A Blended Learning Course in Engineering Materials: Course Design and Analysis

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Abstract
"Engineering Material II" is a Year 3 undergraduate major elective course that offers fundamental training to students who are interested in pursuing a career in materials-related fields or advanced study programs. Over the past three years during pandemic, this course has been taught in both real-time online mode and mixed mode, which combines online and face-to-face elements. Taking into account the positive feedback from students regarding the online components and the benefits of face-to-face interactions, we have successfully integrated and transformed this course into a blended learning mode. This paper addresses the challenges encountered during the conversion process and outlines our approach to designing a cohesive blended learning course. We aimed to ensure a seamless transition between online and face-to-face modules while truly achieving a blended learning experience. Additionally, the paper evaluates students' engagement with a video analytics tool, providing insights into their involvement throughout the course.

Keywords: Blended Learning, Course Design, Video Analytics

Introduction

Blended learning mode has emerged as an effective hybrid teaching mode which combines both online (or digital) learning module and the conventional face-to-face module. Over the past few years, especially during pandemic, blended learning has evolved into an effective educational method across various domains, including K-12 education, higher education, as well as in corporate training.

In higher education field, blended learning has found applications in a diverse range of fields. For example, Bos – van den Hoek et al (2023) has discovered that blended learning improved the healthcare professionals' skills, knowledge, and confidence in supporting shared decision making in palliative cancer care. Sun et al (2024) has conducted a comprehensive review and have found extensively use of blended learning in teaching business English major courses during 2012 – 2022. Niu et al (2023) have investigation the undergraduate nursing student education and concluded that blended learning is more effective than traditional courses in acquiring knowledge and skills and improving the critical thinking capability and with a positive effect on the nursing students' mental health.

The rapidly increased adoption of blended learning across various subject fields has led researchers to investigate its effectiveness on learning outcomes and impact on learners. For example, de Brito Lima et al (2022) have studied the learners' behaviors, uses of resources, and learning pathways, finding correlations between the engagement and performance for secondary schools. Li et al (2024), using the application cases in foreign language education, have emphasized that adoption of blended learning as the main pedagogical approach needs departmental level implementation as the driving force. Wang et al (2024) have researched the effect of role assignments and timing in online discussions on blended learning outcomes and have found little impact. Müller et al (2022) have applied flow theory to describe the positive effect of course flexibility and course interaction, which play an important role in students' perceived learning quality. This highlights the importance of instructors keeping course flexibility and interactions in mind during the course design stage. Mariam et al (2024) have studied the factors that may induce the future intentional use of blended learning in business and management educations, revealing the significance of initial learning experiences with blended learning and the perceived quality of online teaching. However, there is little study in effective tools for analysis and evaluation of students' engagement in blended learning in higher educations. In this paper, we have described how we use video analytics to assist us in the course design and monitor students' engagement throughout the blended learning process.

MECH 3420 Engineering Materials II has been taught in Fall semesters since 2017, with face-to-face-mode in 2017 – 2019, online mode in 2020, and mix-mode in 2021. During the face-to-face mode, I used online resources: such as online videos to explain and demonstrate different fabrication process of engineering materials; and online quizzes for assessment. Through the entire teaching process, I noticed that some students benefit more from face-to-face teaching mode, while some find more advantages in online teaching mode. Since students have experienced different advantages from both face-to-face and online teaching modes and enjoyed the mix-mode teaching and learning as well, I am highly motivated to combine the face-to-face and online elements together to benefit the whole student group and maximize the learning outcomes of this course. Therefore, we successfully converted this course into a blended learning course in 2022 and offered the course in blended learning mode in 2023.

Transition Between the Online Sessions and the Face-to-Face Sessions

The original course is composed of three modules, as shown in Figure 1, where the topics of each module and each chapter are listed.

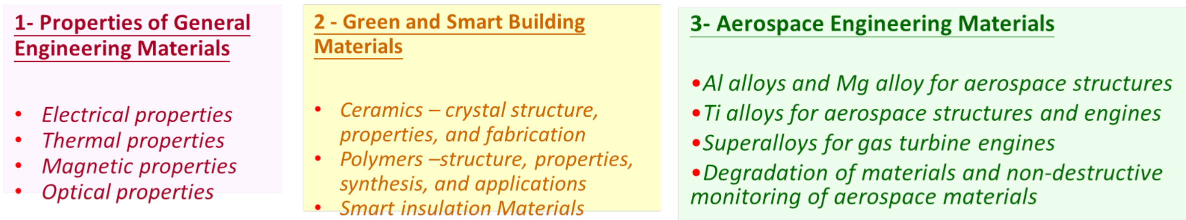


Figure 1: Three modules in this course.

A blended learning course in general contains alternating online learning and face-to-face learning sessions. To convert this traditional course into the blended learning format, we have carefully determined what contents are best suited for online sessions and what other contents are best covered in the face-to-face instructions. The design of online sessions and in-class activities has posed tremendous challenges, particularly in ensuring smooth and seamless transitions for students between the self-paced online learning and face-to-face instructions.

(1) Self-Paced Online Learning

Using Chapter 2 – Electrical Properties as an example, Figure 2 shows the self-paced online learning approach. Chapter 2 is devised into five sub-sections, each in an individual video clip, i.e. (1) electrical conduction; (2) electron band structures in solids; (3) semiconductivity; (4) semiconductor devices; (5) dielectric behavior and other electrical characteristics of materials. Upon completing the watching the five video clips, students are then encouraged to participate in a range of online graded discussions, which may involve answering online questions, or analyzing a chart or a graph (as shown in Figure 2), or investigating a simple case study. The objective of the online graded discussion is to assess students' comprehesion of theoretical concepts and principles.

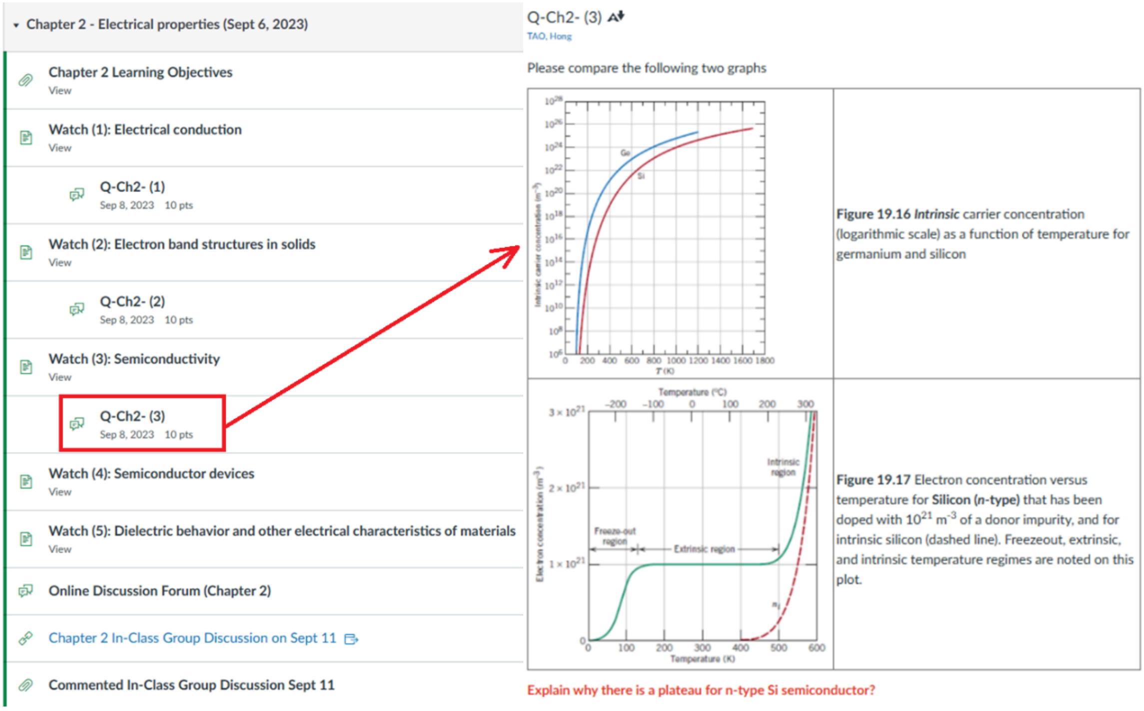


Figure 2: Self-paced online learning: an example.

(2) In-Class Activities

In the face-to-face learning sessions, students are organized into small groups and are seated at tables facing each other. This type of seating arrangement has facilitated collaborations and enabled students to effectively communicate their ideas and address any questions in case applications. The face-to-face instruction sessions consists of two main activities: the graded group discussions and the higher-level thinking practices.

The graded group discussions involve reflection of self-paced online learning questions and clarification of the parts that students find the most challenging. To streamline the grading process, we have utilized MIRO as the collaborative platform for group discussions, as shown in Figure 3. Each group member may contribute their answers and opinions to each question after the collaborative group discussions.

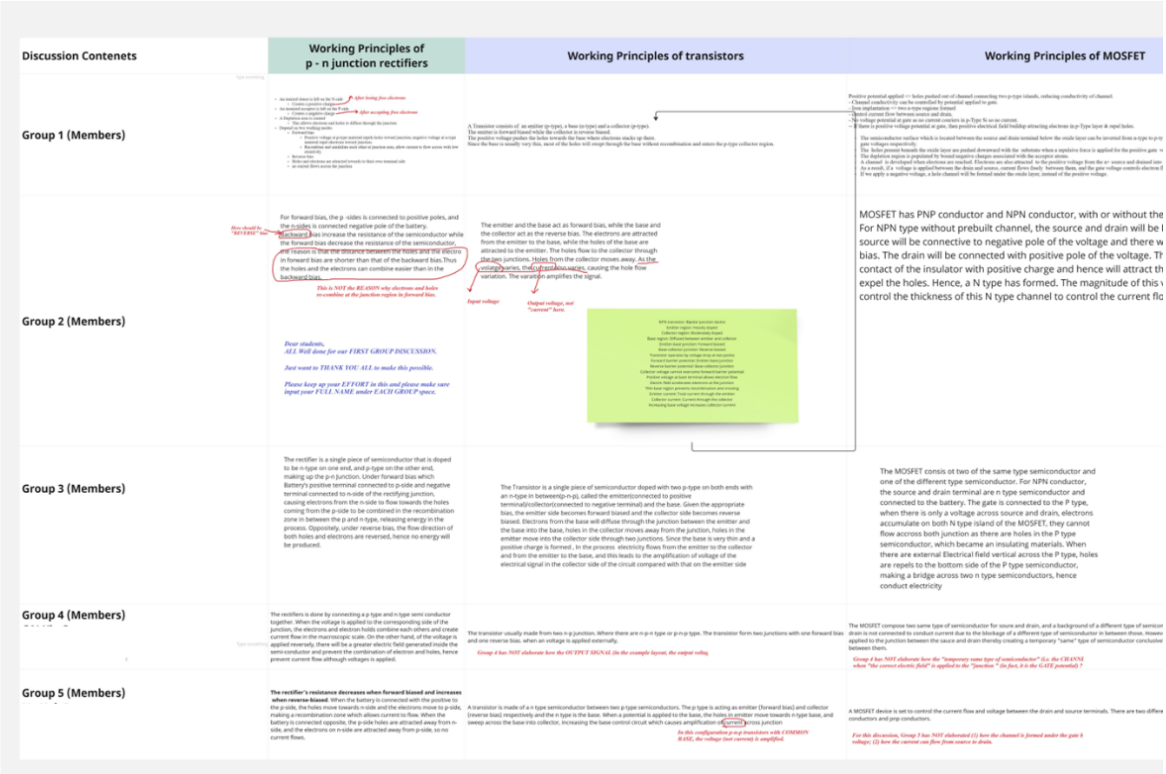


Figure 3: Graded group discussions using MIRO.

The other activity, higher-level thinking, generally involves students collaboratively working together through comprehensive calculations and industrial case application analysis for each chapter. For example, in Chapter 2, students have collaborated in calculation of the carrier concentration, electrical conductivity for intrinsic and extrinsic semiconductors. They also have analyzed the applications of piezoelectric materials.

When transforming this conventionally lecture-based course into a blended learning course, we have discovered that that it is more than just literally blending the online and face-to-face sessions together, it indeed requires careful allocating contents to the online and face-to-face sessions and devising engaging discussion topics that integrate the theoretical concepts and principles into interesting real-life industrial applications. This unique approach aims to create truly cohesive structures in this blended learning course, ensuring students experience seamless and smooth transitions between the online and face-to-face sessions.

Students' Engagement Analysis Using Video Analytics

Two key factors contribute to achieving our main goal of the seamless and smooth transitions between the self-paced online learning and face-to-face learning. The first key lies in the instructor, who has carefully devised each session to ensure its effectiveness. The second key lies in the students, because their active engagement is crucial to the success of a blending learning course. To assess students' engagement, we have employed an effective tool-video analytics.

Video analytics generates various types of reports and summaries, enabling us to monitor the video watching behavior both at the whole class level and at the individual level. Once students have started watching the online videos and performed online tasks, video analytics, as shown in Figure 4, exports an Excel file, containing a report summarizing the number of users accessing the video, the number of access times, average duration, and average completion percentage of the video. We use the average completion percentage as an indicator of students' engagement, with higher percentage indicating greater engagement.

By leveraging this two key factors: careful course design from instructor side and active engagement from students' side, we have strived to achieve our goal of seamless transition and smooth learning experience between self-pace online learning and face-to-face instruction.

Video Name	Length	User	Accessed	Avg. Duration	Avg. No. of Times	Avg. % of Completed	Start Record	End Record
Electrical_Conduction	7:13	12	17	4:40	0.6	55.9	6/9/2023	10/9/2023
Electron_Band_Properties_in_Solids	6:24	17	38	10:54	1.7	89.6	4/9/2023	11/9/2023
Semiconductivity	10:45	17	34	20:26	1.9	89.0	4/9/2023	11/9/2023
Semiconductor_Devices	7:27	14	24	6:46	0.9	69.2	5/9/2023	11/9/2023
Dielectric_Behavior_and_Other_Electrical_Characteristics_of_Mate	7:49	13	18	8:34	1.1	76.8	5/9/2023	11/9/2023
MECH3420 Course Introduction	2:58	3	6	3:32	1.2	100.0	4/9/2023	11/9/2023
What is Blended Learning?	1:46	2	2	0:39	0.4	48.1	4/9/2023	6/9/2023

Students' engagement for Chapter 2

Total average % completed of all videos 75.5

Video Name	Length	User	Accessed	Avg. Duration	Avg. No. of Times	Avg. % of Completed	Start Record	End Record
C6_V1_Ionic_Arrangement_Geometries	4:01	**15**	26	5:02	1.3	90.8	26/9/2023	8/10/2023
C6_V2_Crystal_Structures_of_Ceramics	4:59	**15**	19	9:16	1.9	82.0	27/9/2023	4/10/2023
C6_V3_Silicate_and_Carbon_Structures	9:19	**13**	21	10:13	1.1	82.8	27/9/2023	8/10/2023
C6_V4_Imperfections_in_Ceramics_and_Phase_Diagrams_of_Ceramics	9:18	**14**	24	12:56	1.4	74.8	27/9/2023	8/10/2023
C6_V5_Mechanical_Properties_of_Ceramics	4:00	**8**	13	5:09	1.3	90.9	29/9/2023	4/10/2023
C6_V6_Types_Applications_and_Processing_of_Ceramics	13:29	**8**	11	14:27	1.1	90.3	29/9/2023	4/10/2023

Students' engagement for Chapter 6

Total average % completed of all videos 85.3

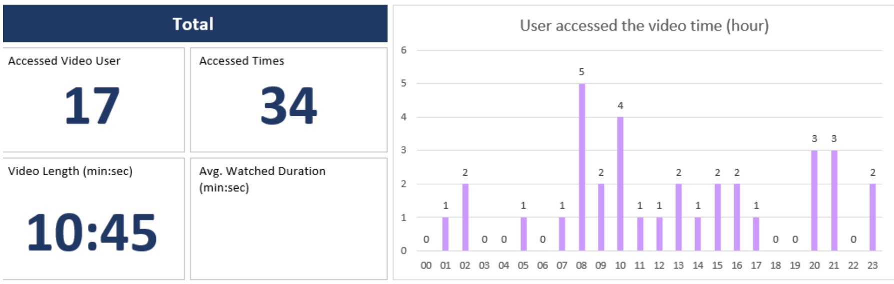
Video Name	Length	User	Accessed	Avg. Duratio	Avg. No. of Times	Avg. % of Complete	Start Record	End Record
C13_V1_Importance_of_Corrosion_Control	2:43	11	13	2:29	**0.9**	**86.7**	17/11/2023	24/11/2023
C13_V2_Electrochemical_Consideration_of_Corrosion	12:14	14	28	15:13	**1.2**	**74.0**	17/11/2023	24/11/2023
C13_V3_Forms_of_Corrosion	5:53	12	19	9:13	**1.6**	**88.1**	20/11/2023	27/11/2023
C13_V4_Corrosion_Prevention_and_Oxidation	6:31	12	16	6:11	**1.0**	**77.7**	20/11/2023	27/11/2023
C13_V5_Degradation_of_Polymers	4:27	8	10	4:48	**1.1**	**87.3**	20/11/2023	24/11/2023

Students' engagement for Chapter 13

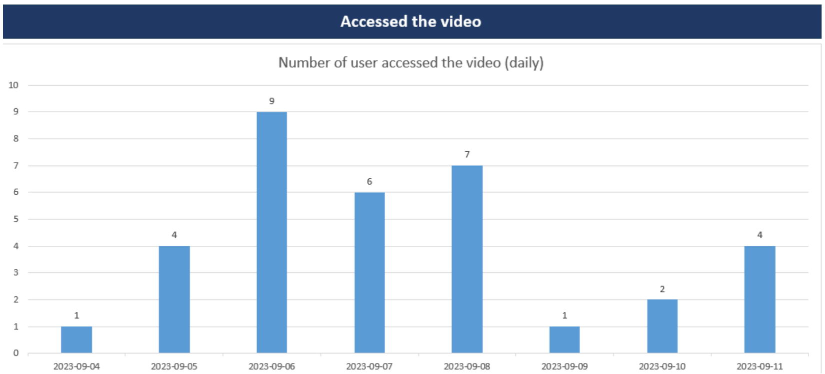
Total average % completed of all videos 82.8

Figure 4: The whole-class video list report for Chapter 2, 6, and 13.

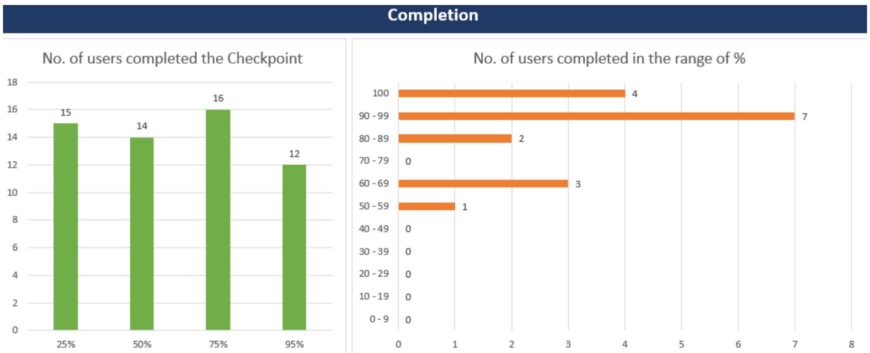
The Excel file also summarizes the breakdown components for each video clip. As showcased in Figure 5, besides the number of access users and accessed time, other details such as the number of users accessing the video for each hour of a day (Figure 5 (a)) and for each day in a week (Figure 5 (b)), number of users who have completed at checkpoint of 25%, 50%, 75%, and 95% (Figure 5 (c)), and the number of users distribution in the range of completion percentages (Figure 5 (d)) are also presented in the report. An interesting observation from Figure 5 (a) is that more students access the video clip between 8 to 10 o'clock in the morning and between 8 to 9 o'clock in the evening. Additionally, more students access to the video from September 6 to September 8, 2023, compared to the other days. Based on the results shown in Figure 5 (c) and (d), we consistently encourage students to complete the video watching in all future chapters.



(a)



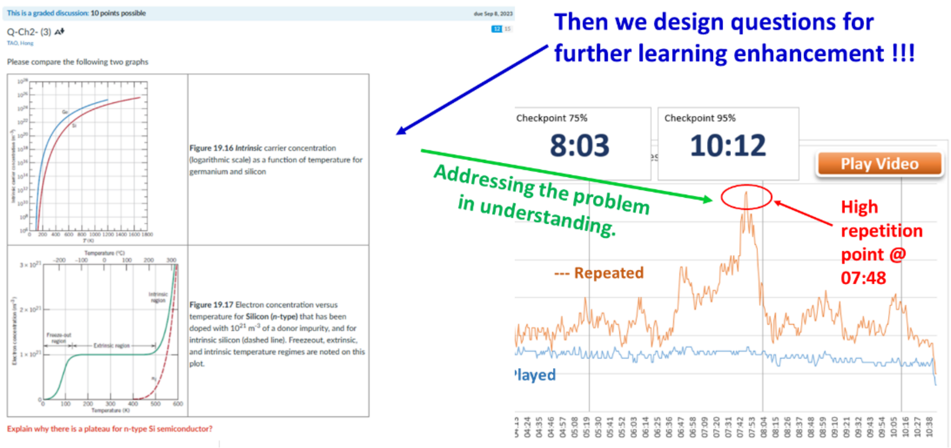
(b)



(c) (d)

Figure 5: Video analytics breakdown components.

By analyzing these statistics and patterns, we aim to increase the completion rate and promote higher students' engagement. Among the various output generated by the video analytics Excel file, we have found a valuable tool: the curve showing the played and repeated access over the elapsed time, as depicted in Figure 6 (b). The curve displaying repeated access exhibits several peaks, with the highest repetition occurring at the time 07:48. Upon reviewing the course contents corresponding to the time at 07:48, we have identified it as the section describing the plateau in the graph of electron concentration versus temperature for extrinsic semiconductors, as depicted in Figure 6 (a). This indicates that students find this specific point challenging and difficult to comprehend. In response, we have incorporated online questions targeting this specific point of challenge and provided additional elaborations in the face-to-face instructions. Using this valuable tool to identify the challenge point, we have addressed it with greater emphasis, facilitated better understanding and alleviated difficulties faced by students.



(a) (b)

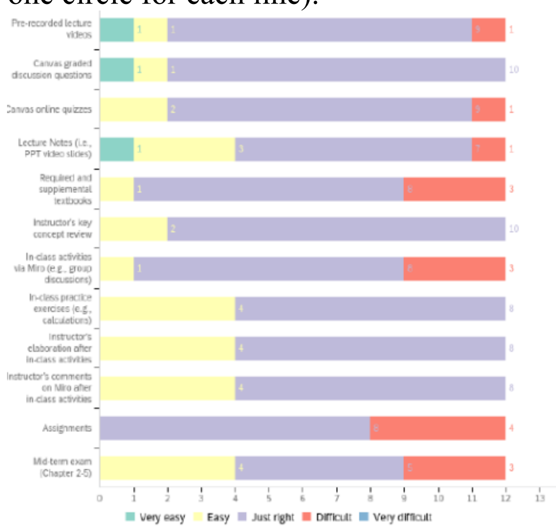
Figure 6: The curves (b) of played and repeated versus time indicate the watching pattern, which guides our course design and re-design (a).

End-of-the-Course Evaluation Results

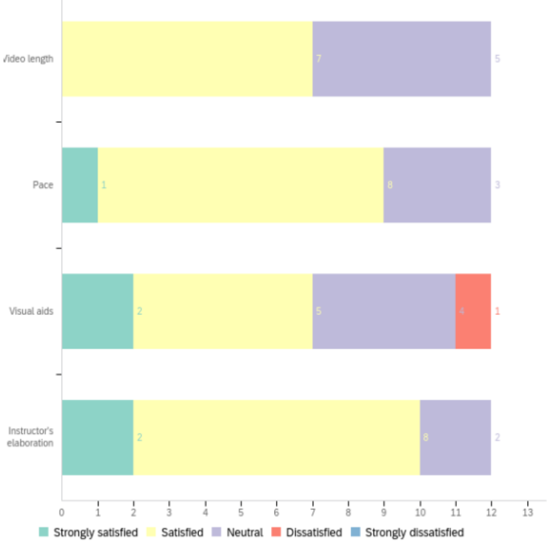
To gain a comprehensive understanding of the blended learning course, we have conducted the end-of-the course evaluation survey, and the survey questions (Q1 to Q8) and survey results are presented in Figure 7. Based on the survey results, students have generally found most course components useful, with three exceptions, i.e. required and supplemental textbook, group discussions on MIRO, and instructor's comments on MIRO. While most students feel each course component is at an appropriate difficulty level, a small number of students feel several components challenging. Students are satisfied with the various aspects of pre-recorded videos and the design of in-class activities. They have found the pre-recorded videos useful for preparation of the in-class activities, which, in turn, are helpful for them to prepare for assignments and assessments. Majority of the students think the work-load is just right, dedicating 1 to 2 hours to prepare for both online tasks and in-class activities. These survey results have provided valuable insight into the strength and weakness of the blended learning course. The feedback received will help us further improve some course components and enhance the overall learning experiences for future students.

Q1 - Please rate the usefulness of each of the following course components. (Check one circle for each line).

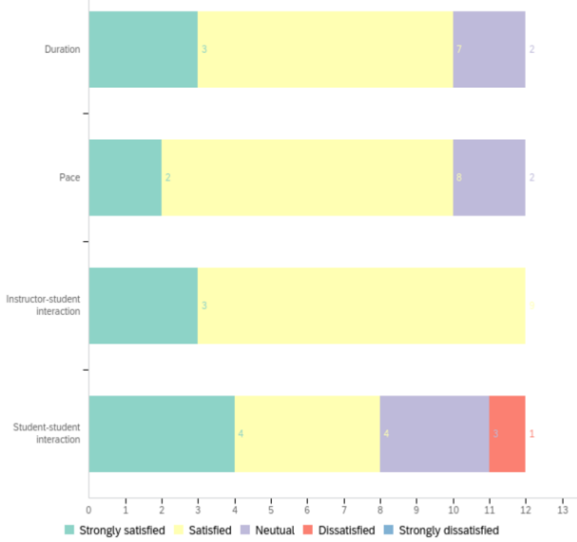
Q2 - Please rate the difficulty level of each of the following course components. (Check one circle for each line).



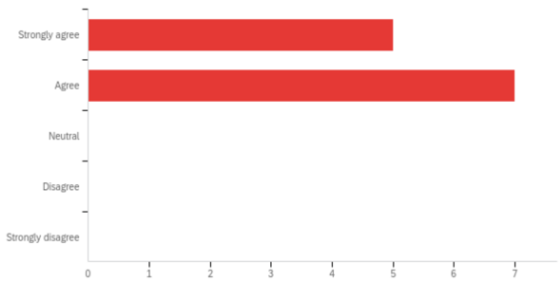
Q3 - Please rate the pre-recorded lecture videos according to the following aspects. (Check one circle for each line).



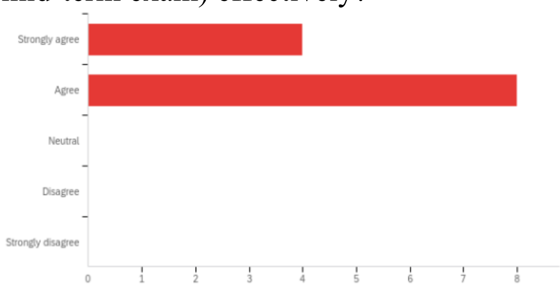
Q4 - Please rate the face-to-face in-class sessions according to the following aspects. (Check one circle for each line).



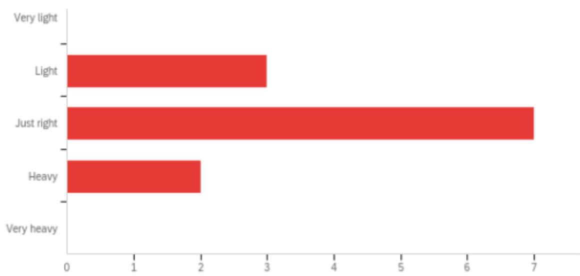
Q5 - Do you agree that the Pre-recorded lecture videos help you to prepare the in-class activities effectively?



Q6 - Do you agree that the face-to-face in-class sessions help you to prepare for the major assessments (e.g., assignment and mid-term exam) effectively?



Q7 - How do you find the workload of this BL course when compared to other traditional courses?



Q8 - What is the average time per week you spent preparing for the face-to-face session in this BL course? (e.g., the time spent watching pre-recorded lecture videos, doing the graded discussion questions, taking the online quizzes, and readng the textbook(s), etc.)

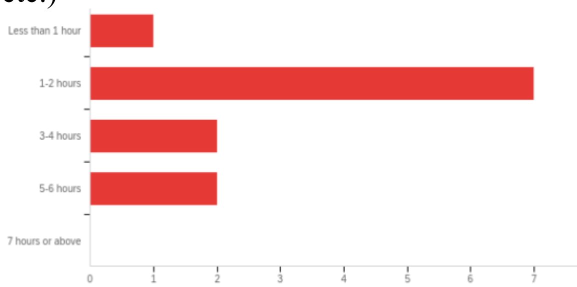


Figure 7: Survey questions and survey results of the end-of-the-course evaluation.

Conclusion

MECH 3420 Engineering Material II has been successfully transformed from a traditional lecture – based course into a blended learning course. The strength of both online and face-to-face teaching and learning are combined together to maximize the learning outcome and to benefit the whole student group. With careful allocation of contents, well -balanced online and face-to-face sessions, integration of theoretical concepts into real-life industrial application cases, the video analytics findings about students' engagement, we have created a cohesive blended learning structure and ensured smooth and seamless transitions between the online and face-to-face instructions.

With the received feedback from students and survey results as the guidelines, we will continue to improve the course design, adjust the course contents, balance the difficulty of some course components and the work load.

Acknowledgements

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