A Monitoring Infrastructure to Improve Flipped Learning in Technological Courses

Francisco Ortin*, Jose Quiroga, and Miguel Garcia

Abstract—**Flipped learning changes the traditional instructional approach of lectures. In flipped classrooms, the students work at home, while in-class sessions are used for other more interactive and active learning approaches guided by the lecturer. While flipped learning has shown many benefits, it is not easy to include remote students in face-to-face in-class sessions, and there is still reluctance from shy students to participate. In technological courses, classroom sessions in flipped learning require the installation of many software packages together with those tools commonly used by the students. Our objective is to improve these limitations in flipped learning by using an infrastructure implemented to deliver synchronous remote labs. Our study was conducted with 50 students of two different courses. Seven different sessions were delivered following a flipped-classroom approach. In the classroom, the participants used our infrastructure to discuss the different approaches, actively searching for the best solution as a group. Student satisfaction was measured with anonymous questionnaires. In their opinion, the infrastructure facilitates discussions, encourages them to participate and be more critical, and increases the quality of their work, skills, and learning process. They evaluated the system with 4.6 points out of 5.**

Index Terms—**Computer monitoring system, flipped learning, technological courses, Veyon, web conferencing platforms**

I. Introduction

According to the Flipped Learning Network (FLN), flipped learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space [1]. The resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter [2].

In flipped classrooms, teachers flip the classes by having students read texts, watch videos, work on projects or solve problems, to later engage flipped learning in the classroom by allocating more classroom time to learning approaches [3]. Students can work at their own speed, with flexible timetables and locations. They can also use additional resources that might not be available in the classroom, while consulting many different sources of information.

Flipped learning provides more time in the classroom for hands-on learning, group collaboration and creative work, reinforcing the learning outcomes [4]. In flipped classrooms, learners have more opportunities to become more active and interactive through group activities rather than passively listening to teachers in their classrooms [5]. As a result, they become engaged in more interactive and higher-order activities like discussions and debates [6]. Teachers can be focused on clarifying tasks and concepts that are harder to comprehend for students, obviating those that seem to be well understood.

In the flipped learning approach, it is very important that students participate in the in-class sessions. In such sessions, it is common that they have to expose their work. Thus, it is vital to engage students in the active activities proposed in the classroom [7]. However, shy students do not feel confident when they have to speak in public or present their work to the rest of the students. They commonly feel ashamed of being stared at by the rest of the classroom.

In the context of technological courses, such as source-code programming or software design, the students commonly use different software packages installed on their computers. However, that software may not be installed on the lecturer's computer used to project their slides. Under these circumstances, it is difficult to present the students' work and, more importantly, see the results of the changes proposed by the rest of the students. Unfortunately, it is not always feasible for students to bring a laptop with all the required software installed and configured, ready to be plugged into the projection system.

Another limitation of the typical face-to-face flipped-classroom approach is that students must be physically present. Some technological tools can be used to allow online students to participate (e.g., webcams, speakers, microphones and web conferencing platforms). However, when there is a significant number of online students and it is required to visualize their work at the same time, web conferencing platforms (e.g., MS Teams, Zoom and BigBlueButton) do not represent an appropriate solution.

During the COVID-19 (Corona Virus Disease 2019) pandemic lockdown, the authors of this paper developed an infrastructure to deliver synchronous remote programming labs over the Internet [8]. It allows the students to attend online classes with their own computer connected to the Internet, while the lecturer monitors what students are doing. In this way, instant feedback can be provided to the students while they are working. The infrastructure was formerly used for programming labs and exams, with high student satisfaction and reasonable resource consumption [8].

The research objective of this paper is to improve flipped learning in technological courses. For that purpose, the use of a synchronous remote infrastructure is proposed to engage students in classroom activities and overcome the technological limitations mentioned. Our infrastructure has

Manuscript received March 23, 2023; revised April 20, 2023; accepted June 26, 2023.

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doi: 10.18178/ijiet.2023.13.10.1960

been used in two different courses with 50 students in a flipped learning environment. According to the student's opinion, the system has been helpful in becoming engaged in classroom activities, boosts discussions and debates, allows the use of any software, improves students' learning, and allows the online participation of students who are not physically in the classroom.

The rest of this paper is structured as follows. Section II discusses the related work, and our infrastructure is presented in Section III. The methodology used in our study is presented in Section IV and Section V details the evaluation. Conclusions are depicted in Section VI.

II. Related Work

Bakonyi *et al*. used the Veyon (Virtual Eye On Networks) computer monitoring system [9] for delivering non-remote programming labs [10]. Although they did not use Veyon in a flipped learning environment, the instructor can show the lab attendants the work of one student to emphasize good programming practices or solve common errors. Lecturers can also share their screen with one single student, when it should not be seen by the rest of them (e.g., a solution excerpt). They did not include students in remote computers because of different limitations of Veyon. Veyon was implemented to be used in a local area network, so the opening of ports, firewall exceptions, remote user authentication, student IP identification and encrypted communications were not considered.

García *et al.* used Veyon to allow students access to the tools used in laboratory sessions outside the official teaching hours [11]. They propose a remote access system comprising three elements: a management tool, the Web-based remote desktop application Apache Guacamole [12] and Veyon for monitoring and controlling students [9]. Their system allows remote teaching and a way for students to access lab resources from home. They are connected to the lab through Apache Guacamole and monitored by the lecturer with Veyon. This means the students could not use the software installed on their own computers, and one computer in the lab should be available for each student. No flipped-classroom sessions were documented.

Medina *et al.* implemented a remote laboratory for testing material properties and machine-learning control of a dielectric elastomer actuator [13]. It was used by PhD students to collaborate during the COVID-19 pandemic. They set up a VPN (Virtual Private Network) to permit secure access to the laboratory computer from off campus. Once connected to the VPN, they shared their screens with the laboratory computer via VNC (Virtual Network Computing). In their experience, configuring VNC was time-consuming, and the connection still ran quite slowly after manual tuning. They ended up using JupiterLab, an open-source project to bring interactive computing and reproducible research through computational notebooks.

GAME MATH is a Virtual Learning Environment (VLE), whose design is based on the phases of flipped classroom and gamification, managed by a Learning Management System (LMS) [14]. This educational tool was applied since 2016 in an educational institution in Cuenca (Ecuador) by nearly 400 students for five different subjects. It supports different digital educational resources such as VideoQuiz with collaborative forums, interactive computer graphics, workshops, games and knowledge tests. EVA (Virtual Learning Environment, in Spanish) was implemented as a Web application, being used by approximately 250 users, including teachers and students from all over Ecuador. They propose the use of Veyon for computer monitoring and classroom management [14].

Böhne *et al*. implemented a synchronous remote lab platform [15]. They developed and evaluated a Web-based lab environment that supports synchronous tele-tutorial assistance by a human tutor. Their work emphasizes the importance of a remote tutor, especially in situations where learners have problems and questions. Without the possibility to get immediate feedback, many learners may become demotivated and abort their learning. Their Web system allows the compilation and execution of Java code and communication via audio, video, and text chat. When learners want to share their screen with the tutor, they use VNC [16]. They conducted an experiment with 19 electrical engineering students. The students worked on different programming tasks, while a tutor assisted them via videoconference, text chat, and desktop sharing. The evaluation showed that synchronous tele-tutorial support has the potential to assist students effectively during the remote laboratories [17]. Their system is based on a constrained Java programming environment. Students can only implement embedded Java code, and it is not allowed to use any IDE (Integrated Development Environment), library, compiler, or component installed on the local computer. Additionally, lecturers cannot see what all the students are doing in the labs.

There are several software tools that can be used in flipped-classroom sessions. Interactive whiteboards such as SMART (Self-Monitoring, Analysis, and Reporting Technology) Board [18] and Promethean [19] may be utilized to enhance in-class discussions and group activities. Lecturers and students can use the whiteboard to display and annotate content, as well as to facilitate student collaboration and feedback. However, it is not as powerful as a distributed monitoring system, where each student can share their work while using the software installed on their computers. Classroom response systems, such as Poll Everywhere [20] and Mentimeter [21], are also commonly used in flipped-classroom sessions. They allow lecturers to quickly and easily gather feedback from students. They can also be sued to assess student understanding, facilitate group discussions, and track student progress over time. Some of them include gamification activities (e.g., Classcraft [22] and Kahoot! [23]) to make in-class sessions more engaging and interactive.

III. Remote Synchronous Infrastructure

As mentioned, an infrastructure was developed to deliver synchronous remote programming labs over the Internet during the COVID-19 pandemic lockdown [8]. Our infrastructure permits the students to attend classes online with their own computer connected to the Internet, while the teacher monitors what the students are doing. Its architecture is presented in Fig. 1.

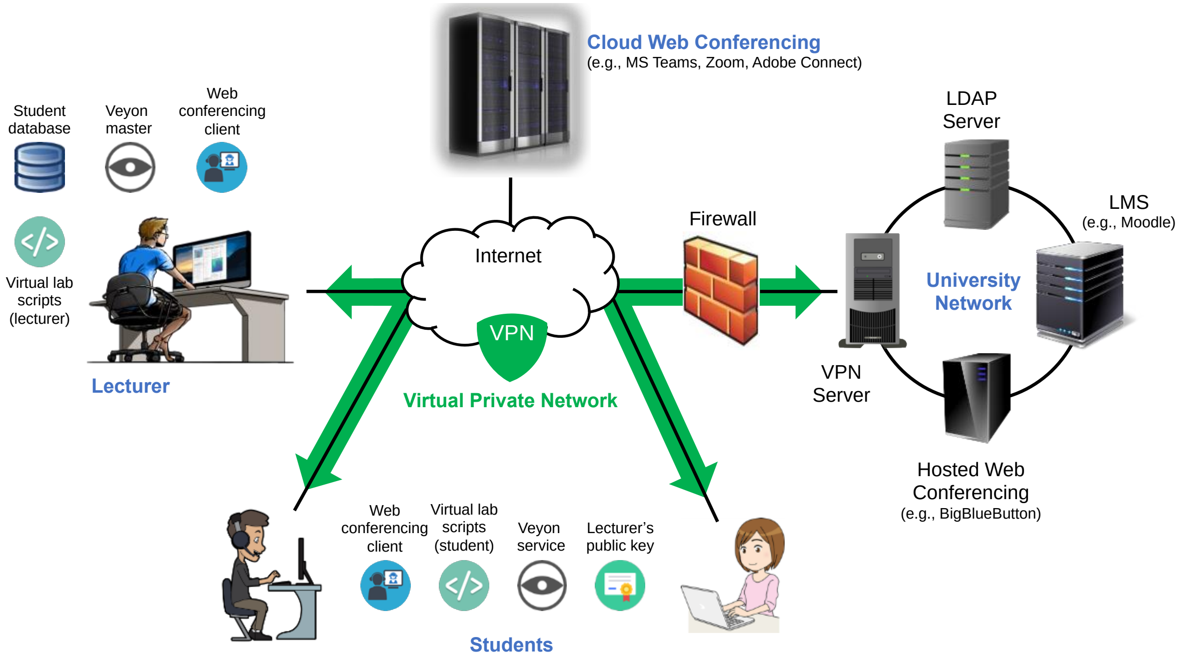

Fig. 1. Architecture of the synchronous remote programming lab infrastructure.

A. Computer Monitoring System

Student monitoring is undertaken with a fork the authors implemented of the Veyon project [9]. Our fork provides video recording of all the students attending the remote lab [24]. With Veyon, the lecturer can see all the screens of the students, as shown in Fig. 2. Lecturers can see one remote computer screen in full size, in a separate window.

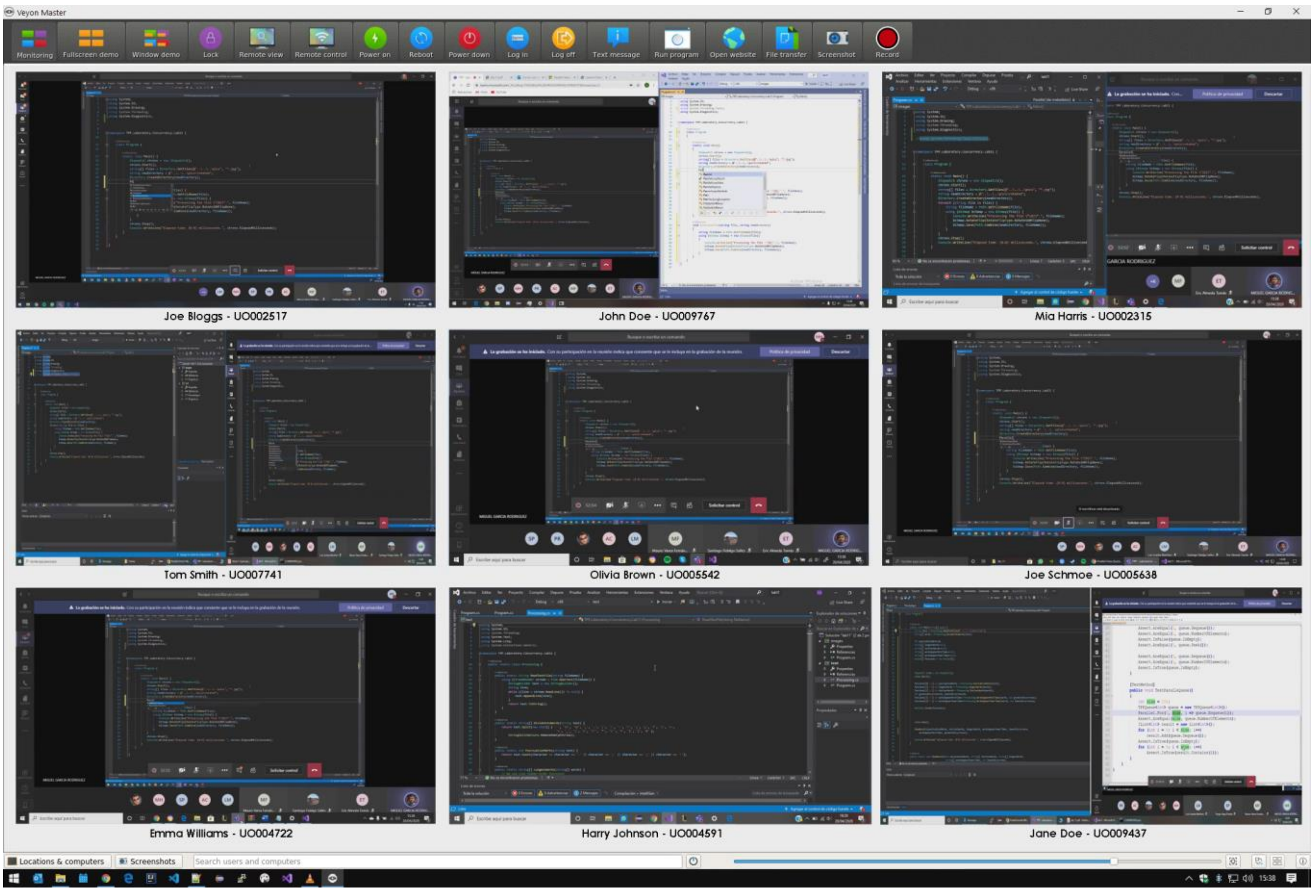

Fig. 2. Veyon master's screenshot of a remote lab with nine students (student IDs and names were changed for the sake of anonymity).

Veyon consists of two components: service and master for, respectively, students and lecturers. Veyon service is a non-graphical application that runs as a server, sending monitoring information to the master. Veyon master is a graphical application used by the lecturer to monitor students' work.

B. Virtual Private Network

Lecturers and students (participants) can be connected to the system through the Internet. A Virtual Private Network (VPN) is created to include all the participants in the same private network. It also frees the students from changing their router settings to open/forward the TCP (Transmission Control Protocol) port used by the Veyon service. Moreover, it allows meeting the Veyon master's requirement of knowing the IP address of students' computers—many ISPs do not provide static IP addresses to home customers.

A VPN server, placed in the University network, accepts all the connections from the participants. An instance of the SoftEther open-source VPN server was deployed [25]. The VPN server permits the authentication of students in different ways, including the use of the university LDAP (Lightweight Directory Access Protocol) server [26]. It also supports AES (Advanced Encryption Standard) 256-bit and RSA (Ron Rivest, Adi Shamir and Leonard Adleman) 4096-bit traffic encryption.

C. Scripts

Different scripts were developed for both students and lecturers, providing different functionalities such as (re)starting, stopping, (un)installing the remote lab, and gathering the information of all the students attending the remote lab (just for instructors) [27]. The scripts are implemented in Windows and Linux shells. They install the lecturer's public key certificate, open in the firewall the port used by Veyon service, gather student information from the VPN server, and create the lab sessions.

D. Web Conferencing Platform

Communication among students and lecturers is mainly supported by a Web conference system. The cloud-hosted Microsoft Teams and an instance of BigBlueButton deployed in servers inside our university network were used. One Web conferencing platform is used to deliver the lecture or lab, interact with students through audio and chat, speak to a single student without disturbing the other ones, share resources, allow students to upload their work, and share the lecturer's screen and whiteboard [28].

IV. Methodology

Our infrastructure was used in two different flipped learning scenarios. The first one is the Programming Language Design course in Software Engineering undergraduate degree at the University of Oviedo [29]—41 students were involved. The students have to implement a compiler of an imperative procedural programming language. It was used before the midterm assignment, where it is checked that they have a working parser that creates an AST (Abstract Syntax Tree) for an input program, using ANTLR (Another Tool for Language Recognition) [30]. The students have to bring their parser (grammar, implementation and AST design) to a flipped classroom, where the objective is to end up with the best solution according to different design and implementation quality standards.

The second scenario was the Web Services course in the Web Engineering Master's degree at the same university. In this case, the students must design and implement two Web services: one for a given furniture corporation and another one for a courier company. The design is modeled in UML (Unified Modeling Language) and the implementation should be provided as A RESTful (Representational State Transfer) API (Application Programming Interface)—nine students participated in this session.

In both cases, the flipped classroom took place in a computer lab. All the students who participated in the classroom used a computer. They used either one computer in the laboratory or their own laptops. In this way, they could install and use any software they need to perform their work. In all the sessions, there were two lecturers involved: one delivered the Web services class and four compiler labs, and the other lecturer delivered two compiler sessions.

Veyon is configured so that all the students in the computer lab belong to the same session, and the lecturer uses Veyon master to monitor their activity (Fig. 3). The lecturer creates a session using the Web conferencing platform (Microsoft Teams or BigBlueButton), so that all the attendants could see what is being displayed on the lecturer's monitor. The students attending the face-to-face session can just watch the projection (Fig. 3), but those connected online use the Web conferencing system to see what is being projected in the laboratory.

In the classroom sessions, the lecturer first asks students about the doubts found while doing their work [31]. To clarify such doubts, Veyon master is used to project the student's computer (Fig. 4) so that the rest of the students (including those online) can watch it. Discussions and debates about the student's approach rapidly appear. They do not need to come to the lecturer's place to show their approach, facilitating the intervention of shy students.

If they have minor mistakes, they are told how to fix them. Then, they can directly improve their solution and immediately see the results, since they have the appropriate software installed. For instance, in the compiler course, they could perform the changes in the grammar, run the ANTLR parser generator, execute their language processor and immediately see the results in the AST by using the Introspector tool [32]. That gives them instant feedback. They learn by trying different approaches and seeing the results of each of them.

It is very common that another student starts a discussion about his/her approach. It only takes a few seconds to change the student's screen that is being projected, enabling the projection of the work of the second student. Both approaches could be even compared by projecting both windows side by side.

V. Results

After each session (six sessions for the Programming Language Design course and one session for Web Services), the students were asked to fill out an anonymous questionnaire published online with Microsoft Forms. The questionnaire consists of nine questions on a 5-point Likert scale, ranging from 1 = "completely disagree" to 5 = "completely agree". The following questions were asked:

1) The system used encouraged me to participate in classroom sessions.
2) It made it easy to create discussions among class members.
3) I prefer it over the traditional approach of presenting my work to the rest of the class.
4) It helped me to improve the quality of my solution.
5) It was helpful to increase the skills I must acquire in this course.
6) It helped me to be more critical of my proposal.
7) I believe that the use of the system is positive in my learning process.
8) It is more effective than the traditional method of sharing the work done.
9) In general, I am satisfied with the system used for the flipped-classroom sessions.

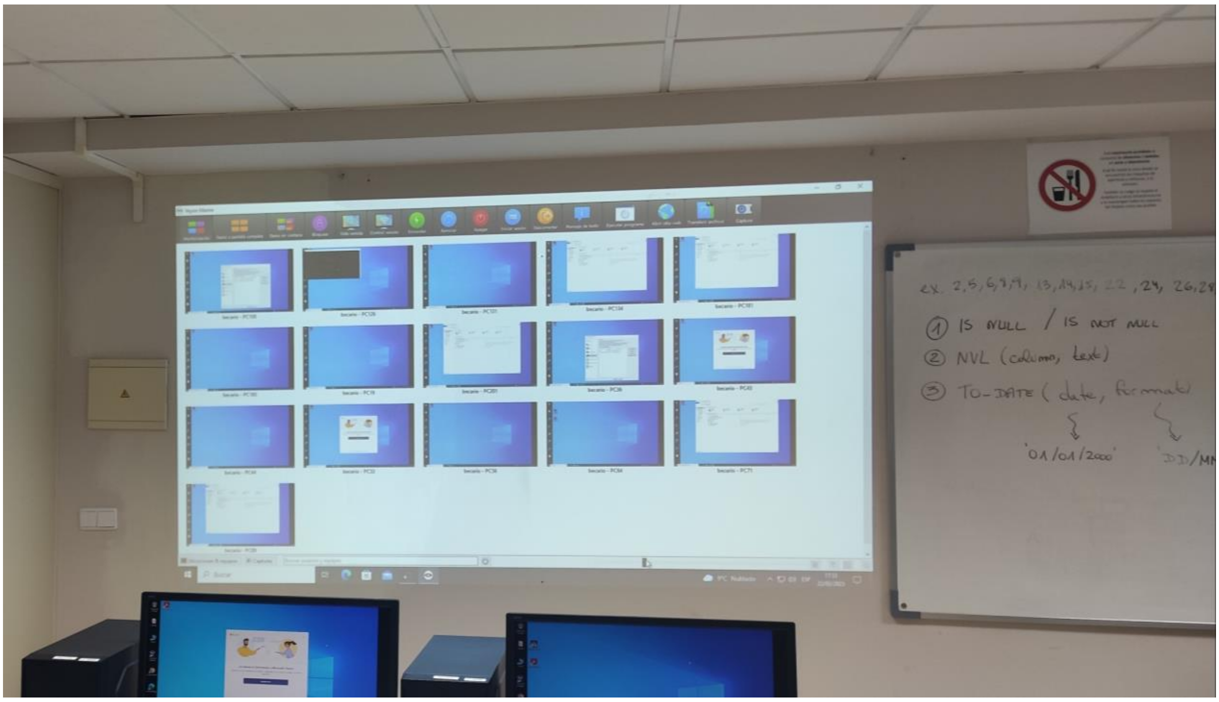

Fig. 3. Veyon master used to monitor students' activity.

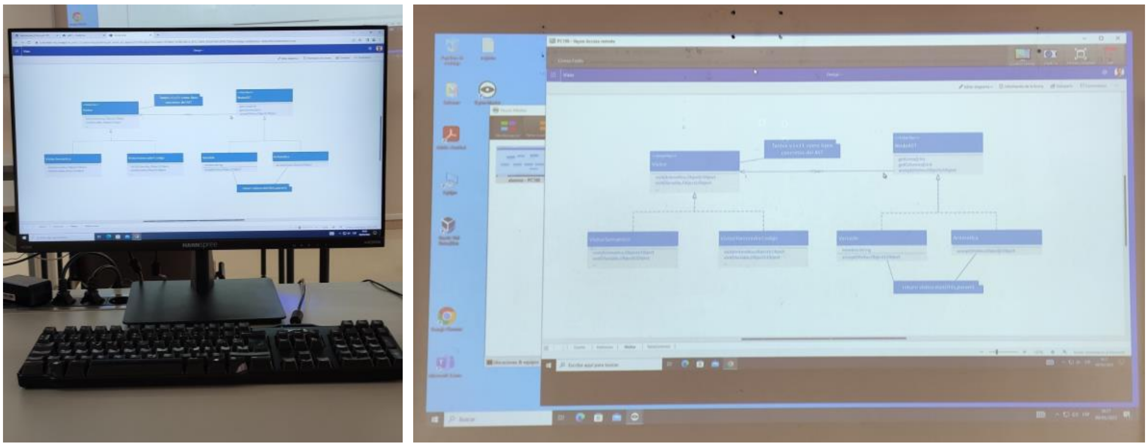

Fig. 4. Student's monitor in a session (left) and the projection of his/her computer in Veyon master (right).

Fig. 5 and Table I summarize the students' answers to the anonymous questionnaire. The Cronbach's α coefficient [33] obtained is $\alpha = 0.8324$, showing good reliability of the questionnaire [34]. For all the questions, the most common response (mode) is "completely agree". All the questions have an average value greater than 4 so, on average, students "agree" with the sentences stated in the questionnaire. Out of the nine questions, seven of them are closer to "completely agree".

The two first questions are related to the participation of the students in the in-class sessions. The first question—"the system used encouraged me to participate in the classroom sessions"—was the one with the lowest average value (4.24) and is the only question with a "disagree" answer, for one single student. It seems the students prefer to share their screens rather than perform the classical presentation as if they were lecturing. The authors think this is particularly true for shy students. This is precisely what is asked in the third question with 4.64 points, having "completely agree" as the closest answer. They also think our system facilitates discussions (4.5 points for Question 2) which, in some sense, could be interpreted as improving participation. The cause may be that it is easier to comment on what is projected rather than to criticize the work of a classmate after delivering their presentation.

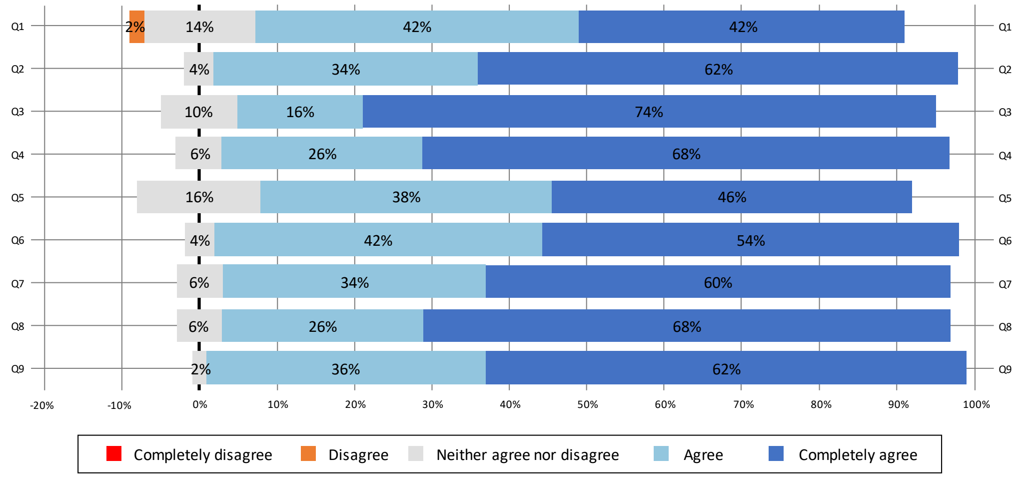

Fig. 5. Student's answers to the Likert scale questionnaire (N = 50).

TABLE I: SUMMARY OF STUDENTS' ANSWERS TO THE QUESTIONNAIRE

Question	Arithmetic mean	Standard deviation	Mode	Median
Q1	4.24	0.77	5	4
Q2	4.58	0.57	5	5
Q3	4.64	0.66	5	5
Q4	4.62	0.60	5	5
Q5	4.30	0.74	5	4
Q6	4.51	0.58	5	5
Q7	4.54	0.61	5	5
Q8	4.62	0.60	5	5
Q9	4.60	0.53	5	5

(N = 50, 1 = completely disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = completely agree)

Questions 4 and 5 are aimed at evaluating whether our teaching approach has helped the students to improve the quality of their work (Question 4) and their skills. Although both questions have an average answer greater than "agree", they think it is more valuable to increase their work (4.62 points) than their skills (4.30 points). Perhaps this minor difference is because skill improvement may be more related to the teaching approach, whereas seeing the result of others is helpful for improving their own work.

This idea is also related to Question 6 (4.51 points). By watching the approaches of other students, they could be more critical of their own work. With a similar evaluation (4.54 points), they believe that the system used is positive in their learning process (Question 7). It seems that the flipped-classrooms delivered, together with the usage of our infrastructure, is a valuable complement to the traditional learning approach followed in the rest of the sessions.

Compared to the traditional method of sharing their work (Question 8), they strongly agree our platform is superior, evaluating that assertion with the highest value (4.62 points). This answer encourages us to abandon the approach of asking students to present their work to the rest of the class in a lecture fashion.

The last question is directly aimed at evaluating our infrastructure for flipped-classroom sessions. "In general" was added to the question to ask the students for their general opinion about it. The average result was 4.6 points, having "completely agree" as the closest value of the five possible answers. Somehow, that gives us the degree of achievement of the objective followed with this research work.

Since the experiment was conducted in two different courses and by two different lecturers, the influence of the course and lecture on the students' answers was studied. To this aim, a t-tests was undertaken for all the questions to know whether there are statistically significant differences between courses and lecturers. Table II shows the results. It can be seen how, for all the questions, there are no significant differences ($\alpha = 0.05$, $p > 0.05$). This means neither the course nor the lecture has significantly influenced the responses of the students.

TABLE II: RESULTS OF THE T-TESTS BETWEEN THE ANSWERS OF STUDENTS FROM DIFFERENT COURSES AND TAUGHT BY DIFFERENT LECTURERS

	Two courses			Two lecturers		
Question	p-value	t-statistic	degrees of freedom	p-value	t-statistic	degrees of freedom
Q1	0.477	0.058	17	0.222	−0.775	37
Q2	0.128	−1.197	11	0.265	−0.632	39
Q3	0.467	−0.084	10	0.478	−0.056	37
Q4	0.287	0.582	9	0.085	−1.396	45
Q5	0.417	−0.216	10	0.347	−0.396	41
Q6	0.241	0.727	11	0.108	1.262	30
Q7	0.413	−0.224	11	0.466	0.086	32
Q8	0.489	0.029	11	0.397	0.263	32
Q9	0.288	−0.577	10	0.455	0.114	35

VI. CONCLUSIONS

This paper discusses how flipped learning has different benefits, but it also requires addressing different challenges. In the scenario of technological courses, those challenges can be addressed by using an infrastructure created to deliver synchronous remote programming labs. It allows including remote students in face-to-face in-class sessions and enhances shy students' participation. Since students' work can be presented with their own computer, it facilitates the use of any software required by each student. That permits them to rapidly show the results of suggested changes in their work.

Our study was conducted with 50 students of two different courses of Graduate and Master's degrees in Computer Science. Seven different sessions were delivered following a flipped-classroom approach. In the classroom, students and lecturers used our infrastructure to discuss the different approaches, actively searching for the best solution as a group.

Our system was anonymously evaluated by the students by answering some questionnaires after each session. According to their opinion, our system facilitates the creation of discussions, encourages them to participate, makes them more critical of their own work, and is a valuable tool to increase the quality of their autonomous work, their skills, and their learning process. They prefer our approach to the traditional one, where their work should be presented to the rest of the class. The overall satisfaction of the students was 4.6 points out of 5. The influence of the course delivered and the lecturer who delivered the sessions on the student's evaluation was also evaluated.

Future work of our research is the development of a machine learning system to assist lecturers in plagiarism detection. It will record videos of the student's screen activity during exams. It is planned to use recurrent convolutional artificial networks, training a model to warn instructors about potential cheating actions.

The infrastructure presented in this article is available for download at

https://www.reflection.uniovi.es/download/2020/tlt/

It includes the source code of Windows and Linux scripts and the Veyon fork implemented to record student sessions in exams.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization, methodology, validation and writing: Francisco Ortin, Jose Quiroga, and Miguel Garcia; software development: Jose Quiroga and Miguel Garcia; analysis, investigation and data curation: Francisco Ortin. All authors had approved the final version.

FUNDING

This project has been funded by the University of Oviedo under the public call for the development of teaching innovation projects (project number 124180).

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