

ORIGINAL ARTICLE



Pre-class online video learning and class style expectation: patterns, association, and precision medical education

Cheng-Maw Ho^{a,b}, Chi-Chuan Yeh^{a,c}, Jann-Yuan Wang^{b,d,e}, Rey-Heng Hu^{a,b} and Po-Huang Lee^{a,b,f}

^aDepartment of Surgery, National Taiwan University Hospital, Taipei, Taiwan; ^bSchool of Medicine, College of Medicine, National Taiwan University, Taipei, Taiwan; ^cDepartment of Medical Education, National Taiwan University Hospital, Taipei, Taiwan;

^dDepartment of Internal Medicine, National Taiwan University Hospital, Taipei, Taiwan; ^eCenter of Faculty Development and Curriculum Integration, College of Medicine, National Taiwan University Hospital, Taipei, Taiwan; ^fDepartment of Surgery, E-Da Hospital, I-Shou University, Kaohsiung, Taiwan

ABSTRACT

Background: Online video learning has been gaining substantial attention in medical education. The purpose of the study was to evaluate medical students' online video-viewing patterns as well as to identify features associated with their class style preferences in precision medicine courses.

Methods: A mixed methods research design was used. Part of the cognitive load of the class content of "acute liver failure" was shifted to a 10-minute pre-class online video learning which was further reduced using threshold concept strategy. In the 2019 academic year, all fifth-year medical students who had viewed the pre-class video were invited to take a survey on their learning process and four class style expectations for the upcoming in-person class. For each round of medical students, teaching assistants helped collect anonymous survey data before the class. The teacher then adjusted the in-person class as part of precision medical education. Furthermore, the researchers coded the video-viewing patterns through an action log transformation, along with the questionnaire results, for analysis. Mann-Whitney *U* and Kruskal-Wallis tests were employed to compare group differences. Qualitative data were content-coded through a descriptive approach using thematic analysis.

Results: Of the 130 medical students, 114 (87.7%) joined the pre-class video learning, 113 (86.9%) responded to the questionnaires, and 87 (66.9%) provided their comments. Most medical students preferred the class styles of a thorough introduction (42.5%) and concept orientation (44.2%). High-engagement viewing patterns were associated with difficult concepts and the provision of comments. Class style expectation and video-viewing patterns did not demonstrate significant linkages. A majority of the substantial comments initiated thought-provoking questions after the online video learning.

Conclusion: Association between medical students' preferred class styles and online video-viewing patterns was not necessarily linked. However, medical teachers are recommended to modify class styles based on medical students' expectations after pre-class learning, thereby providing precision medical education.

KEY MESSAGE




- Implementing precision medical education in the blended class is feasible.
- Online video learning is an ideal platform for balancing the dilemma between increasing the cognitive load of class content and the practice of precision medical education.
- The association between medical students' preferred class styles and online video-viewing patterns was not clearly seen.


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CONTACT Jann-Yuan Wang  jywang@ntu.edu.tw  Section Director, Curriculum Integration, Center of Faculty Development and Curriculum Integration, College of Medicine, National Taiwan University, 7 Chung-Shan South Road, Taipei, 100225, Taiwan; Professor of Department of Internal Medicine, National Taiwan University Hospital, Taipei, Taiwan; Rey-Heng Hu  rhhu@ntu.edu.tw  Department of Surgery, National Taiwan University Hospital, Taipei, Taiwan

 Supplemental data for this article can be accessed [here](#).

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Introduction

Medical practice is constantly changing, evolving, and expanding in response to new information, innovation, and technologies. Medical educators are facing increasing difficulties in smoothly transitioning medical students into clinical fields. Modern methodologies of teaching medical education include case-based learning, evidence-based medicine, problem-based learning, simulation-based learning, e-learning, peer-assisted learning, observational learning, flipped classroom, and team-based learning [1]. However, effectively tailoring medical education tools to individual medical students' needs remains a burning issue.

Using educational videos as learning aids in medical education can be traced back to the 1960s [2]. Online video-based learning presents a feasible learning module that can be applied to clinical medicine [3]. Successful online video learning in medical education requires the active engagement of learners and a well-controlled cognitive load of the video content [4]. Dodson et al. [5] constructed an active viewing pattern for video-based learning using the ICAP framework (interactive, constructive, active, and passive behaviours) and conducted a field study on an undergraduate Applied Science class using the software, ViDeX. Their efforts highlighted the need to identify efficient strategies for video-based learning and to assess the learning processes and outcomes concerning active viewing [5]. Moreover, in teaching with video, there is a distinct gap for instructors to gather information necessary to make informed decisions about how to structure their classes around video [6–8].

Precision medical education is considered an ethical, science-based approach to optimizing and individualizing medical professionals' training and career outcomes based on data, data science, and research [9]. Just as the patient must be at the centre of personalized medicine, the learner should be at the centre of precision medical education [9]. While successful individualized interventions were used to be resource-heavy and time-intensive [10], precision medical education is becoming more accessible with the aid of computing technologies [11,12]. However, there is a paucity of literature addressing how to implement this principle in the current medical education system. In the real world, the practice of precision medical education, a blended learning model supplemented by online pre-class learning modules may help medical students adapt to the era of rapid change, especially in the time of the COVID-19 pandemic [13,14].

Threshold concepts are characterized as having transformative, integrative, irreversible, and bounded features [15]. The teacher (HCM) identified and summarized six threshold concepts (TCs) on "acute liver failure" with the characteristic features and included them in the course design and practice [15]. Before the in-person classes on acute liver failure, we had implemented 10-minute video learning modules online using a threshold concept strategy to reduce cognitive load and improve in-class learning [15]. However, whether further tuning of in-class teaching and learning could be achieved by timely adjusting the subsequent class' style after pre-class exposure, as part of precision medical education, remains unexplored in the setting of clinical science education. The current empirical study tested the feasibility of implementing precision medical education in this setting of a blended learning model and identified features associated with students' class style preferences. This study also measured online video-viewing patterns and identified online video learning features associated with students' class style preferences. The following research questions were addressed in this study:

Is the practice of precision medical education in the current blended learning model feasible?

What features are associated with the students' class style preferences after online video learning?

Methods

Research type, study setting, and participants

This study was a cross-sectional survey and a mixed methods research design was used. The subject, acute liver failure, constitutes a section of a core compulsory surgery course for fifth-year medical students. [Figure 1\(A\)](#) illustrates the study setting. At the beginning of the surgery course, students were instructed to watch the online video that explained the core concepts before the in-person class. Subsequently, they were free to respond to an online questionnaire ([Supplementary Table S1](#)) comprising the following four parts: change of the understanding of concepts rated on a 5-point Likert scale (with the ratings "totally changed", "largely changed", "changed and unchanged in equal measure", "mostly unchanged", and "totally unchanged"); concepts requiring more clarification in in-person class; class style (teaching method) expectation for the upcoming in-person class; and comments or questions. The survey listed the four class styles: complete and thorough introduction (briefly referred to as through); concept orientation to raise study interest (concept); discussions between the

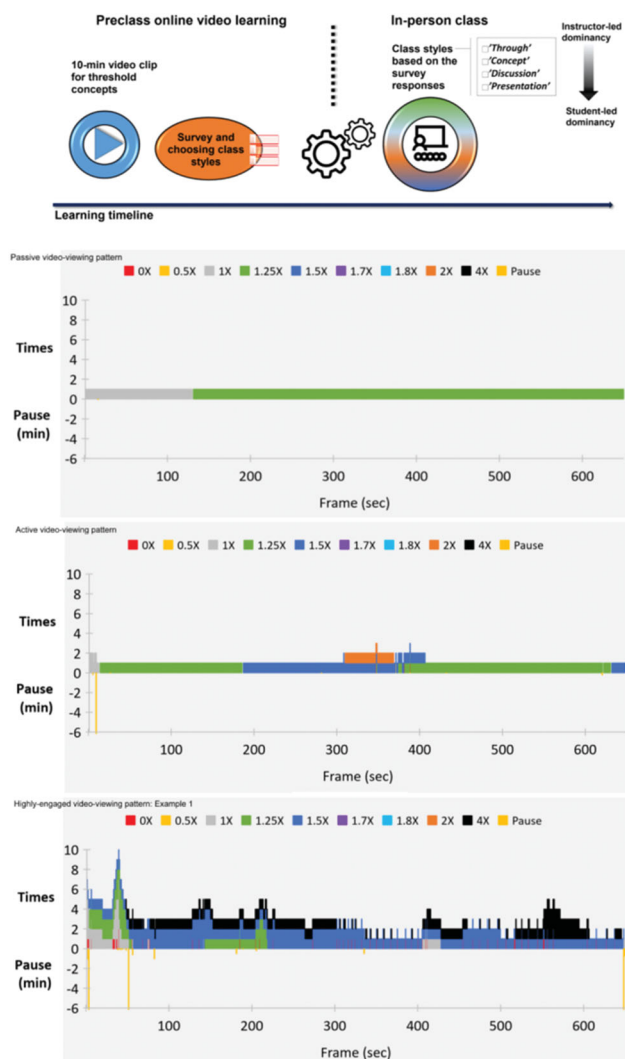


Figure 1. Pre-class online video learning module and study setting. (A) Pre-class video-assisted learning, and processes of student participation for class style determination. (B) Examples of pattern classification of engagement in video watching (X: play rate). (i) Passive. (ii) Active. (iii) High engagement (1); High engagement (2).

teacher and students creating a learning experience (discussion); and self-learning and class presentations (presentation; Figure 1(A), Supplementary Table S1). The class styles chosen by students were the outcome measurement in this study. The teacher developed the in-person class style for each round of students based on the survey responses, aiming towards precision medical education.

Participation in the survey was not mandatory, and administrative teaching assistants helped collect anonymous data for each round of students. The course comprised a 1-h class with 22–24 medical students as a group in each round. Almost all students were between 23 and 24 years of age, with few post-baccalaureate students in every school year. Between

September 2019 and May 2020, 130 fifth-year medical students took the compulsory core course on surgery and they were invited to participate in the survey. The Institutional Review Board of the National Taiwan University Hospital approved this study as an exempt protocol (201809078W and 202006048W). Participation in the survey was considered as implied consent from the participants.

Conceptual framework

The theoretical framework of this study is based on John Sweller's Cognitive Load Theory [16,17] and Richard Mayer's Multimedia Learning [18,19]. Briefly, in Sweller's theory, cognitive load relates to the amount of information that working memory can hold at one time [16,17]. Since working memory has a limited capacity, instructional methods should avoid overloading it with additional activities that do not directly contribute to learning [16,17]. Mayer's theory of multimedia learning assumes that the human mind is a dual-channel, limited-capacity, active-processing system and that presenters must construct multimedia messages (visual images, audio, and text) to manage all three types of cognitive load: extraneous load (reduce needless animations or irrelevant information for distraction), essential load (chunking learning materials and identify technical term in advance), and generative load (organize and make sense of the essential learning materials) accordingly for effective teaching and learning in higher education [18,19].

The cognitive load of class content is divided into two stages: pre-class online video learning and in-person class. Efficient pre-class online video learning can reduce the cognitive load and pressure in subsequent classes. Therefore, the 10-minute online video for pre-class learning was developed to minimize the extraneous load by removing non-essential content, breaking content into smaller segments, and allowing learners to control the pace [19]. Only keywords, pictures, and human narration were included in the video, without unnecessary animation. Further, tailored teaching by adjusting class styles maximizes students' learning while increasing the teacher's teaching preparation load substantially in each round.

Course design, instructional design principles, and quality standards

Clinical teaching on the subject of "acute liver failure" is a section of a core compulsory course (including 23 sections) for surgery students in their first clinical

(fifth) year. Each course section comprises a 1-h class enrolled by 22–24 medical students in each round. Six rounds of teaching are conducted in one academic year at the National Taiwan University Hospital. The curriculum development committee assigned HCM to develop the subject of acute liver failure, one among the entire core course of surgery. The goals of the core course of surgery were to efficiently help medical students understand the surgical science field and inspire their interest in this field. The learning objectives of this blended class complied with the entire core surgery course. The instructional design principles were applied by using the ADDIE model (Analyze, Design, Develop, Implement and Evaluate) [20]. Specific consideration in redesigning the classic course into a blended one was how to divide the learning materials with great provocative effect and to integrate them at the end of the learning journey. Instructional methods for an online video design were based on the coherence principle (excluding extraneous material) and segmenting principle (message is presented in user-paced segments rather than as a continuous unit) of multimedia learning [18,19]. At least twice a year, a quality course revision was made by evaluating the universally accepted quality standards: student engagement, meaningful learning (as indicated by good retention and transfer performance), and goal achievement [21].

Students participated in a questionnaire survey at the end of the course, conducted by the curriculum development committee for quality audit and course improvement. The questionnaire captured their learning experiences and satisfaction. Additionally, clinical teachers were delegated to employ online video teaching in the course design. Subsequently, teachers needed to provide online or face-to-face “office hours” for student-teacher interaction to ensure online video learning quality.

HCM summarized six TCs of “acute liver failure” according to the educational goals of the curriculum development committee and incorporated them into the course section design and practice [15]. An extra concept elucidating why liver transplantation may not always be the ultimate treatment for acute liver failure was added to the original group [15]. Because not all concepts were systematically analyzed to meet all criteria for TCs, the term “core concepts” were used in this study. Therefore, a total of seven core concepts (Cs) were introduced as a 10-minute online video for pre-class learning (Supplementary Table S2). The video was docked on the NTUCOOL

[20] website on the intranet of the National Taiwan University but could be accessed worldwide after registration. Additional learning materials, screened and posted on the webpage by the teacher (HCM) [22], were readily available for students who had watched the online video.

Patterns of online video-viewing behaviours as a study tool

The action logs of video-viewing were transformed into visualization plots, containing the information on watching speed, rewinding, repetition, and pausing, representing online video-viewing behaviours, including completeness, active or passive viewing, and high engagement (Figure 1(B)). Completeness was defined as at least 95% of the video being watched. Passive viewing was defined as no interruptions while the video was being watched. Active viewing was identified through multiple behaviours considered separately or combined, other than simple browsing, including re-watching, changing playback speed [5], and pausing (for >5% of the time frame) (Figure 1(Bii)). High-engagement viewing was a summation of ultra-high active viewing patterns (more than >20% of the time frame) in the video-viewing activity plot (Figure 1(Biii)).

Data collection

For each round of students, administrative teaching assistants helped collect anonymous survey data before the class. Examples of how to practice precision medical education are provided in the result section.

Action logs of the online video-viewing were anonymously collected at the end of the school year by administrative teaching assistants. WJY developed the plot for the video-viewing behaviour for each participant, and HCM and WJY performed the pattern coding independent of each other and subsequently consented.

Qualitative data analysis

Free comments were content-coded through a descriptive approach using thematic analysis [15,23,24], by HCM and WJY independent of each other and subsequently consented. Codes corresponding to learning experiences were previously developed by a team comprising a surgeon specialist (HCM), an experienced medical education specialist (YCC), and

an administrative researcher (WJY). Regular meetings were held to discuss and resolve all coding discrepancies and to combine codes. According to the survey responses in each round of students, the teacher in charge (HCM) answered the questions posed by students, validated the codes that reflected their opinions by anonymous discussions in class, and adjusted the class style.

At the end of the school year, identified themes were combined and compared to generate a final set representing the range of students' feedback on the online video learning process. Each student's comment may include several codes which were analyzed individually and were subsequently grouped by a person to "purely superficial or mechanical" if no "substantial" content was ever noted.

Quantitative data analysis

Quantitative data were expressed in percentages where appropriate. Non-parametric tests were employed to compare group differences. A chi-squared test was used to compare independent categorical variables among categorical outcome variables. The Mann-Whitney *U* and the Kruskal-Wallis tests were employed to compare the difference in continuous variables among quantitative outcome variables for two and three groups, respectively. Kendall's tau coefficient was used to measure the ordinal association between two measured quantities. A two-sided $p < .05$ was considered statistically significant. Statistical analyses were performed using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA).

Results

Characteristics of the participants and class style preferences

A total of 114 fifth-year medical students (88%) opted for pre-class video learning. Among them, 113 (99%) responded to the questionnaire (Figure 2) and were enrolled in the study. Among the enrolled 113 participants (87 males), 48 favoured a through class style, 50 preferred the concept style, 15 preferred the discussion style, and none chose presentation. Table 1 and Figure 3(A) present the characteristics of the participants and their responses. The difference between the three groups—through, discussion, and concept—was not statistically significant in terms of gender, semester (first or second), class, video-viewing patterns, change in the understanding of individual concepts

(Figure 3(A)), request for concept explanation, and the presence or absence of comments.

Examples of practice of precision medical education

According to the survey responses in each round of students, HCM answered the online questions posed by students either on the webpage or in in-person classes. The duration of each class style of the 1-h in-person class was based on the voting summary. For

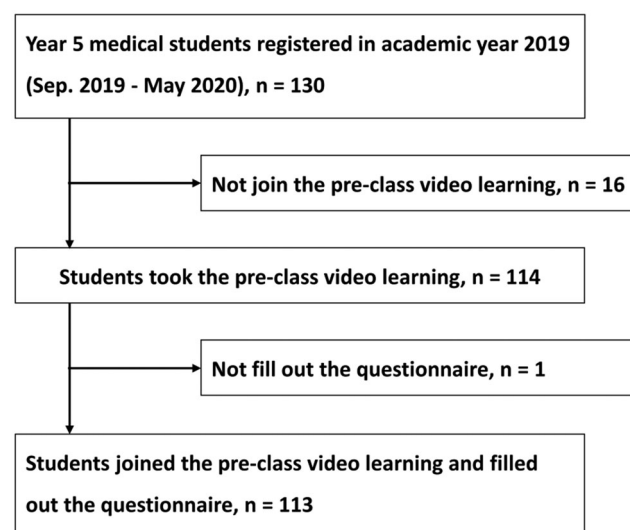


Figure 2. Student participants.

Table 1. Characteristics of participants and their responses after pre-class online video learning, stratified by class style (teaching method) preference for the upcoming in-person class.

Total n (113)	Through n = 48	Concept n = 50	Discussion n = 15	p
Gender				.585
Female (%)	10 (21)	11 (22)	5 (33)	
Male (%)	38 (79)	39 (78)	10 (67)	
Second semester (%)	19 (40)	23 (46)	9 (60)	.386
Class (%)				.411
1	13 (27)	8 (16)	2 (13)	
2	6 (13)	8 (16)	2 (13)	
3	10 (20.8)	11 (22.0)	2 (13.3)	
4	5 (10)	8 (16)	7 (47)	
5	5 (10)	6 (12)	1 (7)	
6	9 (19)	9 (18)	1 (7)	
Video-viewing pattern				
Complete (%)	42 (88)	43 (86)	14 (93)	.925
Active (%)	31 (65)	31 (62)	8 (53)	.745
High-engagement (%)	18 (38)	20 (40)	4 (27)	.691
Concept requested for more explanation (%)				
1	5 (10)	4 (8)	2 (13)	.679
2	12 (25)	14 (28)	6 (40)	.525
3	14 (29)	12 (24)	4 (27)	.876
4	17 (35)	11 (22)	4 (27)	.340
5	12 (25)	12 (24)	5 (33)	.761
6	14 (29)	12 (24)	5 (33)	.675
7	17 (35)	16 (32)	5 (33)	.961
With comments (%)	37 (77)	39 (78)	11 (73)	.907

example, class style preferences in Group 1 (23 students) were 13 (56%) for “through”, 8 (35%) for “concept”, and 2 (9%) for “discussion”, and the time spent on each style was tailored in an approximate percentage, that is, 34, 21, and 5 min, respectively. The teacher referred to the Q2 survey summary (Supplementary Table S1) to tune class contents in each round. However, the teacher maintained resilience of time/content management to integrate the 1-h class to avoid fragmentation. Although not a 1-to-1 class, the teacher allowed a following in-depth online discussion if any student was interested.

Changes of conceptual understanding after pre-class online video learning

Changes (totally and largely changed) in conceptual understanding after pre-class online video learning were noted in 12 (10.6%, C1), 50 (44.2%, C2), 40 (35.4%, C3), 42 (37.2%, C4), 7 (6.3%, C5), 31 (27.4%, C6), and 13 (11.5%, C7) students for the respective core concepts. The correlation between changes in conceptual understanding about individual core concepts after pre-class online video learning and request for further explanation of related concepts was significant for C2 (coefficient = 0.212; $p = .013$), indicating that higher the change in conceptual understanding (difficult-to-comprehend concepts), the more were the requests for further explanation. This correlation was borderline significant for C6 ($p = .090$) and C7 ($p = .085$) and insignificant for other concepts (Supplementary Table S3).

Online video-viewing patterns and their association with class style preferences, learner characteristics, and learners' self-reported gains

Table 2 presents online video-viewing patterns and their association with class style preferences, learner characteristics, and learners' self-reported gains in the seven learning concepts. A total of 42 participants demonstrated a high-engagement video-viewing pattern that warranted further investigation (Table 2). The difference between the high-engagement group and other groups of students was not statistically significant in terms of gender, semester, class, completion of video-viewing, individual concept change (Concept 1, 4, 5, 6, and 7) in understanding (Figure 3(B)), and request for further clarification in most concepts (Concept 1, 4, 5, 6, and 7). Compared with others, these 42 students were more likely to undergo conceptual change after online video learning for C2

(Mann–Whitney U test, $p = .005$) and C3 ($p = .003$; Figure 3(B)) and subsequently requested further clarification for the same concepts ($p = .001$ for C2 and $p = .015$ for C3; Table 2). Moreover, more free comments were observed in the high-engagement group than among other students (88% vs. 70%, $p = .038$). Both groups showed a similar pattern of half-and-half preference for “through” and “concept” style in the majority and “discussion” style in minority. They did not demonstrate any class style preference.

Students' feedback of online video learning experiences

Among the enrolled 113 participants, 87 (77%) students provided comments and demonstrated a negligible difference in distribution among the three-class style preferences. Comments from 53 (61%) students were coded as substantial, and those of 34 (39%) students were considered purely superficial, mechanical (technical), or others (Table 3). A majority (34/53, 64%) of the substantial comments initiated thought-provoking questions concerning analysis, synthesis, and arguments after the online video learning. Others expressed specific interests in further learning, reflected on the learning process, and expected real-world case practice. Table 3 presents a summary of some examples. Although students who provided substantial comments preferred class styles of concept or discussion, others preferred the through style. Notably, the distribution did not differ statistically.

Discussion

This study demonstrated four major findings. First, students who preferred the interactive discussion style constituted the minority, and the majority comprised an equal number of students who preferred the through and concept styles. No significant features of online video learning were associated with students' preferences. The high-engagement viewing pattern was associated with certain difficult-to-comprehend concepts and providing of comments but not with class style preference. Interpretation of the substantial comments suggested that students learned and increased their interest in core concepts through the online video learning process. Figure 4 shows a summary of the integrated framework of background theory, instructional design principles, and strategies in the practice of precision medical education courses.

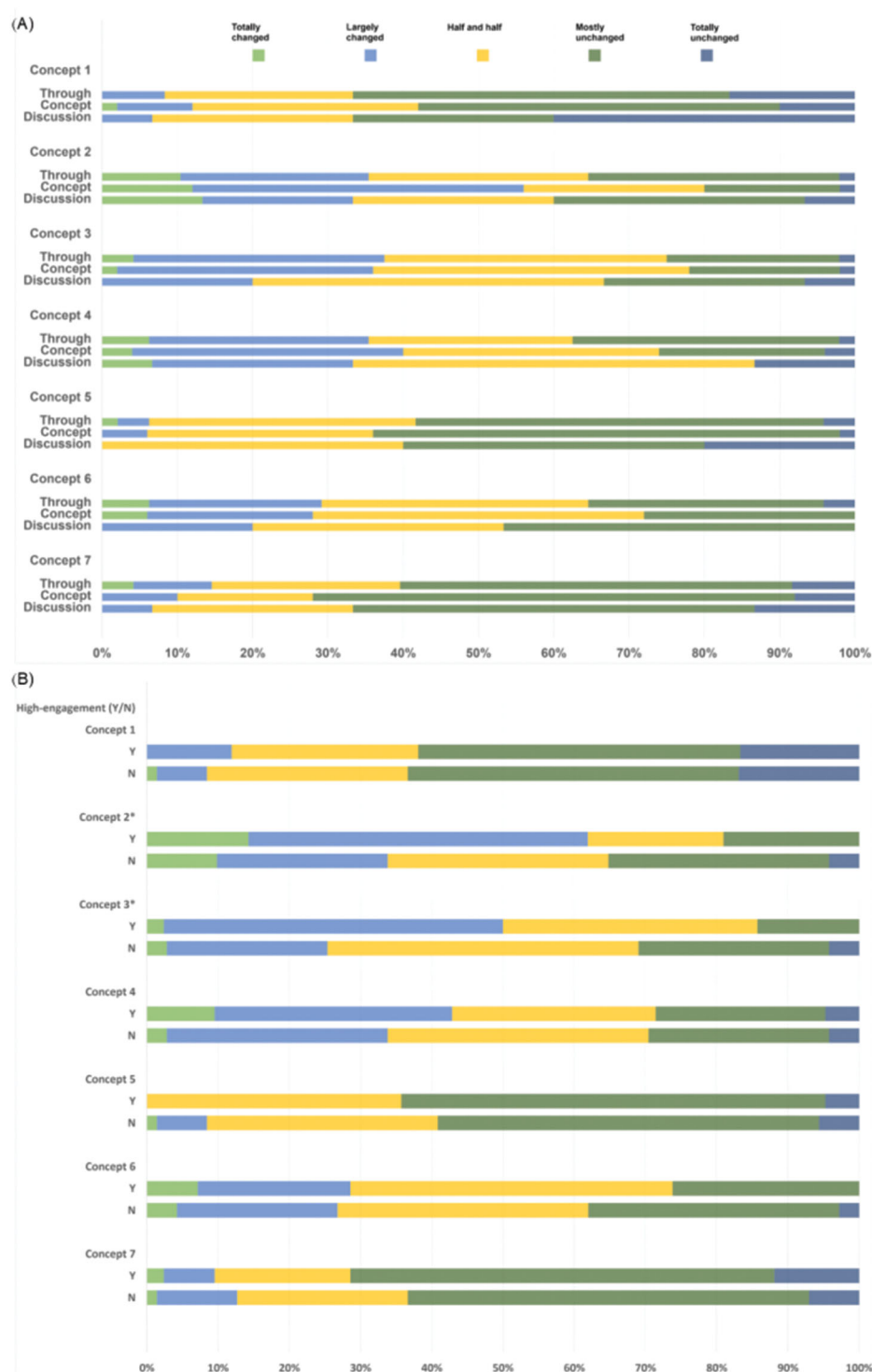


Figure 3. Conceptual change after pre-class online video learning. (A). Triaged by students' preference of teaching method (through vs. concept vs. discussion). (B) Triaged by the high-engagement pattern in video watching (* $p < .05$, Mann-Whitney U test).

Application of online video learning behaviour for education improvement

Our field study applied online video learning in a pre-class setting, bridging the in-person class with tailored classes style dynamically as part of precision medical

education. Estacio et al. [25] visualized university students' online video learning behaviour in blended courses by creating graphics based on action logs, and the visualizations did not seem to correlate with the students' course accomplishments. They suggested

Table 2. Characteristics of students and their responses are classified by the high-engagement video-viewing pattern.

Highly engaged	Yes <i>n</i> = 42	No <i>n</i> = 71	<i>p</i>
Male gender (%)	31 (74)	56 (79)	.645
Second semester (%)	19 (45)	32 (45)	1.000
Class (%)			.601
1	10 (24)	13 (18)	
2	5 (12)	11 (16)	
3	8 (19)	15 (21)	
4	8 (19)	12 (17)	
5	2 (5)	10 (14)	
6	9 (21)	10 (14)	
Video-viewing pattern			
Complete (%)	39 (93)	60 (85)	.246
Active (%)	42 (100)	28 (39)	<.001
Concept requested for more explanation (%)			
1	4 (10)	7 (10)	1.000
2	20 (48)	12 (17)	.001
3	17 (41)	13 (18)	.015
4	16 (38)	16 (23)	.087
5	8 (19)	21 (30)	.268
6	13 (31)	18 (25)	.522
7	11 (26)	27 (38)	.222
With comments (%)	37 (88)	50 (70)	.038
Class direction (%)			.691
Through	18 (43)	30 (42)	
Concept	20 (48)	30 (42)	
Discussion	4 (10)	11 (16)	

that the patterns of visualizations can help course administrators determine the type of strategic interventions needed for courses for future learners [25]. Dodson group investigated the underlying meaning of observed activities (engagement goals and intents) during video-based learning with ViDeX and correlated them with learning contexts (course week or exam) [8]. Different patterns for online and blended courses were observed. Students in the online course showed higher strategic and adaptive use of video, and course week and exam were associated with students' engagement with videos [8]. As the course week progressed, an increase in the playback speed or skimming forward was observed among the blended learning students who want to save time because the content is familiar to them [8]. These reflected learning adaptations of students, probably attributed to the availability of their offline education resources. Our study model reflected an effective and successful online video learning module evolving with time. An increasing number of incoming medical students are digital natives (coined by Marc Prensky in 2001 [26,27]) who are technologically savvy. They have clear expectations and expect frequent and individualized feedback on their performance [28], evolving teaching strategies that include shorter, more interactive instructions, and are divided into more easily digestible segments [29]. The video-viewing patterns in our

study, presenting an intuitive visual representation of learning, clearly illustrated the students' processes involved in online video learning, aiding educators to remodel their online and offline learning content and modify video production for future students.

Class style preferences

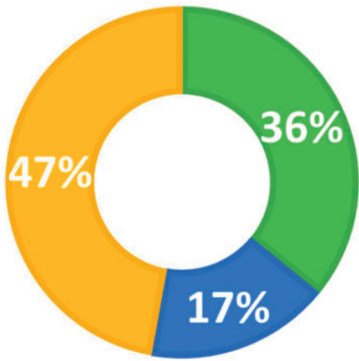
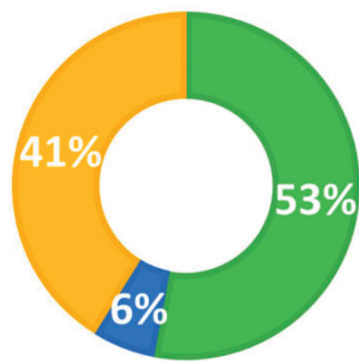
No significant features of online video learning were associated with students' class style preferences. Pre-class learning is often designed to help students develop curiosity and interest before they learn new material. This helps instructors better engage students in lessons, using the pre-class content as a trigger or stimulus to initiate conversations and critical thinking before lessons begin. Students might then be more willing to participate in other kinds of lesson styles, leading to a different finding, such as our results.

The unexpected finding in our study was that no students expressed class style preference for self-learning and class presentation. In addition to the explanations mentioned before, this phenomenon might be attributed to Asian culture, a tendency of exhibiting collectivism rather than individualism [30]. Another possibility is that, like problem-based learning, learning through problem-solving can only be applied when students have already equipped themselves with profound domain knowledge but not at the early stages of knowledge acquisition [31]. Therefore, students might prefer the "safe mode" of class style.

Cognitive load, multimedia learning, and course design: a reflection

We applied the theoretical framework of Sweller's cognitive load theory and Meyer's multimedia learning for designing the course aiming for meaningful learning [16–19]. Instructional methods for our online video design were based on the coherence principle and segmenting principle [18,19]. To reduce the cognitive load on an online video learning platform, it may take the risk for learning content fragmentation after the reduction of the overall cognitive load of a course. According to Meyer's theory, a good multimedia learning design is not simply an information delivery system, but rather a cognitive aid for knowledge construction [18]. However, the gap between knowledge pieces and an integrated knowledge system could exist unless the learning content is totally the same between the online video learning and the in-person class. Therefore, instructional designers must create a learning environment for integration (either

Table 3. Thematic analysis of comments in students' feedback.

		Class style preference		
		Through	Discussion	Concept
Coding	Examples			
Substantive (n = 53)				
Thought-provoking questions	Through immunology perspective, can inhibiting inflammation reduce whole body damages? Is there any guide as to how to maintain a balance of fluid and electrolytes during patient management for acute liver failure?			
Analysis	Does INR, as a prognostic marker for acute liver failure, work well in patients who take medications that interfere with INR results?			
Synthesis	I summarized what I learned as ... , so how can I suspect and manage patients with acute liver failure in the early stage?			
Arguments	Given phosphate is released during extensive cell destruction, why phosphate is deficient during the liver regeneration phase of acute liver failure?			
Arouse study interest (Motivation)	Would like to learn more about fluid management. Interested in how to prescribe empirical anti-microbial agents. Want to learn more about the hepatorenal syndrome. Would like to learn more about the role of steroid in systemic inflammation of acute liver failure. I had managed a patient with acute liver failure in a general ward and faced a management dilemma between hepatic encephalopathy, diet protein restriction, and sarcopenia. I would like to learn more about nutritional support in patients with hepatic encephalopathy.*			
Reflection on the learning process	I can clearly catch the learning points through the key-point summaries. I can catch some concepts but I still cannot get the whole picture after watching the video. I enjoyed the learning by exploring the study topic through analyzing key concepts. Although this topic had been taught before, the video content is totally different and inspired me a lot!			
Expect clinical case scenario	Look forward to real-world case practice.			
Purely superficial and mechanical (n = 34)				
Overall, general gratitude	Thanks for your consideration about the course, so much so that I look forward to an in-person class!			
Video design	I hope the teacher can talk at a steadier speed. Very clear verbal expression and good framework!			
Course design	Enjoyed the online course; the diversity of this class facilitates more student-teacher discussion.			
Others	What kinds of specialists are involved in the liver transplant team? How to do liver transplant surgery?			

*Also coded as reflection and thought-provoking questions.

online or in-person class). Students may take this opportunity for a topic review. Besides, in this study, we did not measure the cognitive load, which had been proposed in either direct or indirect methods [32]. Although we applied the theory to reduce cognitive load, whether the load was really reduced and perceived by medical students needs further exploration. Online video learning patterns provide another approach that may indirectly reflect the cognitive load, but this approach may not directly link to the meaningful learning outcome. To improve this framework of precision medical education (Figure 4), further

studies are needed to address the issue of cognitive load measurement and correlate it with the learning outcomes to achieve the ultimate goal of meaningful learning.

Precision medical education into practice

One characteristic of our study was that the teacher adjusted the in-person class style on a time proportion basis as per students' votes. This real-time dynamic teaching is challenging for teachers but can effectively address students' specific needs in precision medical

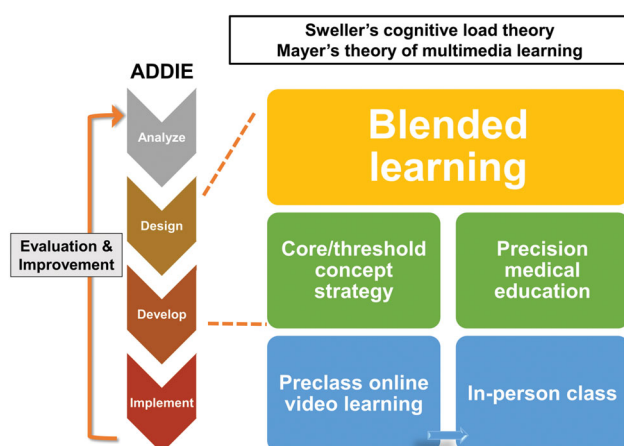


Figure 4. An integrated framework of background theory, instructional design principles, and strategies in the practice of precision medical education.

education [33,34]. This approach to teaching, adopted originally for late learners in special education [35], can be beneficial in teaching clinical medicine because this field has diverse specialty characteristics and poses various learning threshold barriers for undergraduates. According to survey reports in our class, in the context of “precision”, it would make more sense to divide the groups into three, and having a small group that could take a discussion approach, and two larger groups that could take the “thorough” and concept-based approach, so each learner gets an approach that meets their expectations and needs. However, the time budget pressure in each course under the trend of reducing classroom hours in clinical medical education restricts the formal development of such a framework design. Therefore, we employed the current model in practice. As an informal sector of medical education service, the teacher allowed a following in-depth online or face-to-face discussion if any student was interested. The 1-to-1 mentoring method is good and consistent with precision medical education, but medical students may need to follow many medical experts in diverse fields to become clinical doctors of broad-enough medical scopes. As such, taking away student’s time may not be worthwhile. Online video learning of a subject’s core concepts, implemented by an example module in our field study, can level students, shorten the intragroup gap in understanding, and facilitate precision teaching in in-person classes (or during office hours).

Limitations and further work

- We recruited medical students from a top medical school who were good learners, with the majority

being males. Cultural differences between Asian and western students’ learning behaviours were not explored. Hence, the results may not apply to medical students elsewhere, and further external validation is needed.

- Learning patterns of medical students in one academic year may not represent that of students in other years. Additionally, we did not correlate the online video learning features to students’ long-term performance and competency.
- It is important not to label students as active or passive viewers based on the frequency of their behaviours alone [5]. Besides, reading by itself can be considered an active process, and we cannot understand that this “reading” occurs while the videos are playing. This prevents us from exploring online video-viewing features and learning behaviours in a class of these “proactive” medical students. Moreover, the current study measured student learning behaviours based on viewing patterns, not meant to label a universal stereotype behaviour. We tried to explore their association with class style preferences, intending to improve and optimize teaching in the future.
- Although the engagement behaviour of online video-viewing for learning was not associated with in-person class style preference, the current results did provide insights on further studies of engagement behaviour modification and interaction between online learning and face-to-face class. Further refinement of defining active viewing patterns includes requiring students to do some work or action to take part in parts of the media object, such as requesting them to pause the video at some point to answer an online questionnaire before continuing. Incorporating gamification tips [36] into online video learning may motivate students to keep learning and remain engaged.
- A strength of open educational resources is the ability to be reused by teachers other than those who create them. Further, the online video content can be co-edited by teachers with similar education philosophies worldwide, thus improving the quality of medical education.

Conclusion

Increasing cognitive load in clinical science poses threats in applying precision medical education within a time budget. We presented a solution by providing a working example for precision medical education in blended teaching. Although the association between

students' preferred class styles and online video-viewing patterns was not clearly seen, these valuable medical education data are the backbone of implementing data-driven precision medical education in the future.

Insights of how medical students are interacting with online video learning could then be used as guidelines for clinical teachers to make adjustments to their teaching. The visualization graphics of online video-viewing patterns, intuitive in nature, may apply to other medical science education fields. This could be transferable to understand phenomena in other settings, such as pure online learning courses without any in-person contact. The collection of these data across curriculum and disciplines represents another format of the learning portfolio. Further big data analysis would shed light on more areas of precision medical education, such as optimizing and individualizing the training and career development.

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Ethical approval

Approval for the collection and publication of student data was obtained from the Institutional Review Board of National Taiwan University Hospital, Taipei, Taiwan. Consent was not obtained from the students because the study was observational, meaning that the students could not be identified from the study data. Therefore, the need for consent was waived by the IRB.

Author contributions

CMH drafted the manuscript and CCY, RHH, and PHL designed the study. CMH, JYW, and CCY conducted data processing, and CMH and JYW performed data analysis. JYW and RHH were the directors responsible for general organization and instruction. All authors read and approved the final version of the manuscript.

Disclosure statement

The authors declare that they have no competing interests.

Data availability statement

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

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