction.

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