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Flipped Learning Application on the Development of Capabilities for Civil Engineering Education in Labs

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Abstract**—**This work shows the methodology of application and the effectiveness of the *Flipped Learning* technique for Civil Engineering laboratory classes. It was experimented by some of the professors of the Department of Civil Engineering at Tecnológico de Monterrey while teaching their laboratory classes. A total of 28 videos were created. The videos primarily demonstrate instructions of the experimental practices other than the usage of tools and materials. The technique allowed the students to prepare for their classes in advance. A survey was conducted on the participating professors and students (semester of August-December 2019) to quantify the effectiveness of the *Flipped Learning* technique. The students reported it as an excellent way of improving their learning aptitude, including self-learning whereas, the professors felt it as an efficient technique for optimizing their class session, which also provided an extra slot for class-interaction. A comparison of grades was analyzed between the students of the traditional classes and with *Flipped Learning*. It did not distinguish the benefits of *Flipped Learning*. However, the positive responses from the students and the professors provide an impetus for continuing and promoting the *Flipped Learning* technique in future classes.

Keywords**—**Flipped learning, laboratory classes, educational innovation, civil engineering, higher education, competences.

I. Introduction

It is well known that to develop competencies for engineering students in higher education, the practice carried out in laboratories is crucial [1], [2]. The knowledge acquired in classrooms is not enough for the skills development that future engineers need to solve problems, they need to practice as well [3], [4]. Engineering education is incomplete without laboratory practice.

The consolidation of competences through experiments, under controlled conditions, is one of the learning activities that universities consider within their academic programs. These experiments are carried out through specific procedures, with specialized laboratory equipment, devices, materials, tools, safety equipment, hardware and software.

The explanation of instructions by professors in a typical laboratory class, before the student's practice, consists of the following points:

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- The theoretical basis.
- The procedure, including the description of the equipment or apparatus to be used.
- The safety rules to respect.
- The deliverables to grade the practice.
- The rubric for evaluation.

Depending on the practice, the time professors spend to explain each of these points can be considerable, regarding the duration of the class, which is typically limited. On the other hand, apathy or lack of attention of students during instructions sometimes causes issues during the practices. Some issues in practical work have been investigated in [5]. These distractions during instructions can affect students' performance in the practice, in addition to a deficiency in some specific skill. Furthermore, the risk of an accident during an experiment may be greater, particularly if complex equipment is operated or dangerous substances are handled.

In the present work, the implementation of the *Flipped Learning* technique for civil engineering laboratory classes is described. The focus is on student performance during their practice. It is considered that, if students follow instructions and learn through the use of videos at home, the performance of the students can be improved. It is also considered that, with the use of this technique, the time of use of the laboratory equipment is optimized, since students can work simultaneously in several work stations or equipment.

Flipped Learning is one of these reinvented methodologies with success in the United States and, in recent years, internationally [6], [7]. *Flipped Learning* defines a face-to-face educational methodology in which the student becomes an active agent of his own learning. Students acquire knowledge outside of the classroom through multimedia content, selected by the professors or investigated by themselves. The classroom becomes a space where students practice, reinforcing skills and settling what they learn autonomously, whereas the professor acts as mentor [8]-[13]. According to [13], students require less time of dedication to learn through *Flipped Learning*, compared with traditional lectures, which achieves greater efficiency. This opens the possibility to delve into more complex aspects of class content and the development of skills. For these and other arguments in the literature, the *Flipped Learning* technique is proposed to optimize and to improve the learning of civil engineering students, due to the advantages and virtues it offers.

II. Materials and Methods

A. Case Study

Flipped Learning was implemented in different laboratory classes of the civil engineering academic program of Tecnológico de Monterrey, Mexico. The program offers six laboratory courses: Geomatics, Construction Materials, Soil Mechanics, Road Infrastructure, Hydraulics and Sustainable Use of Water. Each course consists of 12 practices on average during a semester, plus 3 sessions for evaluating activities. The duration of each class session is 3 hours.

The number of students enrolled in each course basically depends on the number of workstations available in the laboratory. In most of the cases, laboratories have only one equipment to perform the experiment, so it is preferable to enroll few students in each class, 10 to 12. This fact affects the course efficiency, because the professor spends time to explain the instructions, and then, students work in teams one after another, all in 3-hour class.

B. Preparation of the Videos

To implement the *Flipped Learning* technique, professors recorded videos that basically contain what was previously mentioned: the explanation of the theoretical basis of the practice, an explanation of the procedure of the practice, safety rules, and the evaluation criteria.

The videos were recorded in high definition and uploaded to a YouTube channel, specifically created to host them (link: https://www.youtube.com/channel/UCV1b4mI74_bFrwERfTZsUiQ/playlists?view_as=subscriber). The videos were organized by laboratory class through playlists: Road Infrastructure Laboratory, Sustainable Use of Water Laboratory, Hydraulics Laboratory, Geomatics Laboratory, and Soil Mechanics Laboratory. Also, the audio was carefully treated, since usually the laboratories are enclosures that are not built with good acoustics. For this reason, some of the audios were recorded separately from video recording through the use of cell phone applications, and the videos were subsequently edited to synchronize audio and video.

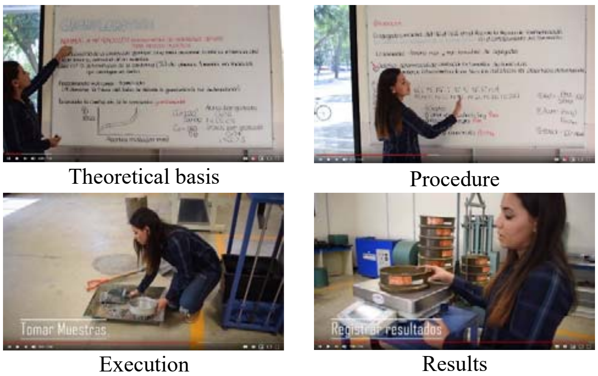

Fig. 1 Video sequences of the practice "Granulometry" of the Road Infrastructure laboratory, Guadalajara Campus

Regarding the duration of the videos, it was preferable the videos be no more than 30 min time (in some cases not possible), to prevent the loss of attention by students. However, care was taken not to omit information about the instructions of the practice. This fact was a challenge for professors, who had to be concise and brief during the instructions.

The videos were recorded in private sessions (without the presence of students) to avoid interruptions. For reasons of time during the semester, it was possible only to record some of the practices of each laboratory course. The sequences of some of the videos created in the different laboratories are shown in Figs. 1-4.

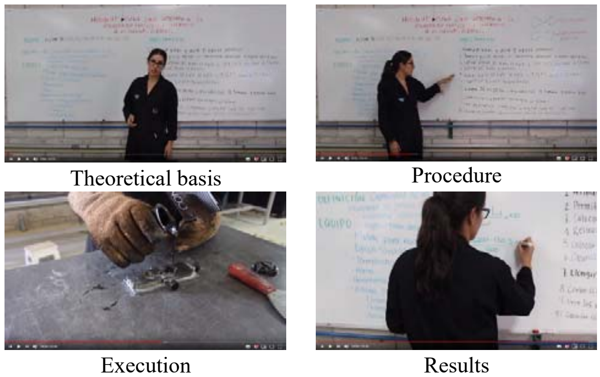

Fig. 2 Video sequences of the practice "Determination of the elastic recovery by ductilometer of the asphalt materials" of the Road Infrastructure laboratory, Campus Querétaro

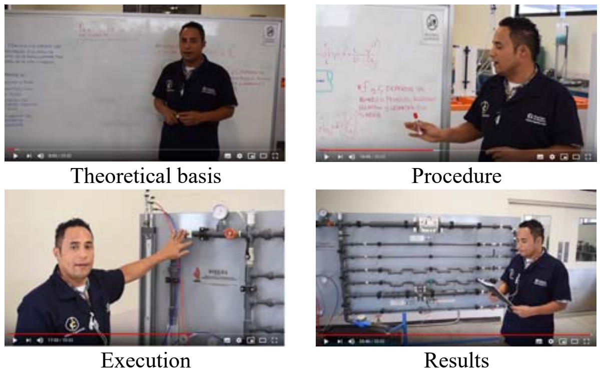

Fig. 3 Video sequences of the practice "Heat loss in pipes" of the Hydraulics laboratory, Campus Guadalajara

Fig. 4 Video sequences of the practice "Cross-leveling" of the Geomatics laboratory, Campus Guadalajara

C. Implementation

Fig. 5 shows a traditional class sequence, in which the professor spends class time for instructions. During this period, all students enrolled in class obviously must attend the professor's explanation. The case of Fig. 5 is commonly usual when there is only one equipment available to carry out the practice. After the explanation, students are grouped in teams and, to carry out their practice, turns must be assigned. Because of this turn assignment, which is usually luckily, the students, whose turn is the last, must wait several minutes before working. They usually distract the rest of the students who are working; some of them leave and come back when it is their turn.

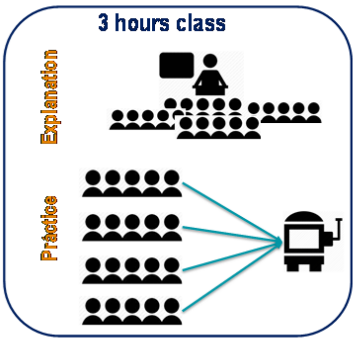

Fig. 5 Typical time sequence of a traditional laboratory class

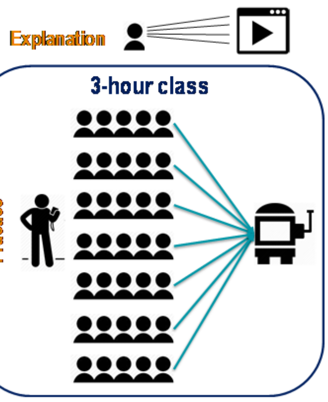

Fig. 6 Time sequence of a laboratory class under the Flipped Learning technique

Fig. 6 shows the class sequence applying the *Flipped Learning* technique, in which the professor's instructions are followed by students at home through the videos. Under this scheme, it is not necessary to book all students at the beginning of the class. The students are grouped in teams, a turn is assigned to them in advance and they attend the class when it is their turn. The professor's role in this dynamic is only as an advisor and evaluator. The professor is in charge of checking if the students carry out the procedures described in the videos, correct if necessary, resolve doubts and evaluate skills. With this technique, the time invested during the 3-hour class is better used for students to demonstrate the development of skills. It is even possible to have more students enrolled in the course, even though there is only one equipment, which lets improving the efficiency of the group.

In summary, 28 videos were created in different Campuses of Tecnológico de Monterrey, and several photographic sessions of tools, equipment, and materials used in the experiments were carried out. Ten professors participated in the recordings, in addition to 2 students of the On-Campus Jobs program of the Tecnológico de Monterrey.

To observe the relevance and effectiveness of the technique, surveys were applied to both students and professors (see Appendix).

III. Results

A. Students Impacted

Table I shows the number of students impacted by *Flipped Learning* through the use of videos. The implementation was carried out in Guadalajara Campus and Querétaro Campus in different groups, impacting a total of 180 students of the Civil Engineer academic program. At the Monterrey Campus, videos for the Sustainable Use of Water Laboratory were generated; however, the videos were not applied in the August-December 2019 semester.

TABLE I
List of Impacted Students

Course ID	Course name	Semester	Students impacted
CV3006	Hydraulics Lab	AD 2019	26
CV2029	Sustainable Use of Water Lab	AD 2019	15
CV2006	Construction Materials Lab	AD 2019	26
CV2028	Road Infrastructure Lab	AD 2019	59
CV2022	Geomatics Lab	AD 2019	26

B. Opinions of the Surveys

The surveys shown in Appendix were applied to a sample of students from the different laboratories. In total, 56 students responded, with the proportion of students per laboratory shown in Fig. 7.

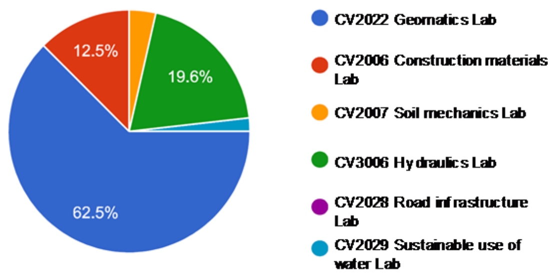

Fig. 7 Students per laboratory who answered the survey

The answers of the students surveyed are shown in Figs. 8 and 9. Regarding class time consumed per practice, most students indicated that it was more than 60 min, which probably implies that the 3-hour class can be a short time for students to receive instructions and to practice. Most students reviewed the videos once and a low percentage reviewed them more than five times. Concerning the duration of the videos, the students considered that the time is adequate, while there is another percentage that definitely thinks the videos are long and difficult to follow. A fraction of 41.1% of the students strongly agrees with the material shown in the videos, it was enough for them to carry out their practice. Most of the students also strongly agree on the effectiveness of the videos and they consider that the videos help them to better understand the concepts and practice procedures. Despite this opinion, the vast majority of students feel that even with the use of videos, an explanation of instructions is necessary in the classroom. The students said that a better understanding of the practice can be achieved or doubts can be responded if professors take time explaining in class. However, the vast majority also consider continuing with the use of videos.

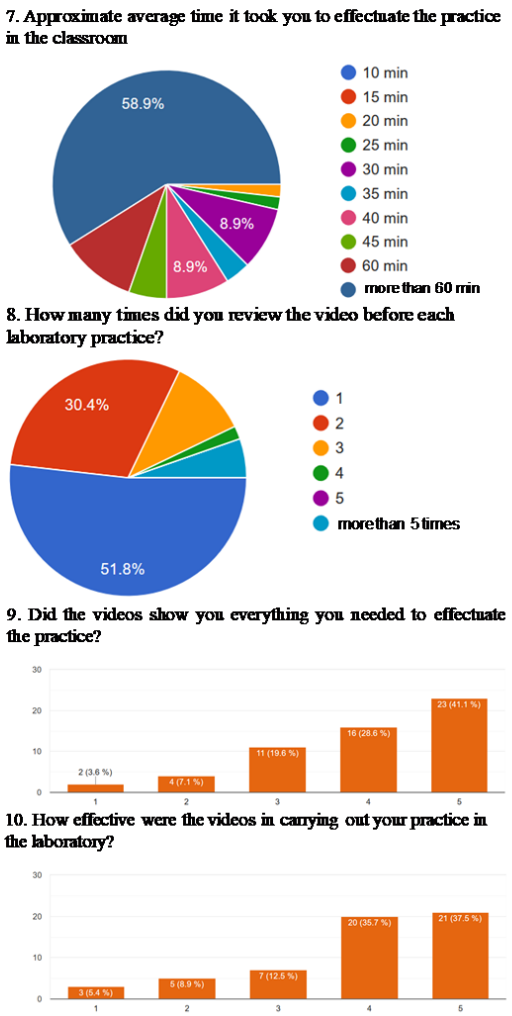

Fig. 8 Statistics of the opinions given by the students, questions 7 to 10

In summary, the students consider that: the activity brings several advantages, the videos are useful, they have access to good quality material, they can review countless times, the information is clear, the practice takes less time to be achieved, among other comments. Some other opinions indicate some issues: the duration of the videos is long, they are somewhat tedious, it is preferred that professors explain in class, or even they accept the activity can fail because of a lack of interest to review the videos at home.

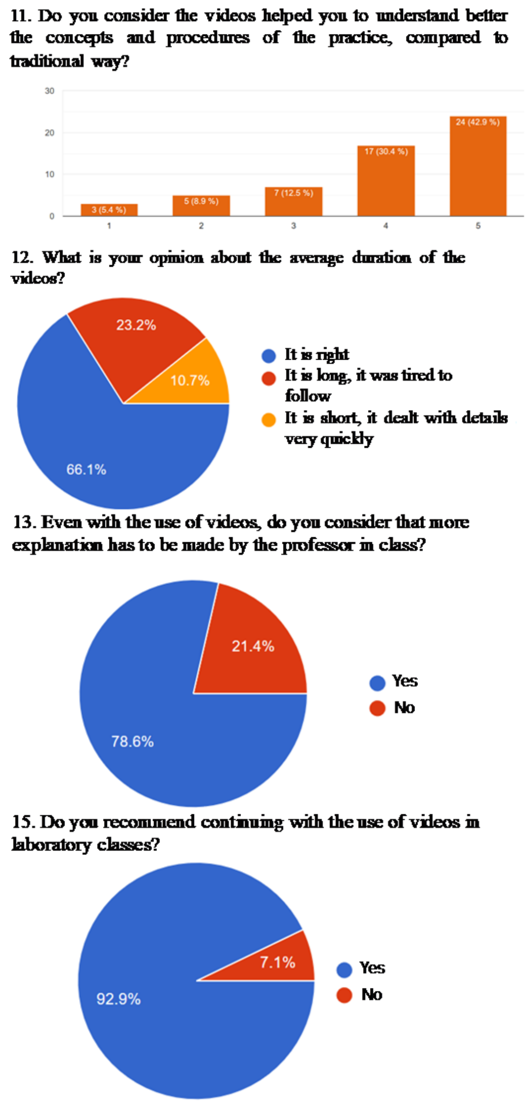

Fig. 9 Statistics of the opinions given by the students, questions 11 to 15

Fig. 10 shows the results of the survey applied to professors. The survey was answered by the professors who implemented the activity. In general, the professors agree that the videos show the necessary information so that the students could effectuate their practice, however, they still consider the possibility of making improvements such as: include FAQs or emphasize on policies or legacy when they apply. The professors also agree that the videos were effective, regarding the performance of the students during the practice. They think that the video helped to understand the concepts and procedures in a better way, compared with traditional class, and that the class time was better spent. However, 20% of the professors felt that the reinforcement of some instructions in the classroom is necessary. The students still exhibit many doubts or they did not review the videos at home. Finally, everyone agreed that it is recommended to continue using the videos in class.

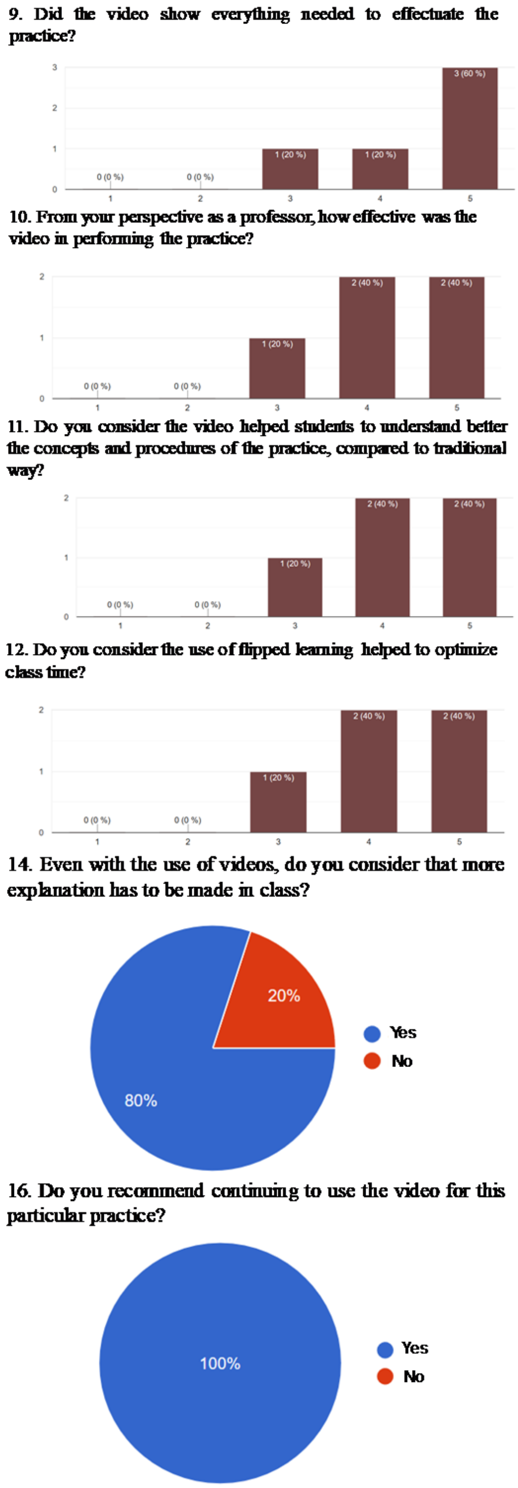

Fig. 10 Statistics of the opinions given by the professor

In general, the comments of the professors indicate that the learning is improved in some way since the instructions are strengthened, the process is simplified, and its role changes to that of mentor or advisor.

C. Report Cards

A comparative analysis was conducted between the grades of students from previous semesters taught in a traditional way and students taught under the *Flipped Learning* technique. In fact, there was no marked difference between the evaluations of one and the other. Exceptionally, the comparison of grades history of one class of the Laboratory of Construction Materials shows some improvements when *Flipped Learning* activity was applied (see Fig. 11). The professor of this class observed not only an increase of the averaged grades but also in the quality of the conclusions effectuated by the students in their practice report.

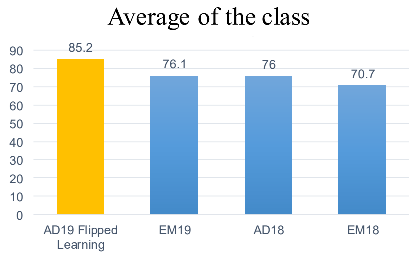

Fig. 11 Grade history of Construction Materials Laboratory class, practice "Granulometry", Campus Guadalajara

IV. Conclusion

In this work, the *Flipped Learning* technique was applied in some classes of the civil engineering laboratories of Tecnológico de Monterrey. For this, a series of videos were created by the professors with the instructions they use to explain at the beginning of each class. The implementation of this technique allows the professors to use better class-time as the students prepare for their practices at home in advance.

The authors consider that it is difficult to verify the efficiency of *Flipped Learning* in students learning since each group has different characteristics and capabilities. Comparisons between traditional groups and *Flipped Learning* groups have not been relevant to demonstrate an improvement in learning and skills development. However, the opinions of professors and students confirm that *Flipped Learning* is a positive technique, which reinforces knowledge and skills, makes practices more efficient, lets the development of student self-learning through technology and allows a repository of video practices that can be reviewed even in later stages.

Appendix

A. Survey Applied to Students

General Data

1. First and last name:
2. Student ID:
3. Class:

- CV3006 Hydraulics Lab
- CV2029 Sustainable Use of Water Lab
- CV2006 Construction Materials Lab
- CV2028 Road Infrastructure Lab
- CV2022 Geomatics Lab
- CV2007 Soil mechanics Lab

4. Semester:
- JM2019
- AD2019
- JM2020

5. Group:
6. Name of the professor:
- Francisco David Navarro
- Yuly Astrid Romero
- Paola de la Torre
- Sergio Armando Ortega
- Rubén Ernesto Hernández
- Gabriel Alejandro Gutiérrez
- Sinhue Arahat Gaxiola

Opinion on the application of videos in class

7. Approximate average time it took you to effectuate the practice in the classroom:
- 10 min
- 15 min
- 20 min
- 25 min
- 30 min
- 35 min
- 40 min
- 45 min
- 60 min
- More than 60 min

8. How many times did you review the video before each laboratory practice?
- 1
- 2
- 3
- 4
- 5
- More than 5

9. Did the videos show you everything you needed to effectuate the practice?

disagree — agree

1	2	3	4	5

10. How effective were the videos in carrying out your practice in the laboratory?

nothing effective — highly effective

1	2	3	4	5

11. Do you consider the videos helped you to understand better the concepts and procedures of the practice, compared to traditional way?

disagree — agree

1	2	3	4	5

12. What is your opinion about the average duration of the videos?
- It is right
- It is long, it was tired to follow
- It is short, it dealt with details very quickly

13. Even with the use of videos, do you consider that more explanation has to be made by the professor in class?
- Yes
- No

14. In case of an affirmative answer in the previous question, why?
15. Do you recommend continuing with the use of videos in laboratory classes?
- Yes
- No

16. In case of a negative answer in the previous question, why?
17. Briefly, give a general comment on the use of videos in class (advantages, disadvantages, areas of opportunity or improvement):

B. Survey Applied to Professors

General Data

1. First and last name:
2. Professor ID:
3. Position:
- Part-time professor
- Full-time professor
- Other

4. Class:
- CV3006 Hydraulics Lab
- CV2029 Sustainable Use of Water Lab
- CV2006 Construction Materials Lab
- CV2028 Road Infrastructure Lab
- CV2022 Geomatics Lab
- CV2007 Soil mechanics Lab

5. Semester:
- JM2019
- AD2019
- JM2020

6. Group:

Opinion on the application of videos in class

7. Name of the practice in which the video was used:
8. Date of application of the activity in class:
9. Did the video show everything needed to effectuate the practice?

disagree — agree

1	2	3	4	5

10. From your perspective as a professor, how effective was the video in performing the practice?

nothing effective — highly effective

1	2	3	4	5

11. Do you consider the video helped students to understand better the concepts and procedures of the practice, compared to traditional way?

disagree — agree

1	2	3	4	5

12. Do you consider the use of *Flipped Learning* helped to optimize class time?

disagree — agree

1	2	3	4	5

13. Do you consider that your role during class changed, yes, no, why?
14. Even with the use of videos, do you consider that more explanation has to be made in class?
- Yes
- No

15. In case of an affirmative answer in the previous question, why?
16. Do you recommend continuing to use the video for this particular practice?
- Yes
- No

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References

[1] D. Newble, R. Cannon, "Handbook for Teachers in Universities and Colleges, a guide to improving teaching methods," *Ed. Routledge Falmer Editor*, 4th Edition, 2000, pp. 2–10.

[2] A. Hofstein, and V. N. Lunetta, "The Role of the Laboratory in Science Teaching: Neglected Aspects of Research". *Review of Educational Research*, vol 52, no. 2, 1982, pp. 201–217.

[3] V. Romanas, V. Krivickas, and J. Krivickas, "Laboratory Instruction in Engineering Education," *Global J. of Engng. Educ.*, vol. 11, no. 2, 2007, pp. 191-196.

[4] G. T. C. Kandamby, "Effectiveness of laboratory practical for Students' Learning", *International Journal for Innovation Education and Research*, vol. 7, no. 3, 2019, pp. 222–236.

[5] I. Abrahams, and R. Millar, "Does Practical Work Really Work? A study of the effectiveness of practical work as a teaching and learning method in school science," *International Journal of Science Education*, vol. 30, no. 14, 2008, pp. 1945–1969.

[6] T. Simko, I. Pinar, A. Pearson, J. Huang, G. Mutch, A. S. Patwary, M. Lui, J. Carberry, and K. Ryan, Flipped learning – a case study of enhanced student success", *Australasian Journal of Engineering Education*, vol. 24, no. 1, 2019, pp. 35–47.

[7] T. Van Hung, M. Yellishetty, N. T. Thanh, A. Patil, and L. T. Huy, "The Application of Flipped Classroom in Teaching University Students: A Case Study From Vietnam." *International Journal of Quality Assurance in Engineering and Technology Education*, vol. 6, no. 1, pp. 40–52.

[8] Z. Zainuddin, and S. H. Hajar, 2016, "Flipped Classroom Research and Trends from Different Fields of Study," *The International Review of Research in Open and Distributed Learning*, vol. 17, no. 3, 2016 pp. 313–340.

[9] B. Prevalla, and H. Uzunboylu, "Flipped Learning in Engineering Education." *TEM Journal*, vol. 8, no. 2, 2019, pp. 656–661.

[10] J. S. Jeong, F. Cañada-Cañada, and D. González-Gómez, "The Study of Flipped-Classroom for Pre-Service Science Teachers." *Educ. Sci.*, vol. 8, no. 4, 2018, 163.

[11] H. Gwo-Jen, Y. Chengjiu, and C. Hui-Chun, "The era of flipped learning: promoting active learning and higher order thinking with innovative flipped learning strategies and supporting systems," *Interactive Learning Environments*, vol. 27, no. 8, 2019, pp. 991–994.

[12] C. Santiuste, E. M. Ruiz-Navas, and D. Segovia, "On the application of e-learning in engineering education." *43rd Annual SEFI Conference*, Orléans, France, July 2015.

[13] G. Castilla, and M. G. Romana, "La percepción del aprendizaje de los estudiantes de ingeniería en función de la metodología de aula aplicada: Flipped Learning vs. Convencional." *Revista de Formación e Innovación Educativa Universitaria*, vol. 9, no. 2, pp. 116–131.

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