The best flip: student-focused designs for online flipped classrooms

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1 Introduction

Higher education research has established that engaging students through active learning strategies leads to a deeper understanding of the course content and better overall student performance than traditional lectures (Prince, 2004). In particular, flipped or inverted classrooms turn the structure of traditional lecture-based classrooms that are followed by individual homework practice, on its head (Lundin et al., 2018). Instead of being passive receptors of knowledge that is imparted by the lecturer, students engage in active learning tasks, *in* the classroom. On the other hand, with the proliferation of Information and communication technologies (ICT), instructors have adopted various online educational technologies into their classrooms, many of which facilitate active learning strategies within the classroom.

The devastating COVID-19 pandemic has impacted instructors and students' lives, whether in terms of their physical or mental health. The pandemic precipitated a mass exodus of teaching and learning from in-person to online formats. However, people who care for family members or children, experience difficulties in simultaneously working from their homes. As people rely extensively on video-conferencing tools for their personal and professional communication, including academics, they experience fatigue and depletion of motivation, known as "Zoom fatigue" (Bailenson, 2021). Many students have relocated and may be living in areas with poor internet connectivity, which may impact the quality of instruction that they receive and their overall classroom experience. Moreover, online education platforms may not be interoperable with students' personal devices, and they may struggle with operating the platforms. Simply requiring students to attend online lectures may not ensure fair and equitable access to all (Scott, 2020, Section 5).

Providing active learning techniques in the online classroom thus becomes very pertinent in these times. Indeed, some instructors have seized the opportunity presented by online teaching in the pandemic, to "flip" their classrooms creatively. Though ensuring fair access to all students limits face-to-face time to less number of hours per week than usual, this in-class time can be spent effectively in a flipped format. Active learning tasks in pairs or groups can be facilitated using features of existing video-conferencing applications, and the instructor can focus on clarifying misconceptions etc., to ultimately foster deep learning.

However, designing flipped classrooms is known to be time-consuming for instructors, and requires many instructional support resources. Even if the instructor plans an effective flipped classroom design, as mentioned earlier, students may struggle with the online platforms used. They may also fail to manage their time well, especially when they are undertaking a high course load. Importantly, as active learning tasks often engage students with their peers, students may perceive that instructors are not putting in effort in "teaching" the course content. When novel teaching strategies, such as active learning, are used, students' perception of their performance may differ from the reality. From an instructors' perspective, therefore, it is important to identify which aspects of a flipped classroom *satisfy* students more and in particular, which active learning strategies and assessments improve *overall performance* as well as perceived performance. Establishing a set of design principles, based on the evidence of students' satisfaction and performance, will help instructors prioritize their course design to provide these crucial elements as well as to organize external supports for help.

We delve into high-level systematization of literature on the topic in Section 2, and then proceed to describe evidence for the impact of flipped classrooms on students' satisfaction and performance in Section 3. We also glean crucial design elements, such as assessments and activities, to which the success of flipped classrooms can be attributed. In Section 4, we examine an instructional design model that has been used in related literature as a basis for design principles for flipped classrooms. We compile key design principles, synthesized from this literature, into a diagram in Section 5, with an accompanying summary. We also apply these principles to our own teaching experience in that section and conclude in Section 6.

2 A bird's eye view of flipped classrooms

Lundin et al. (2018) conduct a qualitative and quantitative review of flipped classroom literature from 2010–mid 2016, beginning with over 500 ($n = 530$) most-cited publications. They characterize each publication by publication criteria, such as its year of publication, its subject area or discipline, its keywords and country of affiliation of its first author. They found that the rate of flipped classroom publications per year began increasing exponentially from 2011 onwards, indicating heightened interest in the topic. Unsurprisingly, more than half of the first authors were affiliated with the United States, followed by Australia and China. As most publications are by authors affiliated with English-speaking countries, instructors from the Global South may have few other experiences to draw upon. They observe that a majority[1] of these publications are in STEM disciplines. When co-occurring citations were graphed by the venue of publication, two strong clusters of venues were found, namely subject-specific higher education domain venues and educational technology domain venues. The authors report that the likelihood of co-occurring citations across these

[1] The sum of publications across subject areas add up to 764, which is significantly more than the total number of publications consulted (530). It is unclear whether the authors categorize each publication into multiple subject areas (and a similar inconsistency exists for multiple countries of affiliation for the first author).

two clusters is generally low, with the exception of a few of these venues being heavily cited across clusters as well as within their own cluster. Therefore, their analysis demonstrates that the most cited articles on flipped classrooms are confined to a particular subject, and are cited infrequently across subjects.

Lundin et al. filter the rest of these papers for a qualitative analysis of their content, as follows. They eliminate a large majority of them as they have not been cited enough (less than 15 times) and then, they manually eliminate any publications out of the remaining ones ($n = 37$) that are not relevant to flipped classroom research ($n = 6$) through a peer-review process, resulting in $n = 31$ publications for their qualitative research. An underlying common goal of flipped classrooms that emerged was that "flipped teaching alters traditional instruction so that deeper levels of learning can take place in class rather than rely on homework" (Lundin et al., 2018, p. 12). Flipped classrooms were generally thought to engage students in deep learning through collaborative activities in class, instead of leaving them to finish homework tasks individually. Instructors could, therefore, "optimize" in-class time to seize opportunities to work through students' difficulties with the course content. With this basic understanding in mind, we can now explore design elements of a flipped classroom.

What are common design elements for flipped classrooms? We glean common elements of a flipped class structure, including in-class and out-of-class learning and assessments, that can be used to achieve the aforementioned goal, from the qualitative analyses by Lundin et al. (2018, pp. 11–13, Table 4). We also discuss the frequency distribution of common design elements presented by van Alten et al. (2019, Fig. 2) in their quantitative meta-analyses of $n = 114$ papers, which we describe in detail later.

First, students are expected to learn the conceptual basics, or pre-requisites for in-class activities before the class. The role of technology, and in particular video lectures as they can be re-watched, was emphasized in acquainting students with course material outside the classroom. van Alten et al. (2019) determined that almost all (95%) of the $n = 114$ flipped classroom studies in their meta-analysis involved students in watching lecture videos before the flipped classrooms, in contrast with less than 10% for the traditional classroom. The time duration spent by students in pre-class preparation may vary. Out of the studies reviewed by Lundin et al. (2018), Mason et al. (2013) reported generating a total of 675 minutes of pre-class videos over 10 weeks, averaging to over an hour per week, whereas Critz and Knight (2013) reported that their weekly modules included 20–40 min of presentation slides' videos, textbook materials and 4–5 journal articles; students were expected to spend a min of 10 hours on it.

Second, Lundin et al. (2018) characterize in-class activities as collaborative group activities, wherein students work on cases or solve problems together. Flipped classrooms were approximately three times as likely (over 80%) than traditional classrooms to incorporate group activities and almost twice as likely (over 60%) to incorporate individual activities (van Alten et al., 2019). These tasks enable students to apply or practice the concepts learned earlier and should thus be aligned with the out-of-class self-learned content (Kim et al., 2014; Pierce & Fox, 2012; Strayer, 2012). While conducting these activities, the instructors would engage with students and ultimately identify common problems and knowledge gaps (Mason et al., 2013). The instructor addresses these common problems, which are identified through these activities as well as the students' responses to pre-class assessment, through short in-class lectures that are interleaved with these activities. Indeed, van Alten et al. (2019) determined that about half of their analyzed studies ($n = 114$) included in-class lectures for the flipped classroom.

Fully *online* flipped classrooms only differ from traditionally flipped classrooms in that the in-class activities and lectures are conducted online, over video conferencing platforms. Moving from face-to-face interactions to online platforms requires students and instructors to adapt to traditional body language cues; we discuss the implications of this in Section 4.

Third, regular formative or summative assessments were often included in flipped classroom designs. Online quizzes were common in STEM flipped classrooms for various reasons, whether in order to use the same assessments as the control (traditional) classroom for a fair evaluation (Mason et al., 2013), or as an out-of-class assessment for the aforementioned self-learned course content (Critz & Knight, 2013), or as an in-class assessment to spurn off discussion in the flipped classroom (Tune et al., 2013). van Alten et al. (2019) also observed that flipped classroom designs in their studies were approximately twice as likely to include pre-class and in-class quizzes when compared to traditional classroom designs.

Students reported that these assessments motivated them to engage with the course content before the class (Tune et al., 2013). Interestingly, Mason et al. (2013) observed that despite having the same assessments as their peers in the traditional classroom, students in the flipped classroom agreed more with a statement on whether the assessments appropriately evaluated the learned skills. They attributed this result to an increase in the flipped classroom students' confidence when they were taking these assessments, as they may have been better prepared than their peers. Instructors may require out-of-class assessments to be completed sufficiently in advance of the flipped class, so that they can process students' responses and identify which concepts need further elaboration or clarification in the flipped class. Apart from aligning these regular assessments with the learning outcomes, the instructor may also scaffold them such that students need to process course content or participate actively in class (Pierce & Fox, 2012). In summary, flipped classrooms designs commonly include the following three elements: pre-class preparation through lecture videos, formative or summative assessment of the learned content such as pre-class or in-class quizzes, and in-class individual or group activities, which may be interleaved with short in-class lectures.

Most of the studies examined by Lundin et al. (2018) were reported to have a small sample set of 20–40 student responses on course evaluation questionnaires or their overall test performance results. Due to a lack of complete descriptions of the flipped classroom design, such as the pedagogy, Lundin et al. (2018) expect that these small sample study results are not reliable and may be difficult to reproduce. Thus, we need to further explore moderating factors that affect students' performance in and satisfaction with flipped classrooms, such as the instructor, flipped classroom design elements such as the choice of in-class activities and assessments and so on, across multiple studies.

3 Student satisfaction and performance studies

van Alten et al. (2019) conducted a meta-analyses of studies that reported students' performance in end-of-class assessments ("assessed learning outcomes") as well as their perceived performance ("perceived learning outcomes") and satisfaction with the course, given by their evaluations in course questionnaires. Strelan et al. (2020) conducted a similar meta-analyses, focusing only on student satisfaction with the classroom and the instructor. While both studies started with over a thousand literature search results, they eliminated a majority of these records due to irrelevance, as well as lacking descriptions of the flipped or traditional classroom designs or inappropriate statistics, echoing the findings presented by Lundin et al. (2018). Ultimately, van Alten et al. (2019) evaluated a total of $n = 114$ studies from 2006 to 2016, whereas Strelan et al. (2020) analyzed a total of $n = 53$ studies from 2013 to 2018, effectively drawing upon 8429 students' satisfaction levels. As we discuss below, both studies further delve into design characteristics of the flipped classroom, and evaluate how these factors moderate the observed variables. (Stöhr et al. (2020) present student performance results for a single course in traditional and online formats. In the absence of large-scale studies on fully flipped classroom design elements, student satisfaction and performance, we rely on these studies that include traditionally flipped classrooms.)

Do flipped classrooms improve students' performance in the course? What design elements help or hinder their performance? van Alten et al. (2019) found that flipped classrooms (FC) had a moderate positive effect ($g = 0.36$) on the assessed LO, in comparison to traditional classrooms (TC). Removing the largest outlier study in their computation of the effect size retained the same moderate positive effect size in favour of flipped classrooms. In Section 2, we have discussed their observations on design elements that were frequently present across flipped classrooms examined in their analyses, namely pre-class preparation via lecture videos, in-class individual and group activities, as well as pre-class and in-class quizzes. We may now inquire how effective each of these design elements are, in terms of their impact on the assessed LO of the flipped classroom.

For quizzes, in-class group activities and in-class lectures, van Alten et al. contrasted effect sizes for the assessed LO of flipped classrooms that were classified into either a reference label or a changed condition label. Studies that explicitly reported *adding* quizzes to their FC, which were coded into the changed condition, saw a significant weak positive effect size ($p = 0.04, g = 0.19$), when compared to studies that either included quizzes in both their FC and

TC or did not explicate whether quizzes were included in their TC, which were represented by the reference condition. No significant effects were detected for the assessed LO for studies that added group assignments to their FC or had in-class lectures during the FC. Therefore, van Alten et al.'s study points to the effectiveness of regular quizzes in improving students' performance in flipped classrooms, however, it fails to discover evidence for the effectiveness of group activities or in-class lectures. Interestingly, studies that reported *decreasing* the face-to-face time in their FC saw a weak *negative* effect size ($p = 0.03, g = -0.26$) for the assessed LO, in contrast with studies that maintained the same face-to-face duration. We can thus deduce that flipped classrooms *should include* the same duration of face-to-face time between instructors and students as traditional classrooms; decreasing the face-to-face time to seemingly optimize the use of the instructors' time may lead to a drop in students' performance.

Do flipped classrooms improve students' satisfaction with the classroom and the instructor, or in their perception of their performance? Again, do any design elements significantly impact their satisfaction or perceived performance? In the meta-analyses by van Alten et al. (2019), only few studies ($n = 8$) measured students' perceptions of their performance correctly and no significant effects were detected for the perceived LO in this small sample size. Across $n = 22$ studies that reported a total of 3501 students' satisfaction with the course, they similarly did not observe significant differences' in students' satisfaction between flipped and traditional classrooms. Strelan et al. (2020) observed a weak-moderate positive effect on students' satisfaction in favour of flipped classrooms over traditional classrooms, across all studies for higher education courses ($n = 48$). van Alten et al. also reported measures of between-study heterogeneity (I^2, τ^2, Q-test) and found high variability that cannot simply be attributed to sampling error ($I^2 > 75\%$) for all of their observed variables. We can infer that the aforementioned discrepancy rises from a high variance of results between studies, as Strelan et al. (2020) *also* detected a similarly high variance ($I^2 > 75\%$) in the satisfaction results across their examined studies.

Instructors are known to impact students' perception of courses. A *weak* positive effect size was observed in favour of students' satisfaction with the flipped classroom over the traditional classroom, for studies that involved the same instructor. On the other hand, studies that did not report instructors or had different instructors for the flipped and traditional offering, saw a *moderate* positive effect size with larger confidence intervals. Often, better informed instructors who may have more experience with active learning techniques may choose to deliver a flipped offering of the course. We discuss a theoretical model for students' evaluations of online courses, which delves into the instructors' roles in conducting an online classroom; as we posit later, different instructors may have different "teaching presences" in their flipped classrooms, which may have impacted students' satisfaction.

Furthermore, as flipping a course may require re-designing components of it, instructors may deliberate whether they should flip the entire course or parts of it. Courses that are flipped for the entire duration experience a moderate positive effect from flipping, whereas courses that are only flipped for a duration do not experience any significant positive effects on students' satisfaction, over traditional classrooms. Thus, we have evidence for the thesis that students will be most satisfied with the flipped classroom design when it is retained for the entirety of the course; the impact of partial flips may be transient and thus insignificant.

van Alten et al. (2019) did not find significant effect sizes for any of their design elements, that is, lectures, group activities and quizzes, on students' satisfaction or perceived LO. They confirmed the low statistical power of the small sample of studies to detect significant results. However, their study illustrated the impact of quizzes on students' performance in flipped classrooms, and highlighted the prominence of activities and lectures. Strelan et al. (2020) similarly defined a "classic" flipped classroom as one that requires students to prepare before class, has in-class activities (with or without lectures) and either assesses students before class or at least, engages students in a discussion before in-class activities. For all studies labeled with the same code for a given design element, they then computed the effect sizes of satisfaction across flipped and traditional classrooms. They observed that classically flipped classrooms have a moderate positive effect on student satisfaction, but the effect weakens when *either* of these three elements is absent. That is, either simply having in-class activities with no prior preparation, or requiring prior preparation without following it up in class with active learning, or not assessing preparation material, does not result in a statistically significant increase students' satisfaction. Thus, from Strelan et al.'s analyses, we have evidence for a flipped classroom design to incorporate each of these three elements, at least when we are concerned with improving students' satisfaction.

Although Strelan et al. do not further code pre-class preparation by the type of media used (such as video or text), they do code the other two design elements. Formative assessments as well as discussions before in-class activities, both saw a moderate positive effect size, whereas no significant effects were detected when reflective assessments were used, as presumably they were summative and/or not further invoked in class. As most flipped classrooms in their study had student-centered activities, the same moderate positive effect was retained; there was an insufficient sample size to derive any conclusions for teacher-centered activities such as in-class discussions or Q&A. Engaging the students in group work resulted in a similar moderate positive effect size in favour of flipped classrooms. We observe that students' satisfaction with the instructor was also in favour of the flipped classroom instructor, with similar effect sizes for all moderating factors discussed above. Through their meta-analysis, Strelan et al. (2020) demonstrate that flipped classrooms should require students to prepare *before* class, engage them through pair or group activities and evaluate their understanding *in* class.

4 Instructional design models for online flipped classrooms

We now discuss instructional models that can be used by instructors to implement an effective flipped classroom. Lundin et al. (2018) report that although some publications in their literature review do refer to active learning, flipped classrooms are not clearly distinguished from these other teaching strategies. (Interestingly, they did not record any references to just-in-time teaching, which similarly aims to tweak in-class instruction to identify and address problems in students' understanding.) In one of the publications considered in their review (Kim et al., 2014), the authors examine three flipped courses in different disciplines at the same university. They utilize the revised Community of Inquiry (CoI) survey instrument (Shea et al., 2012) to assess students' satisfaction with these courses. Along with students' subjective responses in these surveys, they ultimately arrive at nine design principles for flipped classrooms. The revised CoI framework extends the original Community of Inquiry (CoI) framework proposed by Garrison et al. (1999) with another criteria on students' self-regulation, namely learner presence. Wart et al. (2020) extend the original CoI framework with three new factors, and use this as a survey instrument to assess 987 business students' perceptions of online classrooms. The original CoI framework outlines three important aspects of online teaching, focusing on web conferencing in higher education. We focus on this framework that was designed for online education, as we seek to arrive at design principles that also translate for fully online flipped classrooms. Garrison et al. (1999) describe three factors, namely cognitive presence, social presence and teaching presence, and break each element down into further categories. We proceed to describe these factors, and discuss new factors introduced by Kim et al. (2014) and Wart et al. (2020), as well as our own recommendations, in the context of online flipped classrooms.

Cognitive presence: The four categories for cognitive presence derive from Dewey's practical inquiry model, as follows: a learner is first in "a state of dissonance" on encountering something new or unexpected (triggering event), then seeks information that may explain the new experience (exploration), then aggregates this new information into some "coherent idea or concept" (integration) and finally, works to resolve the issue identified in the first step, by applying the newly formed concept (resolution). Garrison et al. (1999) view cognitive presence as an element that benefits from high social and teaching presence. Indeed, the correlation analyses conducted by Kim et al., 2014 across the revised CoI factors suggests that cognitive presence is moderately correlated with, and thus thrives from improvements in, both social and teacher presence.

Flipped classroom instructors can seek to design their out-of-class content and activities, such that the first half of the aforementioned cognitive process occurs in this time period. The student may be exposed to a new phenomena by posing a question in a quiz or by alluding to a real-world example in a prior class. The pre-class content should include relevant information sources (videos, textbooks, readings) to guide the student through this new information. Similarly, in-class activities, including peer-to-peer and individual activities, work towards the other half of the cognitive process, as learners would need to further assimilate their knowledge and apply the concepts learned to real-world examples. We discuss later on so as to how effective social and teaching presence can be used to incentivize students to prepare before class, and to guide them through in-class activities.

Social presence: Through this element, Garrison et al. (1999) aimed to capture aspects of learner-to-learner communication that allows learners "to project themselves socially and emotionally, as *real* people (i.e., their full personality)". As traditional body language cues are absent in text-based media such as discussion boards, gauging others' emotions is necessary to decode the intent of written messages, as well as to support peers in their learning. Garrison et al. thus emphasize using emojis and humor for emotional expression, which is their first category of social presence.

Synchronous communication channels such as video conferencing are used extensively in the COVID-19 era. As many students find it difficult to concentrate for an hour or more at a time, the instructor should schedule periodic breaks, and encourage students to avoid technological distractions and multi-tasking (Peper et al., 2021). Importantly, instructors may find that requiring students to turn their cameras on during these video calls can provide them with body language cues. However, students often feel anxious or self-conscious of their appearance or learning environment; they may perceive such camera footage as violating their privacy or that of those they live with. Castelli and Sarvary (2021) advocate that instructors should instead clearly convey expectations on camera use in-class, engage students via in-class activities and survey them regularly, in order to identify if the class environment can be improved so that more students are comfortable with turning their cameras on. Therefore, we posit that enabling emotional expression remains relevant *even for* these channels. Instead of relying on visual cues only, instructors should adopt aforementioned mechanisms to build social presence. They may also elicit immediate feedback via emojis or chat storms and encourage students to use humourous avatars or display pictures. For instance, funny memes can be used in a "chat storm" to poll whether students understood a concept discussed in class; this strategy engages students and provide feedback to the instructor, without subjecting the student to privacy violations.

Through the second category of social presence, namely open communication, Garrison et al. (1999) capture characteristics of a safe learning environment that result in "reciprocal and respectful exchanges". Learners should be able to voice their own thoughts and opinions, as well as engage with others' opinions, acknowledging their peers' contributions and comfortably disagreeing with them. Ultimately, the learners should collaborate as a group (or in groups) by completing activities within this safe learning environment, which was fostered on a given communication channel. Garrison et al.'s third category of social presence, namely group cohesion, relates to how learners' dialogue facilitates collaboration as a group. They surmise that the social presence element plays two roles, in that it supports critical thinking to build cognitive presence, and in building real-life skills such as team-work.

What technology features matter for online flipped classrooms? Interestingly, Garrison et al. (1999) deny the type of communication media used as a major determiner of social presence, rather they expect that a combination of factors intrinsic and extrinsic to the student may directly impact the resulting social presence. Their proposed intrinsic factors include students' ease of use and familiarity with the medium or tool and their motivation to use it, whereas extrinsic ones include organizational or instructional support for the medium or tool, suitableness of activities and the time duration for which they are to be conducted.

However, Kim et al. (2014) and Wart et al. (2020) have differentiated aspects relating to technology use into separate factors in their survey instruments, on top of the social presence factor. The ninth design principle proposed by Kim et al. (2014) focuses on "providing technology that is familiar and easy to access". The "technology use" factor in their survey assesses these aspects as well as whether the platforms' features distract students from learning. In one of the three flipped classes monitored in their study, students recommended breaking down long videos into engaging shorter ones (15–20 minutes). Whereas, students in another class felt uncomfortable recording themselves on video for one of the assessments. Thus, the ease of use of the platform and choosing activities that students are comfortable engaging in, are both important extrinsic factors that contribute to social presence. Wart et al. (2020) include three technology factors in their survey instrument, namely "basic online modality", "online social comfort", and "interactive online modality". They collect the second and third categories of social presence into the "online social comfort" factor, leaving only items related to emotional expression and a sense of belonging in their "social presence" factor.

As the remaining technology factors in van Wart et al.'s analysis hint at specific technological features, we first summarize common online educational technologies that instructors may use in modern classrooms. Learning management systems (LMSes) serve as all-in-one platforms to host course content (slides, videos, readings), to submit assessments such as reports, assignments and quizzes, and to conduct automatic grading ("D2L - Creators of the Brightspace Learning Management System Software (LMS Software)", 2021). Specialized platforms cater further to each of these online instructional needs. For instance, various video conferencing applications such as MS Teams ("Microsoft Teams: Online & Remote Classroom — Microsoft Education", 2021) and Zoom ("Education Plan - Zoom", 2021) have been used extensively during the pandemic to deliver online classes synchronously. These platforms support "break-out rooms" wherein small groups of students can participate in learning activities, with monitoring support for the instructor and TAs ("Use breakout rooms in Teams meetings", 2021). Even if the instructors' choice of (and students' comfort with) the platforms is partly determined by the organizational supports, the instructors may need to identify and prioritize which features should be used, in order to conduct activities, share content or assess students.

Survey items for the "basic online modality" factor include ease of navigation through the platform, online submission of deliverables, online grading and gradebooks, class announcements, and online quizzes. In the absence of references from which these survey items were derived, it appears that this factor includes an unsystematic assortment of technology features that are typically present in online LMSes. They do not include survey items on content delivery, or on online assessments other than quizzes. Moreover, LMSes also enable asynchronous communication between the instructor and students as well as among students. For instance, learning activities that involve discussion boards or forums are also supported. Interestingly, "small chat rooms" are one of the survey items for the "interactive online modality" factor. This factor is intended to capture the instructor's use of "high-end" functionality, by which they refer to video conferencing and video lectures, apart from chat rooms. As different types of media, namely synchronous (conferencing) and asynchronous (lectures) as well as low (chat) and high bandwidth (video), are included in this factor, it remains difficult to assess which forms of content delivery are most valuable to, and used frequently by, students in different disciplines. For instance, break-out rooms can facilitate peer-to-peer learning, however, there have yet to be large scale studies of student satisfaction with this feature, especially while considering students' comfort with having their audio/video on and experiencing fatigue through multiple video calls. Similarly, we need to examine the effectiveness of chat-based features in supporting and engaging learners with low bandwidth capacity in video calls. Moreover, as technology evolves, what is considered "high-end" may evolve as well.

We find that the "basic" and "interactive" online modality factors proposed by Wart et al. (2020) to be somewhat arbitrary and suffer from lack of generalizability for future survey instruments across learning platforms' features and disciplines. We utilize the "technology use" factor proposed by Kim et al. (2014), in the absence of well-defined fine-grained factors. In general, researchers seeking to generate survey items and design principles for technology use in flipped classrooms should:

- Systematize features by their role in teaching, such as content delivery, assessments, and activities, in order to develop ontologies that can adapt with future advances in educational technologies. (For instance, we have outlined some open questions on features for teaching activities in the previous paragraph.) In the context of online flipped classrooms, features should be further classified by whether they can be used out-of-class (asynchronous) or in-class (synchronous). Identifying technology features that are more or less frequently used in a discipline may nudge instructors towards experimenting with novel features, or alternately, help them reap the discipline's expertise in integrating frequently used features well.

- Use statistics gathered by the platforms to gauge students' engagement with various platform features for small-scale studies, in order to substantiate students' evaluations of the technology use. If students claim that some feature is easy-to-use, yet use it infrequently, then perhaps the instructional support needs to be revised to appropriately direct and incentivize students to use that feature, or to exploit another frequently used feature for the same goal. Designing open-ended, subjective questions on the role played by the technology in the larger context of the course (and not simply ease-of-use or comfort with the platform) may elicit students' responses that help towards adopting and integrating valuable features into the classroom.

Teaching presence: Just as with a traditional course, instructors of online classrooms need to organize the course content, learning outcomes, activities and assessment timelines, and convey these to students clearly, with teaching assistants' aid. The first category of the teaching presence element, namely "instructional management" addresses the organizational aspects of online teaching (Garrison et al., 1999). For instance, Mason et al. (2013) deduce that simply uploading content videos and requiring students to find the video that explains a concept, in order to answer a quiz question, confuses students and consumes their time with busy-work. Second, instructors can improve social presence by engaging inactive students, acknowledging contributions and "identifying areas of agreement and disagreement, and generally seeking to reach consensus and understanding", as reflected in the second category of teaching presence, namely "building understanding". Finally, our common understanding of the instructor's role is in improving cognitive presence, for instance, by posing questions as a "triggering event" and bridging between social and cognitive presence by "proactively guiding and summarizing the discussion", to aid in the integration step of the cognitive process. The instructor and TAs also provide explanatory feedback on various assessment pieces. These aspects are included in Garrison et al.'s final category of teaching presence, namely "direct instruction". van Wart et al.'s "instructional support" factor closely aligns with Garrison et al.'s original "instructional management" category of teaching presence. They explicitly distinguish "teaching presence" from "instructional support", based on whether the instructor responds dynamically to specific circumstances, such as providing individual feedback (former), or acts as per their prepared plan (latter). We retain this conceptual distinction as we believe it can be useful for instructors to appropriately organize their planning and in-class time, so that their students can be satisfied in the delivery of all aspects of teaching presence.

We exemplify instructional support in the context of flipped classrooms, in terms of designing course components for improved cognitive and social presence, as follows. Flipped classrooms require students to engage in pre-class activity, however, many students may not be motivated to invest their time beforehand in this pre-class activity. In general, not all students may be mastery-oriented learners, in that they may not strive for deep learning. Kim et al. (2014) highlight the need to incentivize students to prepare for in-class activities, and thus instructors should associate some formative or low-stakes summative assessment with the pre-class content. Students may be motivated to prepare for this content by low-stakes assessments, such as discussion board threads on confusing aspects of the content. For students to engage with textual course content, the Perusall platform ("Perusall", 2021) facilitates individual and group annotation of tests, and motivates students to engage through low-stakes assessment of the quantity and/or quality of their annotations (Biro, 2021; Miller et al., 2018). Similarly, the ongoing Videoconservatory project (Singh et al., 2016) supports annotating videos. Instructors are in need of guidance on choosing *online* in-class activities that foster this cognitive process and are yet feasible for large online classes. Additionally, although Kim et al. propose designing assessments that are aligned with the in-class activities and learning outcomes (design principle 3), they do not elaborate on how to achieve this in a limited time frame that instructors may have to (re)design their course.

During a flipped class, Kim et al. (2014) emphasize that instructors should relate the in-class activities with the out-of-class content (either before or after the activity), to ultimately improve students' cognitive presence. Similarly, we suggest that the instructor should also conclude in-class activities, by ensuring students are cognizant of take-aways from in-class activities, either by explicitly discussing them or encouraging students to think about them through personal or group reflections in class, or follow-up out-of-class tasks. For group activities such as jigsaws, students in each group can summarize their experience for other groups as a formative assessment; snow-balling can be effective in summarizing experiences across large classes.

Garrison et al. (1999) and Kim et al. (2014) implicitly interpreted feedback as an explanatory tool for students to learn from assessments. However, as many students may not exploit this feedback to ultimately improve their understanding and learning processes, our understanding of feedback has evolved to one where we effectively treat the process of providing, receiving and using feedback as a learning outcome in itself (Sambell & Brown, 2021). We expect that flipped classrooms would benefit from this evolved understanding, by incorporating authentic assessments and rubrics that allow for continuous improvement, as well as various in-class group activities, with TA facilitation, that focus on this feedback process to ultimately help the learners improve.

Learner presence: Proposed by Shea et al. (2012), this element captures students' ability to regulate their own learning. Flipped classrooms require students to spend some time on the course content out-of-class in order to benefit as much as possible from their in-class time. Since students may often cram content for end-of-term assessments in traditional lecture-based courses, they may benefit from partitioning time to process the course content regularly in flipped classrooms. Although most studies examined in the meta-analysis presented by Lundin et al. (2018) reported positive student experiences relating to self-regulation of their learning, two studies found that some students were overwhelmed with contributing more time (Smith, 2013) and the additional personal responsibility (Wilson, 2013). Few studies also reported that although students were hesitant to the new flipped approach at the start of the course, they "bought in" to the goal of flipped classrooms and re-oriented their learning strategy. Kim et al. (2014) and Wart et al. (2020) find that students' prior experience with classes, and their management of an increased autonomy, in terms of processing course content, is relevant in their overall satisfaction with a flipped course. Abeysekera and Dawson (2015) present a theoretical model to encapsulate various aspects of motivation and autonomy inherent in flipped classrooms. They use their model to explain how flipped classrooms increase intrinsic and extrinsic motivation, as well as, help manage cognitive load. We expect that flipped classrooms can assist in building learning skills. However, it is important to guide students in changing their learning orientation from a passive learner, to an active class participant.

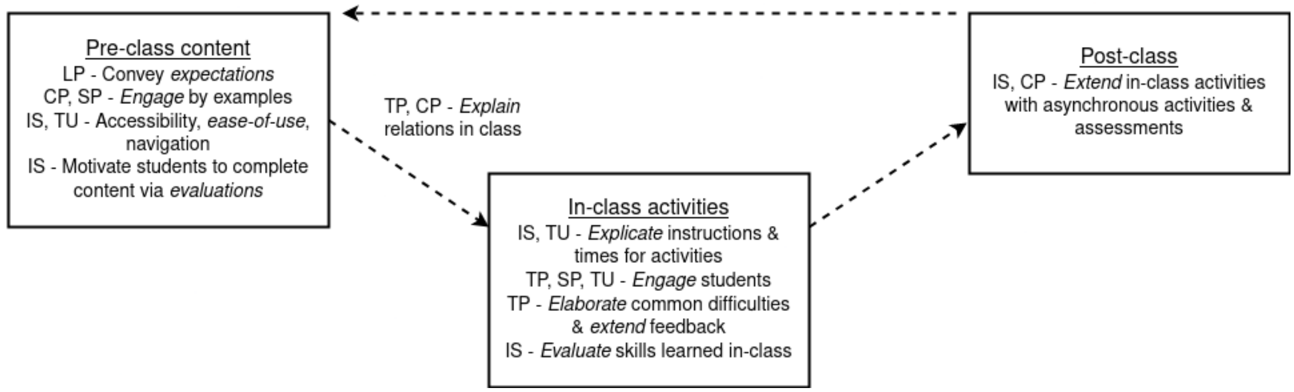

Figure 1: Illustrates different factors of a revised CoI model (Kim et al., 2014; Wart et al., 2020) across three stages of the flipped classroom. Important verbs are derived from the 5E instructional framework presented by Hew et al. (2020) and are italicized. Each of the factors are abbreviated as follows: CP = Cognitive Presence, IS = Instructional Support, LP = Learner Presence, SP = Social Presence, TP = Teaching Presence, TU = Technology Use.

5 Discussion

We have described various design elements for flipped classrooms and their impact on students' satisfaction and performance in Section 3. In Section 4, we have described the revised Community of Inquiry (CoI) model and detailed the technology use component, as proposed by Kim et al. (2014), as well as an instructional support component, as proposed by Wart et al. (2020). We now proceed to summarize our findings in Figure 1.

In the pre-class stage, instructors should aim to prepare students by exposing them to appropriate background or pre-requisite concepts for these activities. For enhancing cognitive presence, this material should include real-world examples or applications to engage students. Instructional support in this stage includes ensuring that any videos are short enough to sustain students' attention, and providing support for subtitles as well as varying qualities of audio/video downloads for low-bandwidth learners. Instructors should also direct students to content on the LMS and outline materials required for in-class activities (software, handouts). Importantly, instructors should incentivize students to study this content by designing low-stakes summative assessment, as this has been found to improve students' satisfaction with the course and performance. Quizzes have been frequently used in STEM disciplines. Teaching presence should also include aggregating students' responses to these assessments, to ultimately determine common difficulties. Students need not complete pre-class preparation and assessments individually; platforms such as Perusall ("Perusall", 2021) facilitate social annotation of text, with automatic low-stakes assessment of the quantity and quality of students' comments. To increase learners' presence, instructors should clearly convey at the start of the course that in order to benefit from in-class activities, students are expected to schedule time out-of-class to study and complete assessments. Additionally, instructors should ensure that these two components indeed only take up as much time as advertised, for all flipped classes.

Second, for online flipped classrooms, the in-class stage is typically conducted synchronously, such as over a video-conferencing platform ("Education Plan - Zoom", 2021; "Microsoft Teams: Online & Remote Classroom — Microsoft Education", 2021). For most of the duration of online synchronous sessions, they should plan activities for groups or pairs of students, over individual ones, so that students can interact with and learn from each other. Break-out room features in these platforms facilitate such activities. Clear instructions, goals and times should be communicated to students before, or, as soon as, they enter these rooms. The teaching team should monitor these break-out rooms, and attempt to interact with as many rooms as possible during each class, in order to provide customized feedback. Additionally, the activities can also be explicitly designed for students to seek and deliver feedback to their peers. Apart from facilitating feedback, other crucial elements of teaching presence in class include: clarifying difficulties from pre-class assessment, explicitly relating pre-class content to in-class content, and concluding in-class activities with meaningful (possibly student-led) summaries. In-class microlectures can be used to achieve these goals. During synchronous sessions, the instructors should adopt strategies that do not require students to share their video camera footage and yet develop social presence, as discussed in Section 4. Finally, low-stakes assessments, such as quizzes, should be included to test concepts and skills acquired through in-class activities. After the synchronous class has concluded, the instructor may also organize out-of-class asynchronous activities that substantiate or build upon the learning outcomes achieved in-class, such as group work milestones or discussion board posts.

In summary, the flipped classroom consists of pre-class and in-class stages. We have discussed above how different aspects of the extended CoI model, namely instructional support as well as teaching, cognitive, social and learner presence can be achieved across these stages.

5.1 Application to own teaching

Flipped classroom serve as a good starting point to redesign a traditional lecture-oriented course as their design re-orients focus from including content only towards ephemeral exam questions, to incorporating only as much content to instantiate authentic activities and assessments that inculcate real-life skills. I will be co-teaching a part of an upper-year computer science course (CS458) in the upcoming term (Spring 2021). As a part of this, I plan to record revised, short lecture videos in an attempt to update outdated content and provide new examples. Following the flipped approach, I will also be including material that serves as pre-requisites for the in-class synchronous sessions in these videos. Instead of simply conducting lectures in these online synchronous sessions, where the only opportunity for interaction is through questions, I intend to incorporate regular small group activities over break-out rooms. On account of the successful observed impact of quizzes, I will be updating the quiz questions (on the Learn LMS) so that they closely assess the learning outcomes from my lecture videos. I will also utilize quiz statistics provided by the Learn LMS to identify frequently incorrect questions. Through limited use of in-class microlectures, I will address any common misconceptions. Currently, students complete a discussion board blog task and comment in each others' threads. I will refer to relevant blog tasks in my weekly interactive sessions, thereby acknowledging students' work and relating it to class content. I aim to use my experience and students' feedback from the Spring 2021 offering of the course to guide the design of my future classrooms, which I will continue to flip even after the pandemic ends.

Graduate computer science (CS) courses are also "flipped" in that students are required to read papers and submit paper reviews before class. During class, a lead student may present the paper in a conference format, and moderate a discussion period, wherein other students can bring up strengths and weaknesses of the paper. However, students often do not obtain feedback on the paper reviews and thus, do not learn how to provide useful reviews as paper reviewers. Moreover, when CS graduate students *receive* reviews for their papers, they also need to reply back with short, effective rebuttals that acknowledge their own errors, answer reviewers' questions and correct their misconceptions. Both skills of providing and processing feedback can be built in flipped classrooms that are formatted as paper review meetings. Apart from presenting papers and handling feedback tasks, students in these courses complete a course project in small groups. Deliverables typically include project proposals and then an end-of-term paper, which is graded by the instructor after the course ends. Thus, incremental feedback is rarely offered to students. Incorporating intermediate assessments, such as annotated bibliographies or papers with sections or section headings, as milestones allows opportunities to elicit feedback, so that students can improve their academic writing skills and the quality of their project. Each student group should regularly generate feedback for its pair group's milestones and then grade each feedback item that they received from their pair group, using the instructor's rubric as criteria. Thus, flipped classroom designs that use effective peer instruction can build paper reading and writing skills that real-life CS researchers use regularly.

6 Conclusion

Flipped classrooms begin with *pre-class learning* where students familiarize themselves with basic concepts, and are followed by *in-class active learning tasks* (and possibly microlectures) that facilitate deep learning in-class, as well as in-class assessments that evaluate the students' mastery of the in-class content. Optionally, the instructor may include out-of-class activities and assessments that ultimately serve as a prelude to the next flipped classroom's pre-class activities. We have summarized evidence for the impact of flipped classrooms, in terms of improvement in students' satisfaction and performance. In doing so, we have highlighted design elements, such as pre-class content, in-class activities and assessments, that contribute to the success of flipped classrooms along these criteria. We have also placed these qualitative results in the context of an existing instructional design model (CoI framework) that had been developed for online teaching and has since been revisited in the context of flipped classrooms. Specifically, we have presented recommendations from related literature, as well as our own observations, on how each of the aspects of this model can be applied in the flipped classroom to improve students' satisfaction with a flipped course. For instance, we have concluded that we still need further research, classification and measurement on how technology factors impact students' satisfaction with recent online flipped classrooms. Finally, we have integrated key findings on flipped course design into a clear diagram, which we hope can be applicable to future classrooms. We have also exemplified applications of these principles to our future teaching experiences. We hope that our evidence-based design framework for flipped classrooms will be extended and reused by future researchers.

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