Redesigning a Cornerstone Course, Lessons Learned from a Pandemic

Dr. Catalina Cortazar, Pontificia Universidad Catolica de Chile

Catalina Cortazar is an Assistant Teaching Professor at DiLab Engineering Design at the School of Engineering at Pontificia Universidad Catolica de Chile. Catalina holds a Ph.D. in Computer Science at PUC, a MFA in Design and Technology at Parsons The New School for Design, a MA in Media Studies at the The New School and a bachelor's degree in Civil Engineering, with a concentration in Structural Design at PUC.

Miss Isabel Hilliger P.E., Pontificia Universidad Catholica de Chile

Isabel Hilliger is Assistant Professor of Practice and Associate Director for Assessment and Evaluation at the Engineering Education Unit in Pontificia Universidad Católica de Chile (PUC-Chile). Isabel received a BEng and PhD in Engineering Sciences from PUC-Chile, and an MA in Policy Organizati

Gabriel Astudillo, Pontifica Universidad Católica de Chile

Gabriel Astudillo is Coordinator for Measurement and Evaluation at the Engineering School in Pontificia Universidad Católica de Chile (PUC-Chile). Gabriel received an MA in Social Sciences from Universidad de Chile.

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Abstract

This evidence-based paper describes the process of implementing and evaluating a flipped classroom approach, in conjunction with a project-based learning methodology, in a remote Cornerstone Engineering course and how it was kept in the face-to-face return. In the first year, cornerstone engineering courses are taught mainly using project-based learning. This methodology allows students to develop teamwork and communication skills and promotes critical thinking allowing students to solve real-world problems. Traditionally, project-based learning courses are taught face-to-face. Due to COVID-19, educational institutions were forced to move from face-to-face teaching to remote teaching and learning. In this new setting, enhancing online teamwork became a challenge. In order to promote teamwork, a flipped classroom methodology with project-based learning was introduced into a Cornerstone Course during the lockdown in 2020. The flipped classroom is a teaching methodology where students learn the concepts before class meetings. In the classroom, the students apply the concepts learned asynchronously. This methodology allows students to take responsibility for their learning and to interact with their peers during classroom hours. It also allows professors to have a more productive time with students. In 2022, educational institutions returned to face-to-face teaching; this course was no exception. The teaching team maintained the flipped classroom methodology with project-based learning face-to-face. A survey was conducted to understand the students' perceptions concerning this methodology. The survey took place at the middle and end of the semester in conjunction with a small discussion group once the semester finished. The student body values the activities in class, where collaboration and teamwork are encouraged. However, they perceive an additional burden by having to watch videos before class. This article contributes to Engineering Education by providing guidelines for implementing a flipped classroom in a Cornerstone project-based learning (PBL) course.

Keywords: First-year Program, Engineering Design, Project Based Learning, Cornerstone Course, Teaching Methodologies

Introduction

Cornerstone courses are first-year design courses that aim to connect first-year students with engineering faculty and its practice [1]. In cornerstone courses, the student body works autonomously in teams [2], solving real problems [3, 4]. Project-based learning is one of the most used methodologies in cornerstone Engineering courses [5, 6] since they introduce students to their life as engineers [7]. Project-based learning (PBL) is a student-centered methodology [8] that promotes the development of various transversal skills such as effective communication [5], teamwork [9, 10], and critical thinking [11], among others.

Traditionally, project-based learning courses are taught face-to-face [12]. Due to COVID-19, educational institutions abruptly changed their learning strategy from face-to-face to remote teaching [13]. Enhancing online teamwork became a challenge in online settings [14]. In this course, it was decided to implement a flipped classroom methodology in conjunction with project-based learning to promote teamwork.

The Academy of Active Learning Arts and Sciences [15] defined the flipped classroom methodology as a teaching method in which the student body must learn the concepts before arriving in the classroom where the concepts learned are applied, thus inverting the traditional class. One motivation for teachers to implement the flipped classroom in their courses is to have a more productive time with the student body [16]. The flipped classroom gives students responsibility for their learning by learning the theory asynchronously, allowing them to interact in the classroom with their peers [17].

In the first semester of 2022, educational institutions returned to the face-to-face version; this course was no exception. The teaching team decided to maintain the flipped classroom methodology with project-based learning. This evidence-based paper presents the flipped classroom implementation in a project-based learning methodology course and the student body's perception of this methodology. The objective is to contribute to Engineering Education by delivering flipped classroom implementation guidelines in a cornerstone course with project-based learning (PBL).

Research Context

Cornerstone course

This cornerstone course received 838 students in the first semester of 2022. The student body worked in teams of six to seven students within ten sections of around 83 students each. The number of team members varied, aiming for 12 teams per section mainly due to practical limitations. These limitations are the time required for the teams to present their progress, resource limitations, and the number of teacher assistants available (five per section) [11]. Table 1 presents a summary of the course for 2022.

Table 1. Summary of the course 2022 (based on [11])

Teaching methods	Project-based learning flipped classroom In-class work activities, cross-feedback activities, and in-class teamwork workshops
Course content	1. User-centered design process (based on Design Thinking), data analysis (qualitative and quantitative), estimation, effective communication, presentation, and poster design.
Learning outcomes	1. Solve a real problem by applying the engineering design methodology creatively and innovatively. 2. Design a device relevant to the studied user, considering their social, economic, and environmental characteristics. 3. Articulate individual contributions in teamwork to develop a joint project.
Assessment methods	1. Individual assessment: Tasks. 2. Team evaluation: oral presentations on the design process (research advances and prototypes). 3. Peer evaluation after each equipment delivery.
Evaluation Criteria	1. The academic team (teacher & assistants) evaluates the design process during the semester. 2. Stakeholders: The final deliverable is presented at a technology fair, where a jury of experts evaluates them.

During the semester, the student body worked on the topic: Externalities of our Food, following the design process presented below in Figure 1.

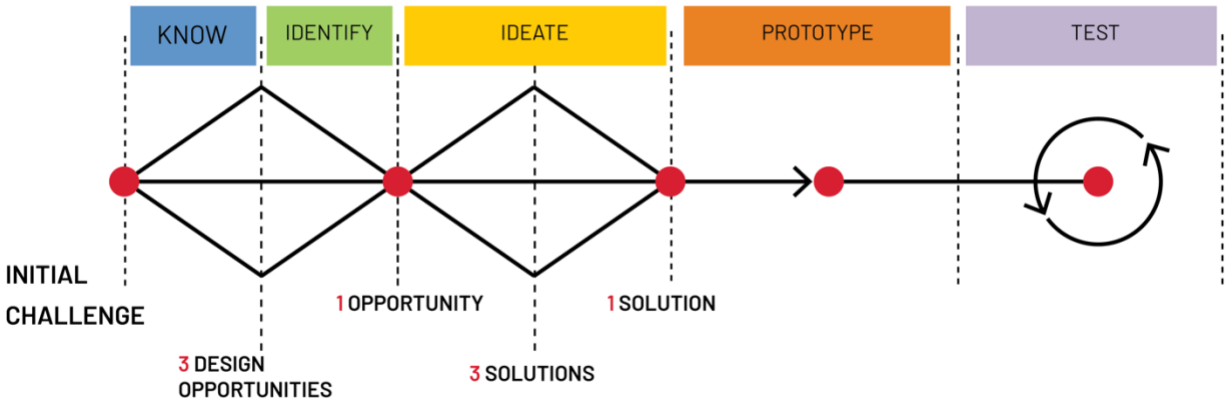

Figure 1. Design process adapted from [18]

As seen in Figure 1, the design process has five phases. They are presented linearly, but the red dot line shows it is an iterative process. The final deliverable of the course is a poster and a functional prototype graded by an external jury.

Inverted Classroom Implementation

The flipped classroom is characterized by audiovisual material prepared for the students to learn the theoretical content asynchronously [19]. The students had to watch short videos in Canvas before classes in this course. As each video explained one concept, every class consisted of short videos the students had to watch. Table 2 shows the class content, the number of videos the students had to watch, and their duration.

Table 2. Flipped classroom videos

Lecture Content	Number of Videos	Duration of each Video	Total Duration of Videos
Know	4	V1: 3 min 55 sec V2: 5 min 47 sec V2: 6 min 16 sec V4: 4 min 48 sec	20 min 48 sec
Qualitative analysis	3	V1: 3 min 17 sec V2: 2 min 45 sec V3: 5 min 49 sec	11 min 54 sec
Quantitative analysis	5	V1: 0 min 55 sec V2: 4 min 28 sec V3: 4 min 40 sec V4: 3 min 35 sec V5: 7 min 39 sec	21 min 18 sec
Estimate	5	V1: 1 min 28 sec V2: 3 min 41 sec V3: 2 min 48 sec V4: 2 min 10 sec V5: 4 min 14 sec	14 min 24 sec
Identify design opportunity	4	V1: 4 min 16 sec V2: 5 min 30 sec V3: 3 min 34 sec V4: 9 min 40 sec	23 minutes
Ideate	4	V1: 5 min 15 sec V2: 4 min 41 sec V3: 5 min 01 sec V4: 4 min 21 sec	19 min 18 sec
Prototype	4	V1: 5 min 33 sec V2: 6 min 36 sec V3: 6 min 18 sec V4: 3 min 13 sec	21 min 36 sec
Testing	4	V1: 2 min 49 sec V2: 2 min 55 sec V3: 2 min 53 sec V4: 3 min 53 sec	12 min 30 sec

As seen in Table 2, the duration of each video ranged from one to 10 minutes. The most extended video session was 23 minutes.

As a strategy for self-evaluation and motivation after watching the videos on Canvas, the students had to answer a questionnaire about the concepts learned [20]. This questionnaire was a formative assessment. Formative assessments aim to gather information about the student's learning situation to review the learning process [21]. Students were eligible for a bonus when answering a total of nine questionnaires.

When arriving at the classroom, each team member brought their learning, thus creating a dynamic between individual and collective learning [22]. The activities carried out in the classroom were context maps [20], guided discussions, project support, and presentations of the progress of their projects.

Methodology

With the research objective of evaluating the implementation of this flipped classroom approach, we used mixed methods. This study implemented an explanatory sequential design, starting by collecting quantitative data and then collecting qualitative data to elaborate on the results [23]. Specifically, an explanatory sequential design was used to obtain a general picture of the course through quantitative data, followed by the collection and analysis of qualitative information to evaluate the flipped classroom approach. The following subsections describe the data-gathering techniques and the corresponding data analysis plan.

Survey

An optional online survey was conducted on the students at the middle and end of the semester to collect quantitative data about their perceptions of the course (see Table 3).

Table 3. Number of participants

Total Students	838	100%
Total number of students who respond to the mid-semester survey	440	53%
Total number of students who answer the end-of-semester survey	265	32%
Total number of students who answer both surveys (mid- and end-of-semester)	135	16%

As shown in Table 3, from the 838 students, only 135 (16%) answered both surveys.

Based on existing surveys to evaluate the effectiveness of course methods, such as the course experience questionnaire [24], a 5-point Likert scale was used to assess students' level of agreement with eight different items, ranging from 1: strongly disagree to 5: strongly agree. Table 4 presents the scale items with one statement about the flipped classroom approach.

Table 4. Survey scale items

Item id	Item statement
Flipped classroom approach	My experience with the flipped classroom approach, that is, watching content videos before class and performing activities and discussions during the class module, has benefited my learning.
Classroom activities	The activities performed during class, like group exercises, have allowed me to apply what I have learned in the course.
Lesson clarity	The course instructor explains the contents of each class clearly.
Assessment	The assessment methods have instructions that are clear and precise.

methods	
Learning gains	During the course, I had the opportunity to acquire new knowledge.
Cross-team feedback	The activities of cross-team feedback (meetings of feedback between teams of the same section) have contributed to our project.
Teamwork	I consider that teamwork has been beneficial to my learning of the course content.
Course challenge	I believe I could tackle the challenge proposed in this course through my prior knowledge and what I learned in class.

As shown in Table 4, each item had a positive statement regarding the item being asked. Additionally, the survey included optional open-ended questions about beneficial aspects of student learning and aspects that could be improved in future versions of the course.

Discussion Group

After conducting both surveys, qualitative information was collected throughout a group discussion session. Group discussions are a commonly used technique among qualitative social researchers, following the guiding principles established by [25]. This technique differs from interviews and focus groups because the researcher actively influences the conversation on two levels: between the participants and between the group and the researcher [26]. Thus, the conversation stays in a shared direction. On one level, it is directed by the conversation between the participants; on another, it is provoked and controlled by the researcher's action.

When carrying out a discussion group, representativeness is not sought, but a group of people is selected to understand a specific phenomenon [27]. Since the objective was to understand why students exhibited divergent opinions about the course methodology, a sample of students was selected from different course sections and with different levels of agreement regarding the flipped classroom item (see Table 4). Out of the total number of students contacted, three voluntarily participated in the session after signing informed consent. One participant presented a positive evaluation of the flipped classroom approach, and two had negative perspectives about its implementation. To contrast opinions and perspectives about this course methodology, the discussion moderator used the following prompt:s

"The mid-semester survey had two open-ended questions. One asked about a specific aspect of the course that contributes to your learning, and someone answered, 'I think the flipped classroom is an excellent system.' The second one asked about any suggestion that would support better course development, and a student answered, 'Avoid the flipped classroom system.' So, we want to understand why these contrasting opinions exist from your point of view."

Then, the moderator motivated the discussion among students who shared different opinions regarding the flipped classroom approach and specific curricular elements, such as using content videos and classroom activities. The discussion was recorded and transcribed verbatim.

Data Analysis

Concerning quantitative data collected from mid- and end-of-semester surveys, the number of students who agreed or strongly agreed with the items in Table 4 was divided by the total number of responses. Then, we contrasted the responses between both surveys and ranked items from highest to lowest percentage of agreement.

Concerning qualitative data collected through the group discussions, the transcript was analyzed by the same researcher who moderated the discussion by following the phases of thematic analysis suggested by [28]:

1. Getting familiarized with the data (reading transcripts and answers to open-ended questions on their own)
2. Generating initial codes derived from the data (along with conducting peer debriefs to develop an agreed coding scheme)
3. Searching for themes
4. Reviewing themes' adequacy by extracting quotes from the raw data
5. Naming themes
6. Producing a report

Finally, quantitative and qualitative results were triangulated to deepen our understanding of the flipped classroom implementation. This process consisted of contrasting evidence from the different data sources (survey and discussion group) [23]. Further detailed findings are addressed in the results and discussion section.

Results and Discussion

Quantitative Results

Figure 2 shows the percentage of students who agreed or strongly agreed with different statements regarding course elements. These percentages only consider responses from students who answered the mid- and end-of-semester surveys (n=135, according to Table 3).

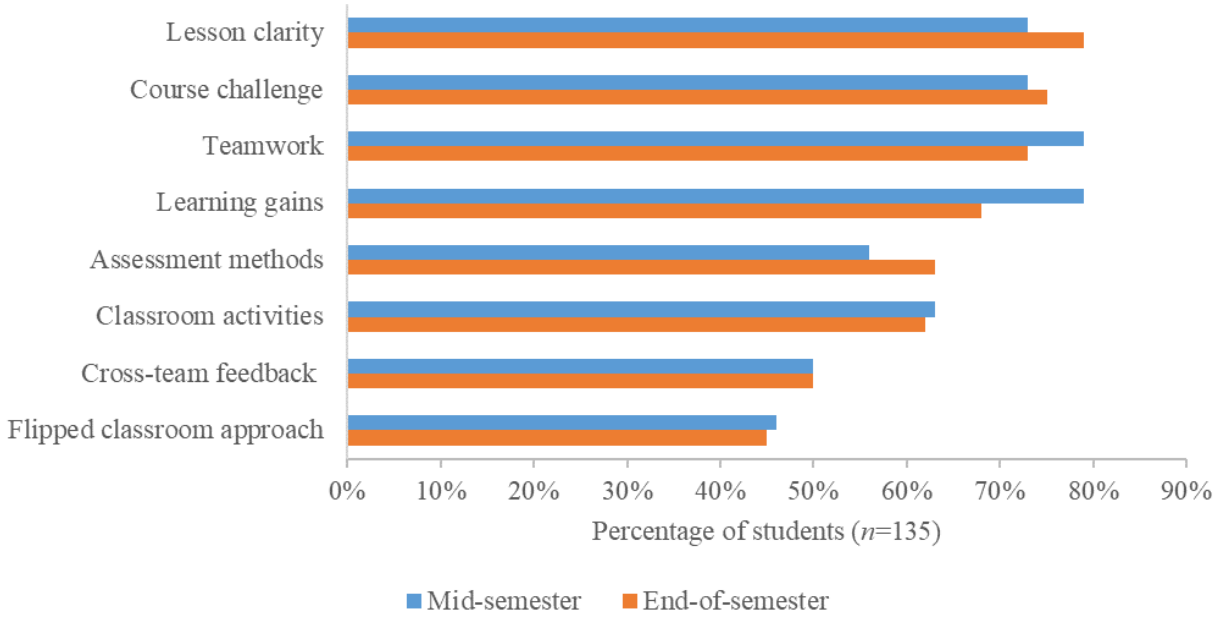

Figure 2. Percentage of students who agreed or strongly agreed with different statements regarding course elements (see Table 4)

Figure 2 shows that lesson clarity is one aspect that presents improvement. In the mid-semester survey, 73% of the students agreed or strongly agreed with the following statement: 'The course instructor explains the contents of each class clearly.' This percentage increased to 79% in the end-of-semester survey. Concerning the perception of the course challenge, 75% ended up agreeing or strongly agreeing with the following statement: 'I think I could tackle the challenge proposed in this course through my prior knowledge and what I learned in class.' However, the percentage of agreement with the items associated with learning gains decreased. The significant decrease in learning gains during the semester could be attributed to the fact that most of the theoretical content in cornerstone courses is concentrated in the first half of the course. The imbalance regarding the distribution of content within the semester is because the first part of a user-centered design process is related to the social dimensions of the design process, being the most challenging for engineers [29].

Figure 2 also shows that less than 50% of the students agreed or strongly agreed with the following statement: 'My experience with the flipped classroom approach, that is, watching content videos before class and performing activities and discussions during the class module, has been beneficial for my learning.' Still, this does not mean most students had a negative experience with the flipped classroom approach. Figure 3 shows the level of agreement with the mentioned statement.

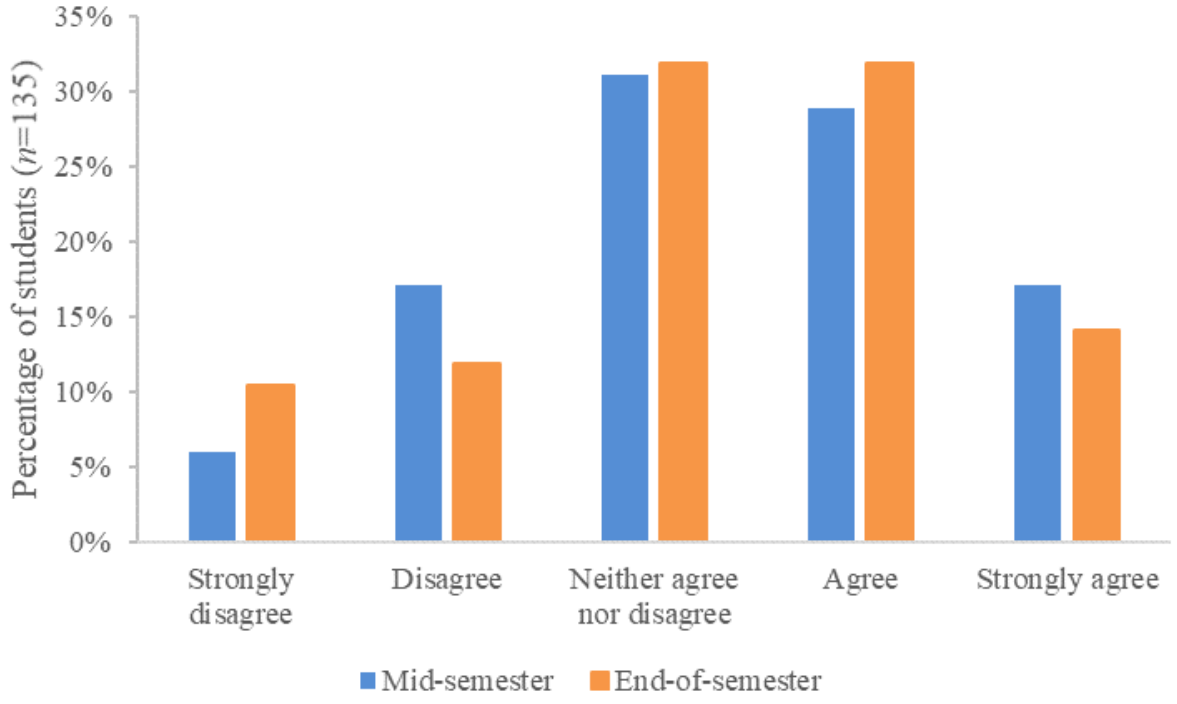

Figure 3. Level of agreement with the statement: 'My experience with the flipped classroom approach, that is, watching content videos before class and performing activities and discussions during the class module, has been beneficial for my learning'

As shown in Figure 3, a substantial percentage of students neither agree nor disagree with the statement associated with the flipped classroom item. Thus, further qualitative information was needed to understand different perspectives regarding this new methodology.

Discussion Group

The discussion group participants commented regarding having to watch videos before class the following:

R1: "…I realize that the study system normally required at the University differs greatly from that at school. At least, I believe you need to study all subjects, regardless of whether you understood them during class. So, I think some people have more trouble adjusting."

A2: "…. I think this has to do with the divided opinions about the inverted method. Not all of us have the habit of getting home and reviewing what was seen throughout the day when enrolling in University. Many people do, but perhaps many people do not. So, I believe that if one brings the habit to the University getting to review the content you saw in the day at night and prepare things for tomorrow, it does not matter to them, or they are already adapted."

It is glimpsed in these answers that the students relate the different perceptions of the flipped classroom with the study habits that they bring with them from school.

Regarding the questionnaire carried out after the videos via Canvas, the participants exposed the following:

A1: "So, of course, not seeing the videos did not affect me because the next day, the teacher checked the forms. As many people told him, they were all wrong, and he said: we will review the content well. Furthermore, the teacher again explains the same content that appears in the videos."

R2: "So, of course, someone who does not see the videos and they hand them out [referring to the questionnaire], and they come and pay attention for a while with that helps you to do the activity."

In both answers, reviewing the content of the videos at the beginning of the class determines that the students do not watch the videos since, with what is explained in class, they feel that they can carry out the class activity.

Regarding the class activities, the participants thought that:

R1: "But if you were really interested in the course, you would benefit greatly [referring to the inverted classroom] because you save time by not having to teach content in a class by watching the videos before, and in most classes, there have been activities, and I find that very beneficial.

A2: "I do not know; I still feel that there are some activities that go beyond class time, and at least in my team, there were several activities that went beyond class time, and then we had to get together to finish them; and that is when the videos are useful."

This answer leads us to the last comments on using the flipped classroom and its impact on the course project.

R1: "In my team, that also happened to us that we had to return to the starting point several times. The videos helped us to remember."

R2: "Of course, since they pass more content in the videos than in the class, if one needs to remember something, or I do not know, or something more specific, I will go to the videos."

These answers allude to the usefulness of the videos in the iterative design process faced by the student. The value of having activities during synchronous meetings is also made explicit.

Limitations, Conclusion, and Future Work

This article presents the flipped classroom implementation and the student perception of this methodology in a cornerstone Engineering course. This analysis presents various limitations, mainly regarding the loss of responses between the mid- and end-of-semester surveys, which left 136 participants. At the same time, only three participants attended the discussion group. For this reason, it was impossible to include the effect teachers could have on the different perceptions of the student regarding the flipped classroom.

During the first semester of 2022, a flipped classroom was implemented in a cornerstone Engineering course with a project-based learning methodology. This methodology was implemented through videos, asynchronous formative questionnaires, and face-to-face synchronous activities during the class.

Asynchronous videos are presented as an obstacle as some students require the habit of studying autonomously. Despite the difficulty presented by the students with generating habits to watch the videos independently, they value the availability of the videos during the semester because the design process they carry out is iterative (Figure 1). Having the videos available, which they can use to revise the material, is consistent with [30], who argue that having this freedom to review the material helps students retain information.

Regarding the questionnaires, the student perceives that the relevant information is repeated when reviewing them in class, making it less relevant to watch the videos before the synchronous meetings.

The student body values the activities in the classroom, as well as teamwork (Figure 2). At the same time, reference is made to the better use of time during class by carrying out team activities instead of listening to the lecture of the teaching staff.

Table 5 presents the proposed guidelines for implementing a flipped classroom.

Table 5. Proposed guidelines for implementing a flipped classroom

Videos	Record short videos, each of them about a specific concept.
	Incorporate the flipped classroom gradually so students learn to watch the videos outside the classroom.
Questionnaires	Replace the questionnaires with different formative evaluation methods, such as open questions and case studies related to the concept presented in the video. Eliminate the reviewing process during class.
Class Activities	Keep the length of the activities within the face-to-face session.

In conclusion, combining project-based learning with the flipped classroom allows students to review the material until they understand the proposed concepts. Reviewing the material supports the development of all-life learning. It allows students to actively learn, interact with teachers, teacher assistants, and classmates using technologies, and improve their communication skills [20].

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