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Successful implementation of a partially flipped classroom to building engineering students: A case study in structural design course

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Abstract:
In this paper, the background of the structural design course and the methodology of partially flipped classroom approach are presented. Details of the learning activities and the various assessment components are discussed. These activities and components involve 1) a set of tailor-made, pre-class, self-learning videos that demonstrates the concepts and usage of a software that facilitates the structural design process; 2) a set of in-class design tasks which coverage aligns with the content of the self-learning video and the curriculum and 3) an after-class, building design project that offers an opportunity for students to demonstrate what they learn in class and to create an innovative and effective solution to a practical problem. The effectiveness of the flipped classroom and its learning environment were evaluated through the use of student surveys. Overall, student survey about the flipped classroom approach is positive. In addition to the survey results, analytics extracted from Youtube channel give direction as to how the pre-class video could be improved in future. Based on the experience gained from this course, some of the essential elements for success in implementing flipped classroom are summarized.

Key Word*:Flipped Classroom; Structural Design; Computer-aided Design.*

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I. Introduction

Structural design is an important subject for civil engineering and building engineering students. In most curriculums, students are usually required to learn the basics of the design theory first and then carry out design work with the aid of computer software. The design work is the major assessment component of the course, in which students learn to apply the basic principles to create effective solutions to practical problems. Designing a structure requires an understanding of basic knowledge, practical considerations, cost consideration, creativity and practical constraints, among many others. In the design process, computer software is a necessary tool to facilitate the design and, comparing to the design work itself, using the computer software is relatively straight forward. Traditionally, the basic design theory is taught in lectures whilst practical design work and computer software are discussed in workshops. However, because of the diverse prior experience of students in computer usage, instructors very often need to spend a lot of time in the workshop just to demonstrate specific commands and usage of computer software, leaving not much time to discuss the design work with students. As such, a lot of the face-to-face meeting time in class was spent only on learning the software.

In order to make better use of the time in the design workshops, the flipped classroom approach[1,2,3] was implemented on a trial basis last year for the teaching and learning of computer software application. The software learning process is divided into three stages, spanning across three teaching weeks, covering the fundamental application of the software to more advanced ones. Three sets of video, complementary notes and assessments were prepared prior to the commencement of semester. Unlike previous years, students are required to watch a video of about 20-minute long on a Youtube channel before coming to each workshop. In the workshop, students are required to apply what they learned in the video to complete the in-class design tasks whilst instructors can discuss about the details of the design tasks with students or some specific applications of the software. Details of the methodology and implementation are discussed in the following section.

To reveal the effectiveness of the flipped classroom approach and its environment, a detailed student survey was conducted. In addition, analytics extracted from Youtube provides useful information on how the learning video was used and how they could be improved before the course is offered next time. Further, students' learning preferences were also included in the survey so as to get a better understanding of students' learning attitude. Based on the experience gained from this course, a brief discussion on how the flipped classroom approach can be further extended to another first year course in applied mechanics is given.

II. Methodology

Structural design is a second year course for building engineering students. In this course, students are required to learn the basic principles of analyzing and designing simple concrete and steel elements and the general layout design of simple low-rise buildings. To facilitate the analysis and design process, application of computer software is necessary. Among various software commonly used in local construction industry, SAP2000[4] is adopted in this course because of its popularity, versatility and user-friendliness. The teaching and learning pedagogy, particularly the rationale behind the flipped classroom approach was made clear to students during the first class in the semester. The importance of the flipped classroom approach is reiterated in Week 7 before commencing the computer workshops in Week 8. During the first 7 weeks of the course, the basic principles are taught in the conventional way through lectures and tutorials. Unlike previous years, however, flipped classroom approach was adopted from week 8 to week 10. Learning of the software is divided into three stages, first the analysis in Week 8, followed by reinforced concrete design and steel design in Weeks 9 and 10 respectively. A pre-class video of about 20 mins is made available on Youtube a few days before each workshop and students are required to watch it before coming to the workshop; screen captures of the three videos are shown in Figure 1. The videos were tailor-made to suit students' background and to cope with the depth and coverage of the course. In each video, a brief review of the basics is given. For consistency and ease of understanding, the same structure is used throughout the three videos, i.e. from analysis to concrete and steel design. Details of the steps and all necessary commands involved are fully illustrated in the video. Keys steps in the video are also summarized separately as a check sheet for easy reference. The last part of the videos illustrates how results of analysis and/or design could be exported to Excel for better data management.

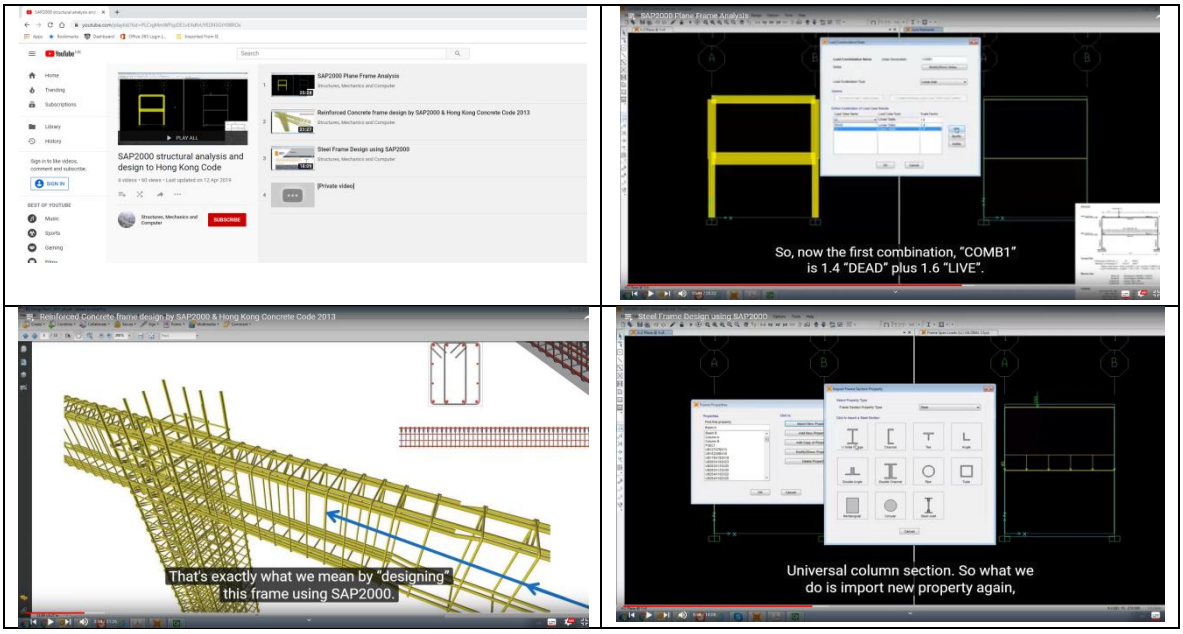

Figure 1: (Top left) Video playlist of the three videos; (top right) Part 1 analysis video; (bottom left) Part 2 reinforced concrete video; (bottom right) structural steel video. Subtitles are provided in all video.

Each workshop lasts for about three hours, during which students are given an analysis and/or design task to complete. The given tasks, although separately given to them in three weeks, are inter-related and formed three consecutive parts of a complete analysis and design work. Subsequent to the completion of workshops, students are equipped with sufficient background knowledge to develop the group design project which forms the major assessment component of the course. In the workshops, although the same frame-type structure is assigned to all students, each of them is given a different set of dimensions and member sizes to work on in order to encourage peer discussion and interaction yet maintaining independence to some degree. Each student analyzed the structure in Week 7 and carried out its design in concrete and steel in Weeks 8 and 9 respectively. The whole set of pre-class, in-class and post-class learning activities and assessments requires a careful planning in such a way that 1) they can finish the work within the time of the workshop; 2) the work reinforce their understanding of the complete design process and 3) it provides the foundation for them to complete the group design project after classes. During the workshop, students are free to discuss with peers and instructors can circulate to discuss with individual for specific questions about the software or the given task. To encourage their active participation in the pre-class and in-class learning activities, each in-class submission carried 5% of

the whole course. All submissions are marked with instructors' feedback and returned to students in about 2 weeks.

Based upon what they learned from the workshops and previous lectures, students formed groups of three to complete the design of a low-rise building at a given site location. Except the given site area and location, students can determine the use of the building and design the architectural and structural layouts accordingly. They are required to complete the design in about 4 weeks and submit both the general and structural layouts and design of its elements by the end of the semester. The project provides an opportunity for them to consolidate what they learn in previous weeks and to demonstrate their creativity and problem-solving skills. The project carries another 15% of the course. To illustrate the learning outcome, a student sample of the building layout submission is given in Figure 2.

Figure 2a

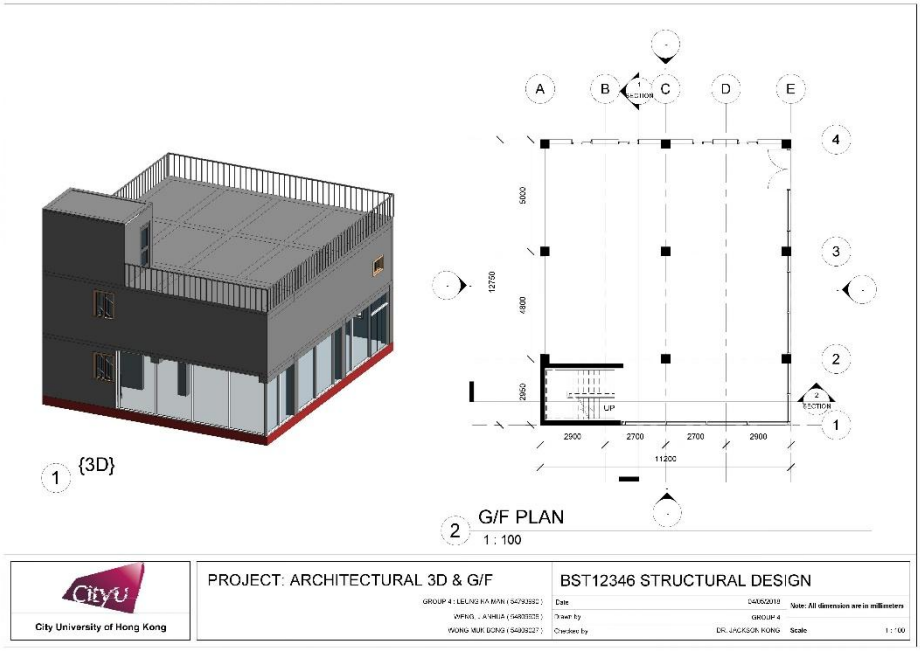

Figure 2b

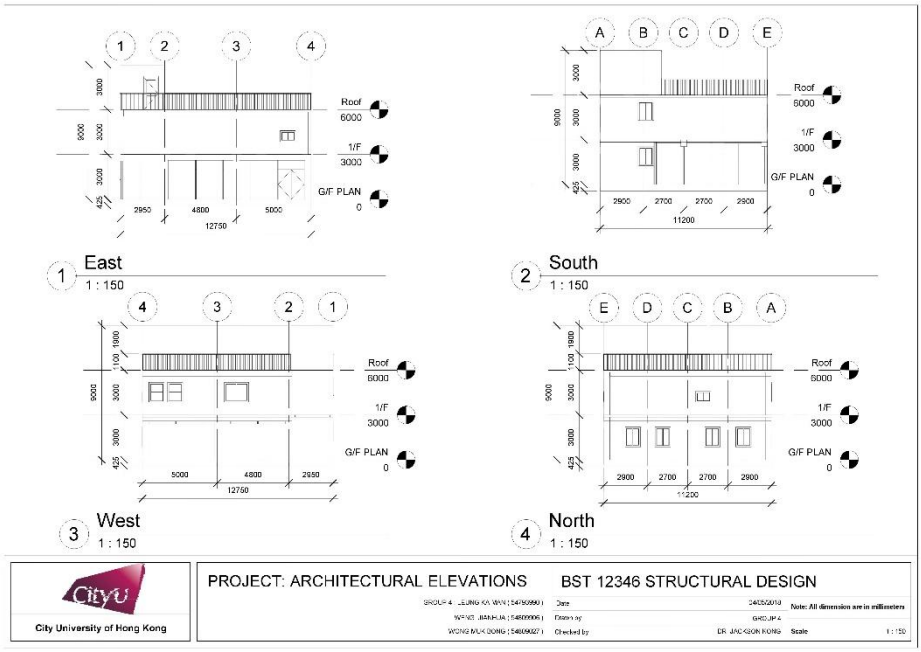

Figure 2c

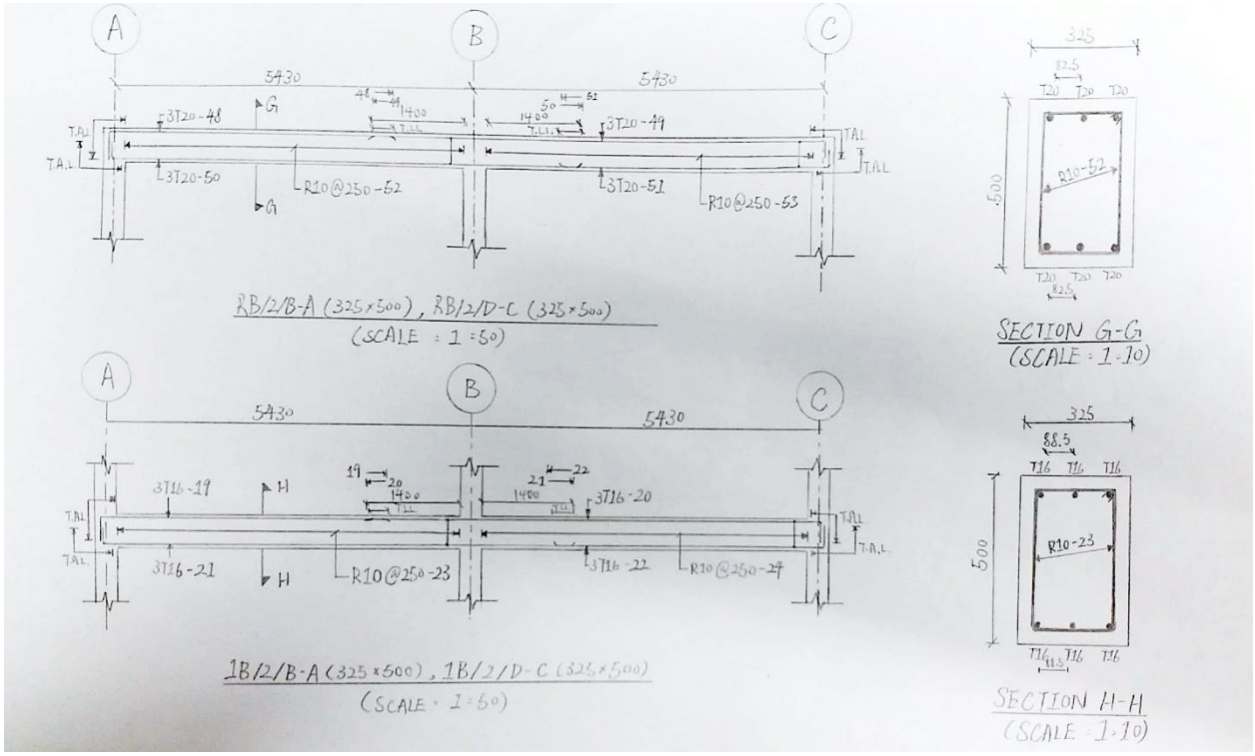

Figure 2d

Figure 2: Samples of student project submission (a) Building layout design (b) General layout plan (c) elevations (d) reinforced concrete details

III. Results and Discussion

Feedback about the Flipped classroom approach

Learning Preferences

The student survey questionnaire adopted in this study was designed by the Joint University Flipped Classroom project team[5]. Its main objective is to reveal students learning attitude and, more importantly, collecting their feedback about the learning environment and overall learning experience of the flipped classroom approach. The survey was conducted subsequent to completion of three consecutive weeks of computer workshops. Although completion of the questionnaire was not mandatory, 36 students responded, out of a class size of 50, i.e. a response rate of 70%. A 5-point likert scale was used in the questionnaire with 1 representing strongly disagree and 5 being strong agree (2 = disagree, 3=neutral and 4=agree).

Table 1 shows the students' learning preferences. In general, they agree to use class time for problem solving, active learning rather than just learning new contents. They also like learning at their own pace. However, it can be seen that they only agree to some extent to learn by themselves online before class instead of being taught everything face-to-face. This is not unexpected given the fact that most of the students, if not all, received their education in local high school where conventional teaching and learning approach dominates. Such responses from students also reflect the importance of explaining the rationale behind the flipped classroom approach to students at the start of the semester.

	Mean	Standard Deviation
1. I prefer online lectures to in-person lectures.	3.722	1.003
2. I like the first time I learn about the contents to happen at home before class.	3.972	0.736
3. I prefer having required learning before I go to class, rather than learning everything in class.	3.806	1.009
4. I prefer using class time for problem solving or active learning exercises, rather than learning new contents.	3.972	0.774
5. I prefer collaborating with other students in class, rather than only listening.	3.972	0.810
6. I like learning at my own pace.	4.056	0.893
7. I like using technology to assist my learning.	4.278	0.615

Table 1: Student survey questionnaire and response on learning preference

Flipped classroom learning environment

In the second part of the survey, students' feedback on details of the learning environment was collected in nine major areas like course instructions and organizations, learning materials, pre-class and in-class activities, method of assessment, feedback to students, technologies involved and motivations to learn. Overall, in this course, students agreed to the flipped classroom arrangement and the learning environment. Their agreement partly reflects the success of the flipped-classroom implementation. Nevertheless, there is still plenty of room to improve in the implementation. From the students' response to the questionnaire, a few important observations can be made:

1) Course instructions and organizations

It is always important to clearly explain to students the course structure, learning objectives and instructions for activities, irrespective of whether flipped classroom approach or conventional teaching and learning approach is used. This can be seen from the students' agreement to our arrangement in this regard. An introductory short video could be made to reinforce students' understanding of the flipped classroom rationale and implementation at the start of the semester.

Course Instructions and Organization	**Mean**	**SD**
The course structure is clear.	4.278	0.659
The learning objectives of the topic are clearly stated.	4.306	0.577
Instructions for the learning activities are sufficient.	4.139	0.593
The learning activities are well-organized.	4.194	0.577
The teacher provides opportunities for pre-class and after-class collaboration.	4.222	0.722

Table 2: Student survey questionnaire and response on course instructions and organization

2) Learning materials

Apart from helping students to learn and complete in-class activities, learning materials provided to students could also be designed to motivate students to learn wider and deeper than the originally designed course content. In the context of structural design, students could be motivated to think beyond design using conventional materials or technology. Such learning motivations could be considered for incorporating into the pre-class learning video and/or the group design project.

	Mean	**SD**
Learning Materials		
The materials are useful to my learning.	4.306	0.525
The materials motivate me to learn more.	3.778	0.866
The materials are helpful to prepare me for in-class activities.	4.278	0.615

Table 3: Student survey questionnaire and response on course learning materials

3) Assessment and feedback for pre-class and in-class learning activities

To encourage students to actively engage in the pre-class and in-class learning activities, it is crucial to ensure that the activities are aligned with each other and compatible with the course content and that the activities could be completed within a reasonable time. In this respect, students agreed with the flipped classroom implementation. Further, students' responses support that learning activities like the in-class design tasks should always be assessed and graded and that timely feedback to students, no matter written or verbal, should be provided to students for their continual improvement.

Pre-class learning activities	**Mean**	**SD**
The teacher gives sufficient time for me to complete pre-class learning activities.	4.167	0.609
There are incentives in place (e.g., grading for completion) to motivate me to complete the pre-class learning activities.	4.056	0.791
In-class learning activities		
The in-class activities allow me to create new ideas.	4.028	0.654
The in-class activities allow me to evaluate different opinions.	3.972	0.810
The in-class time is sufficient for me to apply what I've learned from the pre-class activities.	4.000	0.632
The in-class activities foster my analytical thinking (e.g., organizing and differentiating information).	4.167	0.655
The teacher gives me incentives (e.g., quizzes, extra marks) to engage with in-class learning activities.	4.194	0.577
Course Assessment		

There are various types of assessments to evaluate my learning at different stages (i.e., pre-class, in-class, after-class).	4.167	0.655
The assessments are the main reasons for me to participate in flipped classroom activities.	3.944	0.791
Feedback to students		
I receive feedback from various ways (e.g., the teacher, tutors, and classmates).	4.083	0.732
I receive timely feedback from the teacher.	4.028	0.736
The teacher provides adaptive feedback on group works.	4.194	0.577

Table 4: Student survey questionnaire and response on course activities, assessment and feedback

4) Technologies involved

Technology used in the flipped classroom is preferably easy to use, readily available and that students are familiar with it. In the structural design course, Youtube was chosen to deliver the pre-class videos because, first, it can automatically generate subtitles for supporting students learning, and second, it provides various analytics for instructors to improve the video based on students' viewing history; the improvement works on the video is elaborated in the following section.

Technologies used	**Mean**	**SD**
The technologies (e.g., video platform and online learning system) used in this course are easy to access.	4.222	0.681
The technologies used in this course are stable.	4.111	0.667
I am familiar with the technologies used in this course.	4.250	0.604

Table 5: Student survey questionnaire and response on course technology

5) Flexibility to learn

In the structural design course, the pre-class video was made available to students a few days before the workshop. This allows students some flexibility and freedom to learn at their own pace.

Flexibility to learn	**Mean**	**SD**
I am motivated to learn as I can adjust my own learning pace with a flipped classroom style.	4.139	0.798
I am motivated to learn as I am given more freedom to learn with a flipped classroom style.	4.139	0.683

Table 6: Student survey questionnaire and response on course flexibility

Overall, as shown in Table 7, it is encouraging to see that students agreed that they like learning with the flipped classroom approach and have confidence to achieve the learning outcome.

	Mean	Standard Deviation
Overall, I like learning with the flipped classroom approach.	4.167	0.697
Overall, I am satisfied with the flipped classroom approach.	4.222	0.681
Overall, I am confident to achieve expected learning outcomes with the flipped classroom approach.	4.167	0.609

Table 7: Student survey questionnaire and overall response on overall flipped classroom learning experience

Analytics from Youtube

The pre-class, self-learning videos were made available to students through Youtube channel instead of the Canvas e-learning platform. This is because the former offers various analytics that facilitate instructors to improve and refine the video based on students' viewing history.

In week 8 of previous academic year, there were 175 views for the first video, which implies on average each student watched 3 times or more in order to complete the in-class assignment. The video is about 25 minutes long. The absolute audience retention curve, as shown in Figure 3, shows the number of views for every minute of the video as a percentage of the total number of views. Clearly, it reveals the fact that students only repeatedly watched parts of the video, particularly those at the peaks, thus resulting in an average duration of view of only 11.26 mins, i.e. an average of 45% of view. Very similar percentage of views was also found for the other two videos. In addition, the significant drops in the percentage of views during the first 3 mins, the introductory part of the video, and the last 5 mins, the conclusion part, indicates that these two parts of the video could be shortened by making it more concise. When compared with other Youtube video of similar length, as shown in the relative audience retention of Figure 3b, the video is able to keep viewers watching except the last part of the video. It is also noteworthy that, in this first video, the subtitles were switched on for 70% of the views, thus revealing its necessity and importance in supporting students learning.

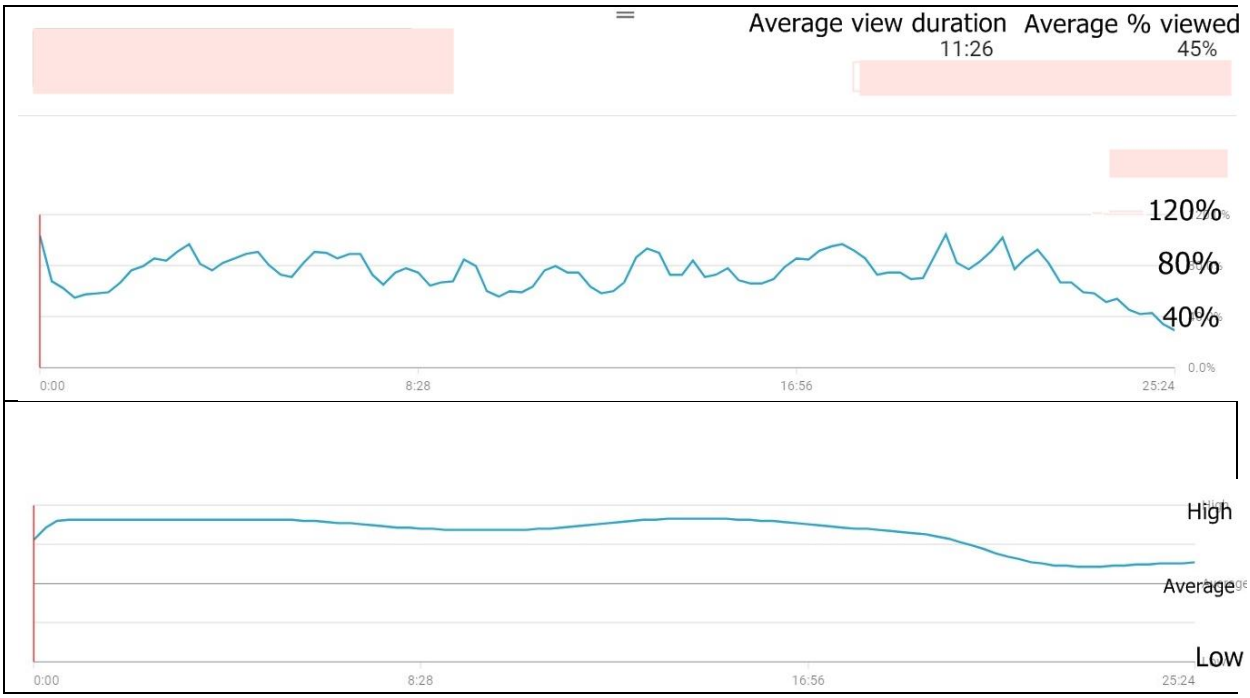

Figure 3 Absolute (top) and relative (bottom) audience retention curves of the first pre-lecture video. Vertical axis represents percentage viewed (top) and ability to keep audience watching (bottom). Horizontal axis represents the timeline of the video.

IV. Conclusion

In a flipped classroom, the role of instructors is changed; instructors are no longer responsible for delivering lectures, instead, they accompany students to learn and work on problems. From students' point of view, a change of mindset and behavior is required; they need to proactively prepare for the class and engage in collaborative works during and after class.

In this paper, a partially flipped classroom for the structural design course is described. The main objective of adopting this approach is to allow more face-to-face time in design workshops for instructors to discuss with students the practical issues in structural design, instead of just spending time on teaching the computer software, the latter only serves as a tool for the design process. Based on the experience of the author during the planning and implementation process of the partially flipped classroom and the survey and student responses collected, there are a number of essential elements for the success in implementing flipped classroom:

1)The rationale behind this new teaching and learning approach and details of its implementation have to be clearly explained to students at the start of the semester;

2)The pre-class learning videos should preferably be made available to students earlier to allow students enough flexibility and freedom to learn at their own pace;

3)In-class learning activities should align with the pre-class learning materials, the after-class project and they should be compatible with the course coverage. The in-class activities must be graded to provide an incentive for students to proactively engage in the pre-class learning and completion of the in-class activities. Timely feedback to students is always essential.

4)After-class project should be assigned to provide students an opportunity to reinforce their understanding in the flipped classroom learning process and to demonstrate their creativities and abilities in solving practical problems.

5)Data collected from Youtube channel and students' response to the course survey provides important guidance for instructors to reflect and refine the implementation.

It is noteworthy that the flipped c1assroom approach does require a significant amount of preparation time during the initial planning stage. However, once the approach is implemented, the subsequent preparation time is no longer than the conventional teaching approach.

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