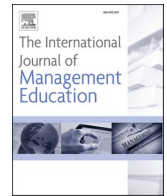


ULRR

Using cluster analysis to identify procrastination and student learning strategies in a flipped classroom

Item Type	Article
Authors	Walsh, John N.
Citation	The International Journal of Management Education 22(1), 100936
Publisher	Elsevier
Download date	2026-10-24 21:47:18
Item License	https://creativecommons.org/licenses/by-nc-sa/4.0/
Link to Item	https://doi.org/10.34961/researchrepository-ul.25102223



Using cluster analysis to identify procrastination and student learning strategies in a flipped classroom

John N. Walsh

Department of Management & Marketing, Kemmy Business School, University of Limerick, Ireland

ARTICLE INFO

Keywords:

Flipped classroom
Procrastination
Learning strategies
Learning resources
Cluster analysis

ABSTRACT

Flipped classrooms are becoming increasingly important in higher education. While their value over traditional practices has been identified, it is possible to implement a flipped classroom in many ways. Therefore, research needs to consider the distinct ways flipped classrooms are structured to identify their relative effectiveness. The usefulness of flipped classrooms is reduced when students' procrastination in the pre-class phase, resulting in a lack of student engagement with online resources. This paper uses a cluster analysis of log-file data from three cohorts of a flipped classroom module, involving 169 undergraduate business students, to identify their learning strategies. It considers when students first begin to access online material and relates this to the timing of their classes and assessments. Two distinct learning strategies were identified. Prepared students accessed online resources as expected in advance of flipped classes. Assessment-focused students used the available resources after class to prepare for impending assessments. Prepared students performed significantly better than those that were assessment focused. In addition, there was more engagement with video-based material over text-based resources and also more engagement when assessments were weekly and low-stakes rather than terminal and higher-stakes. Consequently, the way in which flipped classrooms are structured can reduce the level of student procrastination present and improve the effectiveness of this method.

1. Introduction

Flipped classrooms (FCs) are a 'hot topic' (Turan & Goktas, 2016). They are particularly widespread in higher education (Choa et al., 2021; Jakobsen & Knetemann, 2017; Jang & Kim, 2020) with research on FCs increasing dramatically (Lundin et al., 2018). FCs reverse traditional teaching (Cheng et al., 2019; Wang et al., 2019) with material traditionally taught in class delivered in advance and outside of the classroom (Aznar-Díaz et al., 2020; Cheng et al., 2019). Students in FCs primarily learn outside class (Jakobsen & Knetemann, 2017) so they are prepared for face-to-face interactions (vanLeeuwen et al., 2019). This frees up class time for more enquiry-based activities (Jang & Kim, 2020) making in-class learning more active and engaging (Davies et al., 2013; Kazanidis et al., 2019). The development of flipped classrooms is heavily reliant on educational technology (Elmaadaway, 2018) that makes resources more accessible (Prashar, 2015). It is a student centred approach (Hsia & Hwang, 2020; Lee & Choi, 2019; Steen-Utheim & Foldnes, 2018; Zainuddin & Halili, 2016) where learners actively construct their knowledge (Sohrabi & Iraj, 2016).

It is argued that FCs lack substantial empirical evidence (Al-Samarraie et al., 2020; Luo et al., 2019; McNally et al., 2017). Most research focuses on undergraduates (Cheng et al., 2019; Hendrik & Hamzah, 2021) and consider students that take only a single course

E-mail address: john.walsh@ul.ie.

<https://doi.org/10.1016/j.ijme.2024.100936>

Received 21 March 2023; Received in revised form 8 January 2024; Accepted 8 January 2024

Available online 17 January 2024

1472-8117/© 2024 The Author. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

(Divjak et al., 2022). Currently, there is a lack of research on business-related courses. A review by Hwee and Koh (2019) identified only 9.8% of studies examined Business and Social Science disciplines while a review of 149 papers by Yang et al. (2017) did not include business in the 10 most productive subject categories. Research also needs to measure FC student engagement and performance more objectively (Elmaadaway, 2018). While many studies have compared performance between FCs and traditional classrooms (Choi & Lee, 2018; Kazanidis et al., 2019; Prashar, 2015; Sezer & Abay, 2019; Turan & Goktas, 2016) there is a need to examine how, why, when, and for whom FCs are beneficial (Stöhr & Adawi, 2018). Pre-class preparation is a key activity (Boevé et al., 2017; Lee & Choi, 2019) with student procrastination being problematic (Al-Zahrani, 2015; Turan & Goktas, 2016; Xiu & Thompson, 2020). Such issues lead some to suggest that student activity can be increased using assessments (He et al., 2019; Hwee & Koh, 2019; McNally et al., 2017; Shahnama et al., 2021). The objective of this study is to examine FC pre-class procrastination among business students using cluster analysis, to categorise students' learning strategies. Then the level of virtual learning environment (VLE) activity and performance for each learning strategy is examined.

The remaining sections are structured as follows. The next section reviews FC research, considering online resources, pre-class procrastination and in-class phases followed by a methodology section where the FC structure and participants are outlined along with the variables developed and detailing the use of cluster analysis. The next sections present findings and discuss the theoretical implications. Finally, the conclusions section considers implications for further research and outlines limitations.

2. Flipped classrooms

FCs create an improved learning experience (Steen-Utheim & Foldnes, 2018). They provide more flexible learning opportunities (Dianati et al., 2022) as well as increasing student engagement (Judson & Aurand, 2021; Sarkar et al., 2020) through active learning (Díaz et al., 2021; Elmaadaway, 2018). Some studies find student performance higher in flipped than traditional classrooms (Choi & Lee, 2018; Davies et al., 2013; Hsia & Hwang, 2020; Kazanidis et al., 2019; Pattanaphanchai, 2019; Prashar, 2015; Sezer & Abay, 2019; Shahnama et al., 2021; Turan & Goktas, 2016). Reviews of FC research report different results: some find positive results (Hwee & Koh, 2019; Zainuddin & Halili, 2016) which vary from small (Cheng et al., 2019) to moderate (Zheng et al., 2020) size effects while other studies find no difference (Sommer & Ritzhaupt, 2018; Stover & Houston, 2019). Most studies examined STEM disciplines, with business not explicitly identified (Lundin et al., 2018). Indeed, where business studies were considered no effect was identified (Cheng et al., 2019).

Research has also identified lower motivation among undergraduate students (vanderVelde et al., 2021; Walsh et al., 2021) with FCs being most beneficial for post-graduates (Dianati et al., 2022). Studies have also considered student perceptions of flipped classrooms. Students believe FCs provide a more positive learning experience (Pattanaphanchai, 2019; Price & Walker, 2021; Steen-Utheim & Foldnes, 2018), allowing them to learn more (Masland & Gizdarska, 2018). Nonetheless, the benefits derived from FCs tend to go to those that already possess higher levels of motivation and are diminished when negative student perceptions exist (Chuang et al., 2018).

2.1. Technology

Technological advances make FCs easier to implement (Davies et al., 2013). E-learning tools are important (Al-Zahrani, 2015; Divjak et al., 2022) in overcoming traditional classroom limitations (Sezer & Abay, 2019). In particular, technologies support pre-class preparation through the use of e-books (Judson & Aurand, 2021), slides with audio (Chan et al., 2020) and videos (Choi & Lee, 2018; Hendrik & Hamzah, 2021; Luo et al., 2019; Shahnama et al., 2021). When compared to reading materials, videos have been associated with improved student performance (Lee & Choi, 2019) though less so for undergraduates (Walsh et al., 2021). Videos should encourage student interaction rather than mere passive viewing (Zainuddin & Halili, 2016). Student interactivity can be increased using tests and quizzes (Haagsman et al., 2020; Lo, 2018), especially when online materials are seen as meaningful and helpful (Choa et al., 2021).

2.2. Pre-class phase

In FCs, lectures take place outside the classroom (Luo et al., 2019) with pre-class activities introducing students to new knowledge (Limaymanta et al., 2021; Long et al., 2019; Sarkar et al., 2020). This requires students to engage with material in advance of class sessions (Al-Samarraie et al., 2020; Boevé et al., 2017; Lo, 2018). Typically, FCs involve students watching videos before class (Jang & Kim, 2020) but may also involve reading articles, playing games and taking quizzes (vanderVelde et al., 2021).

Pre-class activities should ultimately reduce learners' cognitive load, enabling them to process information more effectively during class (Cilliers & Pylman, 2022). FCs allow students to engage with material at their own pace (Limaymanta et al., 2021; Zainuddin & Halili, 2016), which promotes stress-free learning (Hyttinen & Suhonen, 2022). Indeed He et al. (2019) found students did not spend more time on study, but rather they spent more time studying before, rather than after, class. Sohrabi and Iraj (2016) argue pre-class material reduces student cognitive load when students engage with in-class activities. Conversely, some studies have also found FCs require more mental effort by students (Al-Zahrani, 2015; Hsia & Hwang, 2020) with higher cognitive loads reported (Turan & Goktas, 2016). Higher mental effort increases the need for student self-regulation of learning (Limaymanta et al., 2021). Too much online material may tire students, decreasing their willingness to engage (Xiu & Thompson, 2020). The FCs 'Achilles's heel' is the assumption that students will adequately prepare for class (Fisher et al., 2020). This is a challenge (Pattanaphanchai, 2019) that can lead to under-prepared learners (Lee & Choi, 2019) who use the flipped resources as a revision aids (Walsh et al., 2019).

Using online material regularly is beneficial for students (vanLeeuwen et al., 2019). Insufficient preparation may arise from a lack of confidence or organisational skills (Fisher et al., 2020). Way of improving engagement involve actions such as guidance (Turan & Goktas, 2016; vanderVelde et al., 2021), including credits (Xiu & Thompson, 2020) and marks for watching videos before class (Sezer & Abay, 2019), pre-class homework (Hwee & Koh, 2019), assignments (He et al., 2019) and quizzes (Haagsman et al., 2020; Lo, 2018; McNally et al., 2017). Exercises and pre-class activities improve student achievement (Shahnama et al., 2021), self-direction (Hwee & Koh, 2019) and self-regulation (Chuang et al., 2018). Engaging in pre-class work reinforces the effort students put into learning (Xiu & Thompson, 2020) and motivates them to study more regularly (Shahnama et al., 2021). Quizzes work best with highly motivated participants (Chuang et al., 2018) with some students suggesting that while quizzes did not improve their performance their inclusion motivated them to study more regularly (Shahnama et al., 2021).

Instructor and student roles change during pre-class activities (Yilmaz & Baydas, 2017). Students need to manage themselves (Hyttinen & Suhonen, 2022) and take responsibility for their own learning (Elmaadaway, 2018). For FCs one such responsibility is that students take control of how they prepare for class (Davies et al., 2013). Such preparation requires students to develop self-regulation practices (Cheng et al., 2019; Dianati et al., 2022). Self-regulated learning is important in developing learning strategies (Davies et al., 2021) and significantly affects pre-class learning performance (Lee & Choi, 2019). Students need to be motivated in order to learn to regulate their activities (Boevé et al., 2017; Yilmaz & Baydas, 2017). They may monitor how they learn, deciding whether existing learning strategies require modification (Yilmaz & Baydas, 2017). One way to increase motivation is by structuring each session similarly, so participants know what to expect (vanderVelde et al., 2021).

Pre-class materials should be made available a few days before class, to provide time for engagement (Shahnama et al., 2021). Regular engagement is more effective (vanLeeuwen et al., 2019). A few studies have focused on temporal access patterns. AlJarrah et al. (2018) found students accessed material near class time, mostly on the day of class, with most variability seen among medium performing students, but no difference in temporal access patterns between high and low performers. AlJarrah et al. (2018) posit high performing students may do this to have the material 'fresh in their minds' while for low performing students it is due to procrastination, with earlier access by medium performing students may be due to their needing time to make sense of the material. Three student clusters each with different learning strategies were identified by Davies et al. (2021) though interestingly with little difference in performance. The 'knowledgeable confident' cohort, accessed less video and reading content but worked quickly on assignments, with slightly more use of pre-class materials by a 'confident traditional' cohort and a 'novice careful' cluster being diligent but unfamiliar with the topic resulting in their accessing more content. While learning strategies among students taking a flipped class can be identified, this is not to suggest that such learning strategies may not be modified over time. Changes in learning strategies was identified in as little as a 5-week period by Yilmaz and Baydas (2017). This indicates the malleability of learning strategies in response to the structure of a flipped class.

2.3. In-class phase

While both pre-class and in-class activities are important (Al-Zahrani, 2015) the in-class phase is considered by some to be the more critical (Lee & Choi, 2019). An objective of FCs is to liberate time for such in-class activities (Masland & Gizdarska, 2018). These activities involve applying knowledge (Sarkar et al., 2020) and concepts (Pattanaphanchai, 2019) through groupwork (Choa et al., 2021) and problem-solving activities (Lo, 2018; Sarkar et al., 2020; Zainuddin & Halili, 2016). They may also include peer collaboration (Hwee & Koh, 2019; Turan & Goktas, 2016; Wang et al., 2019) and group presentations (Al-Samarraie et al., 2020). In-class activities help develop higher-order thinking skills (Davies et al., 2013; Haagsman et al., 2020; Hwee & Koh, 2019; Long et al., 2019) and deeper learning (Hyttinen & Suhonen, 2022). Knowledge acquisition occurs by interacting with more experienced individuals (Li & Suwanthep, 2017). New knowledge and connections are discovered by students as they complete tasks and solve problems (Dong et al., 2021). In-class activities promote emotional and classroom engagement (Elmaadaway, 2018) as well as promoting group dynamics (Díaz et al., 2021). They also result in increased commitment to peers (Steen-Utheim & Foldnes, 2018). In-class activities require a 'scaffolding process' whereby students receive guidance from both peers and instructors until they are in a position to solve problems on their own (Rahman et al., 2018).

FCs support deeper relationships being developed between instructors and students (J.C.-Y. Sun et al., 2017) that come about through increased interactions (Stover & Houston, 2019). This facilitates students in asking questions (Steen-Utheim & Foldnes, 2018) and receiving guidance and feedback (Hyttinen & Suhonen, 2022; S McCallum et al., 2015). Such supports are more immediate (Haagsman et al., 2020; Hwee & Koh, 2019) and individualised (Limaymanta et al., 2021; Steen-Utheim & Foldnes, 2018) to students. This phase encourages students to develop a capability to seek external help (J.C.-Y. Sun et al., 2017) while making instructors more effective (Elmaadaway, 2018).

3. Methodology

Reviews of FC research by both Yang et al. (2017) and Hwee and Koh (2019) found a lack of research on business students. While some studies have recently been published involving business students (Pérez et al., 2019; Price & Walker, 2021; Swart et al., 2021; Walsh & Rísquez, 2020) a gap still remains. This study helps fill this gap by examining a flipped course taken by final year undergraduate business students. As no changes were made in the content, structure, or instructor for this course over a three-year period it was possible to include three cohorts, 169 of students, in total.

A notable limitation of FC studies is that they are over-reliant on potentially inaccurate students self-reported data (Davies et al., 2021). One way to overcome this limitation is to use log-file data as this has the ability to provide 'learning traces' of student behaviours

(Gasevic et al., 2015). Such data can be used to analyse students' learning strategies (Davies et al., 2021). This has been achieved, for example, by calculating a weekly activity score (vanLeeuwen et al., 2019) or a visualisation of work intensity (AlJarrah et al., 2018) as well as analysing temporal aspects of students' behaviours (AlJarrah et al., 2018; Boevé et al., 2017). For this study three years of VLE data for the 169 students were gathered.

Content for each week was released exactly one week in advance of the relevant 2-h class. The flipped course was divided into two sections. Each of the two sections was worth 30% and was assessed separately. While the course included a 40% group project this was not considered in this study as it was not associated with specific flipped classes. For section 1, material was assessed through five weekly assessments, each worth 6%, conducted in separate invigilated sessions a few days after each class. Classes in week 8 were replaced with student meetings to discuss projects. Section 2 of the course ran from weeks 9–12. Flipped classes were held in weeks 9–11 with a final (30%) exam being held in week 12.

Data were analysed using SPSS 28. Similar to prior studies (Lu et al., 2018; Walsh & Rísquez, 2020), variables were calculated from VLE log-file data that represented students' interactions on the class site and viewing patterns of online material. The data extracted totalled 41,690 events. For each event the following data was available: a student identifier, the date and time of the event, the event type, and a session identifier. Each time a student logged into the class site a different session identifier was generated making it easy to identify actions within a single session and to calculate the length of each session. As data for three separate years were included it was necessary to identify the dates for the week in which each lesson was made available, as well as the day and time of the relevant class and assessment, for each year. This allowed several variables to be calculated for each student. Some variables were relevant to the students activities over the entire course: the total number of sessions, total number of events and the average number of events per session. For each of the two sections of the course the following variables were calculated: the total number of sessions, total number of events, the weekly average number of events and the average number of events per session. The material for each class was available on separate 'lesson' pages in the class website. For each week, in each of the three years examined, details of class time were compared to the time that lesson pages were accessed. This made it possible to identify when a lesson was accessed and identify whether it was before a class, after a class but before the relevant assessment or after the assessment. The earliest time each lesson was accessed before each class was calculated. In addition, for each student performance data, a percentage graded out of 30% respectively, for each of the two sections were added. Student identifiers were removed before any analysis was carried out.

By tracking students' interactions with flipped resources educational data mining, using techniques such as cluster analysis, can help identify students' learning strategies (Davies et al., 2021). Cluster analysis has the ability to categorise different (Salehudin & Alpert, 2022), previously uncategorised (Del Valle & Duffy, 2009) groups and '*aims at identifying and characterising the structure or features in data*' so those with similar patterns are placed in the same cluster (Fan et al., 2021). This technique has been used to categorise students based on their perceptions (Carvalho, 2013) and enabled student profiles to be developed, based on their online interactions (Mirriahi et al., 2016). To minimise within-group variability (Kreber et al., 2005), Wards method was used, similar to Carvalho (2013). This study used 2-Step cluster analysis as this categorises non-readily identifiable groups and identifies the value of the input variables (Brown et al., 2016). Various numbers of clusters were examined, with consideration given to the proportions of students within clusters. The final model that was developed, like other studies (Walsh & Rísquez, 2020; Wu et al., 2022), met a goodness of fit requirement with a silhouette score over 0.5.

Research using cluster analysis for FCs (Davies et al., 2021; Fan et al., 2021; Walsh & Rísquez, 2020; Wu et al., 2022) has examined behaviours based on activities such as reading and video watching (Davies et al., 2021; Salehudin & Alpert, 2022; Walsh & Rísquez, 2020). VanLeeuwen et al. (2019) argue that, when trying to explain a link between student activities and performance in a blended learning context, research has not adequately considered temporal aspects, including the timing of activities. It is just such variables that are key elements of this study. In addition, this analysis addresses the need to examine why and for which students the FC works, as identified by (Stöhr & Adawi, 2018) and a call by (Cheng et al., 2019) to examine the effects of different FC designs.

4. Findings

Two clusters of student behaviours were identified. The larger 'Prepared' cluster included 58% of students. These students accessed pre-class materials, on average, before classes and also before assessments throughout the course. A second, 'Assessment-focused' group (42%) was also identified. This cluster accessed online resources, on average, after the relevant class was over, but in advance of their weekly assessments.

The Prepared cluster always accessed material before class, though this occurred earlier for section 1 of the course (19 h before) than section 2 (1 h before). This difference in when flipped resources were accessed could be related to the timing of the assessments and also to the nature of the online materials used. Students prepared well in advance of both classes and assessments for section 1 which used video-based material and small-stakes weekly assessments. This cohort's strategy centred on gaining an initial understanding of material in advance of the class, applying it during in-class activities and then using the online resources to revise any unclear points before the assessment. However, their learning strategy changed for section 2 of the course where they focused on accessing the written material just before class so as to have it available for use during in-class activities rather than engaging with this text-based content before class.

On average the Assessment-focused cluster accessed resources for both sections of the flipped course after the relevant classes but before the assessments. When the structure of the course changed, from weekly low-stakes assessments based on video material (section 1) to a higher-stakes assessment that was based on three weeks written material (section 2) this group procrastinated more before accessing the online resources. This indicates the important role played by how the FC is structured, in this case the timing and the number of marks associated with assessments. This group did not seek to engage with and understand online materials before class,

in order to learn and prepare for their assessments. These findings show that learning strategies can change quickly in response to changes in how the FC is structured. As well as considering when material was accessed, the two clusters were also examined in terms of their performance, and level of VLE activity using independent sample t-tests.

4.1. Performance by cluster

Having identified two learning strategies, the performance of each is now examined. The flipped class had two sections, both of which were worth 30% of the available marks. The course also included a 40% group project but that is not included as part of this study. Section 1 was assessed through a 6% assessment each week for 5 weeks. Section 2 of the course involved a 30% written exam based on three weeks of content. Students in the Prepared cluster performed better (Table 2) than those in the Assessment-focused cluster for both section 1 (22.1% versus 18.3%) and section 2 (13.7% versus 12.8%). Only the performance for section 1 was statistically significant (Table 2). Therefore, it was those students who followed the flipped classroom structure as intended that performed better in assessments than those students that focused on the assessments rather than the classes.

4.2. Activity by cluster

Students' activity was measured based on the number of times they accessed the class website (total number of sessions), the number of activities that took place within each section (total number of events, average number of events per session). As each section of the course had a different duration a weekly average number of sessions and a weekly average number of events figure was calculated to allow for more direct comparisons to be made.

At the semester level, differences between cluster activities were statistically significant (Table 3). The Prepared cluster accessed the class site more often with a higher number of sessions than the assessment focused group (72.22 vs. 58.96, $p = 0.026$). Students from the prepared cluster also engaged with the class site more over the semester, with a higher total number of events (256.39 vs. 216.75, $p = 0.039$) than the Assessment focused group. The Prepared group had a slightly lower number of events per session (3.59 vs. 3.94, $p = 0.013$). The low number of events per session, for both groups, suggest students accessed the VLE for a specific purpose each time.

The Prepared cluster accessed the VLE more often. For section 1, the number of times the prepared cluster accessed the class website (23.95) was higher than the Assessment-focused session (16.97). For session 2, the Prepared number of sessions (21.22) were again higher than the Assessment-focused (15.90) at $p = 0.000$ and 0.001 significance levels respectively. In terms of events, again the Prepared cohort had 104.93 events for section 1 and 135.03 events for section 2 compared with lab-focused students' scores of 82.39 and 116.90 respectively. However, this was only statistically significant for section 1.

The average number of sessions per week was examined for each cluster for each of the 12 weeks of the semester (Fig. 1). For section 1 the Prepared cluster was more active every week. It is worth noting that while there was no class in week 8 there were individual group meetings regarding the group project which might help explain the increased activity that week.

Instead of weekly assessments, section 2 (weeks 9–11) was examined in week 12. In addition, online materials changed from videos to journal articles. The Prepared cluster were consistently active in accessing material, albeit closer to class time (Table 1). Activity for the Assessment-focused cluster for section 2 dropped until the week of the last class when, for the first time, it exceeded the Prepared cluster level indicating that this group engaged with online material when an assessment was imminent (Fig. 1).

5. Discussion

A key difference between flipped classrooms and traditional lectures is that, for FCs, online material is provided before class (Aznar-Díaz et al., 2020; Cheng et al., 2019; Shahnama et al., 2021) to enable preparation (Shahnama et al., 2021; vanLeeuwen et al., 2019). This paper focuses on the 'Achilles's heel' (Fisher et al., 2020) of the FC, namely the underlying assumption that students will not use the available online resources to prepare for in-class sessions. In doing so this research fills a recognised gap, answering answers calls by Stöhr and Adawi (2018) to examine how and why the FC works and Cheng et al. (2019) to examine the effects of different ways in which the FC can be designed and implemented.

This study is methodologically novel in the way it uses cluster analysis. This analytics technique was used to identify learning strategies used by students based on when they interacted with online pre-class materials. Although cluster analysis has the ability to

Table 1
Description of clusters.

Cluster	Prepared	Assessment-focused
Description	Accessed all elements ahead of time.	Only Accessed Labs ahead of time.
Proportion of population in cluster (Cluster size)	58% (n = 98)	42% (n = 71)
Variables:		
Earliest access time before section 1 classes ^a	19Hours, 11 Minutes	–3 days, 7 Hours, 23 Minutes
Earliest access time after class but before weekly section 1 assessment ^a	4 Days, 8 Hours, 44 Minutes	2 Days, 2 Hours, 28 Minutes
Earliest access time before section 2 classes ^a	60 min	–10 days, 14 Hours, 55 Minutes

^a Positive cluster variable values indicate the length of time before the event while negative values indicate the length of time after the event.

Table 2
Cluster performance.

Percentage Score (out of 30)	Prepared Cluster (n = 98)	Assessment Focused Cluster (n = 71)	t	Sig
	Mean (SD)	Mean (SD)		
Section 1	22.12 (5.00)	18.30 (5.54)	4.68	0.000
Section 2	13.79 (4.81)	12.83 (4.69)	1.29	0.100

Table 3
Cluster activity.

Variable	Prepared Cluster (n = 98)		Assessment-Focused Cluster (n = 71)		t	Sig
	Mean	SD	Mean	SD		
Section 1						
Total number of sessions	23.95	8.71	16.97	7.17	5.53	0.000
Weekly average number of sessions	3.42	1.25	2.42	1.02	5.53	0.000
Total number of events	104.93	54.96	82.39	42.50	2.86	0.002
Weekly average number of events	14.99	7.85	11.77	6.07	2.86	0.002
Average number of events per session	4.53	1.97	5.04	1.86	-1.70	0.045
Section 2						
Total number of sessions	21.22	12.04	15.90	7.57	3.28	0.001
Weekly average number of sessions	4.25	2.40	3.18	1.51	3.28	0.001
Total number of events	135.03	97.62	116.90	80.77	1.28	0.101
Weekly average number of events	27.00	19.53	23.38	16.15	1.28	0.101
Average number of events per session	6.30	3.12	7.62	5.81	-1.90	0.029
Both Sections						
Total number of sessions	72.22	47.31	58.96	37.55	1.96	0.026
Total number of events	256.39	156.78	216.75	121.63	1.78	0.039
Average number of events per session	3.60	0.82	3.95	1.29	-2.23	0.013

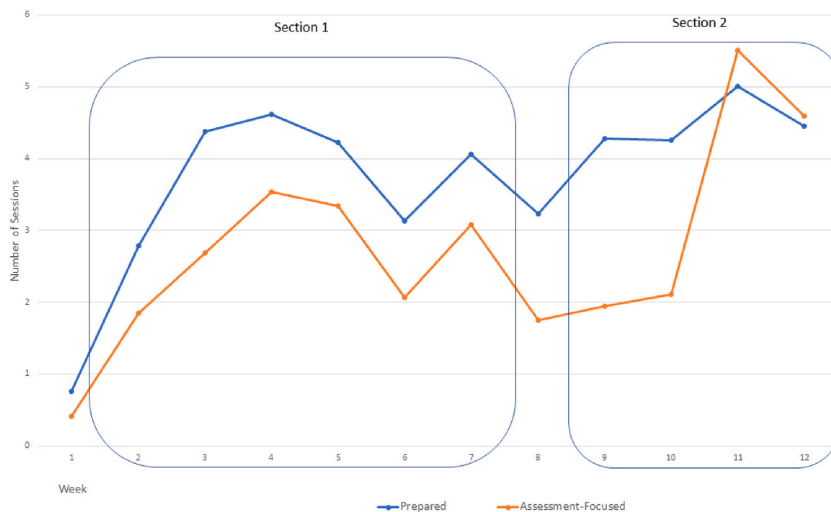


Fig. 1. Average number of sessions per cluster per week.

identify patterns of student behaviour the technique has not been used extensively in FC studies. While [Davies et al. \(2021\)](#) identified clusters based on activity codes, this study was novel by including, as input variables, the length of time prior to class and prior to assessments that online material was first accessed. Some studies have used cluster analysis to identify clusters based on students' perceptions of the FC such as [McNally et al. \(2017\)](#) who found flip resistors and flip endorsers or [Salehudin and Alpert \(2022\)](#) who grouped students based on preferences for videos. However, this research categorises students based on the timing of their interaction with online pre-class materials. Given flipped classrooms rely on students interacting with such resources in advance of class it is clearly important to examine whether this took place, or whether students procrastinated, before then considering their ultimate activity and performance in a flipped classroom. The inclusion and emphasis on this temporal perspective in future studies could help explain the differences in findings that currently exist in the flipped classroom literature.

This study identified two distinct learning strategies used by FC students. The Prepared cluster accessed material prior to class, in a way that is expected and consistent with the flipped classroom method. The second, Assessment-focused group, did not access online

material before class but rather waited until an assessment was looming. This latter group procrastinated, confirming the existence of the flipped classroom's 'Achilles's heel'. Indeed, including temporal variables in the analysis helped to quantify the degree to which such procrastination took place.

Our findings, for undergraduates, are similar to results for post-graduates that were examined by Walsh and Rísquez (2020) who identified average and below average performance among what they termed clusters of last-minute preparers and exam-focused students respectively. However, our findings differ from Davies et al. (2021) whose high-performing student cluster used videos very little while their Novice-Careful cluster relied more on video material. Additionally, while Davies et al. (2021) found students relied more on written material over video resources, this study found the opposite. A key difference was that while Davis et al. (2021) point out some of their students would have a knowledge of the material before, this was not the case in the current study, which explains why online resources were used more in this FC. Fan et al. (2021) used the length of time students spent on activities, identifying learning strategies that were search, content, content and assessment, and assessment orientated: this study extends their analysis by including additional variables such as the timing of when content was accessed and also whether this occurred pre-class or pre-assessment. Like Yilmaz and Baydas (2017) this study also found that students adapted their learning strategy over the course of only a few weeks. However, while Yilmaz and Baydas (2017) attributed this change to students increasing familiarity with the FC, this research posits that adaption of students' learning strategies also occurs in response to changes in changes in the structure of the FC. Therefore, it is important that FC research findings are considered in light of the particular way in which the flip is implemented.

Previous work has considered the importance of self-regulation within learning strategies (AlJarrah et al., 2018; Cheng et al., 2019; Davies et al., 2021; Dianati et al., 2022). The two learning strategies identified in this paper have implications for self-regulation. For the Prepared cluster, regular small-stakes assessments, coupled with video-based resources in section 1 of the course, helped students regulate their learning in a manner that was to be expected in a FC. This implementation of the flip allowed students to take advantage of in-class learning opportunities such as problem-solving (Lo, 2018; Sarkar et al., 2020; Zainuddin & Halili, 2016) and collaboration (Hwee & Koh, 2019; Turan & Goktas, 2016; Wang et al., 2019). Even in section 2 of the course, an element of self-regulation and preparation was present: instead of reading material, the articles were downloaded before class for easy access and use during the in-class activities. Assessment-focused students engaged with material, so that transmittal was achieved, albeit after class. This strategy meant they could not capitalise on a key advantage of the FC, namely deepening higher-order skills by drawing on pre-class knowledge during in-class activities (Davies et al., 2013; Haagsman et al., 2020; Hwee & Koh, 2019; Long et al., 2019). Without having accessed the online materials in advance of class they then had limited opportunity to engage with in-class discussions and exercises which Lee and Choi (2019) deem the most important phase of the FC. Inadequate preparation limits students' in-class collaboration and problem-solving abilities, increasing student passivity. Therefore, the way in which a flipped classroom is structured, in terms of the type of resources and assessments used, can facilitate, or detract from, students self-regulation.

The existence of Prepared and Assessment-focused groups raises issues for in-class group formation when engaging in-class exercises. Allowing groups to self-form may result in prepared students working together to maximise their own learning. This would have the effect of limiting the less prepared students involvement, placing them merely in the role of onlookers. Alternatively, randomly allocating class groups, mixing preparedness levels, benefits the less prepared students and limits the learning opportunities for prepared students. By limiting the value derived from preparation, a possible consequence of this would be to reduce subsequent preparation and reduce the overall value of the flipped classroom.

In both sections of the course Prepared students performed better than their Assessment-focused counterparts indicating FCs increase learning when used as intended. Performance differences between groups was less apparent in section 2. This was to be expected as, even for the Prepared group, less engagement was evident from both groups with participants not having time to read and digest material in advance. AlJarrah et al. (2018) and Perera et al. (2009) first categorised students by performance before applying cluster analysis when examining temporal patterns of student behaviour. This study was different as it used cluster analysis based on student activity to categorise students and only then examining cluster performance. This approach allowed learning strategies to be determined first, among the three years of students that took the course, with the performance of each strategy then compared. Rather than consider the time spent on activities as input variables for clustering, like Davies et al. (2013), this study examined the length of time material was accessed before events rather than time spent on events. Luo et al. (2019) found student agency aids higher performance. In this paper an important aspect of agency was accessing pre-class material sufficiently well in advance of class to aid increased learning and performance. This study found that the FC benefitted prepared students who engage consistently with online materials in advance of class. This confirms the value of regular assessments both in increasing interactivity with online material (Haagsman et al., 2020; Lo, 2018) and in regulating student activity (Shahnama et al., 2021).

6. Conclusion

A key problem with the flipped classroom method is student procrastination and a lack of pre-class preparation which limits the potential value of subsequent in-class activities. This paper is novel by examining how far in advance of class students begin engaging with online materials, identifying the main learning strategies used, and the relative performance of each. Using cluster analysis, two learning strategies were identified: 'prepared' and 'assessment-focused'. While cluster analysis is a widely used learning analytics technique there is a need for its increased use when examining FCs. In particular, temporal variables should be included in future analyses. A limitation of this research is that both the timing of assessments and the type of online material used both changed from section 1 to section 2 of the course. Future studies should examine each change separately.

Compared to traditional lectures, FCs provide students with additional online resources. The Prepared cluster, using the FC largely as expected, had higher performance than the Assessment-focused cluster. Such findings raise the question of whether higher

performance in FCs, compared to traditional methods, is partly due to the increased availability of online materials which can be used for learning and revision. This would mean that, for some students, it may not necessarily be the FC method that resulted in improved performance but rather it was the availability of online resources. There is a need for more research that uses VLE data to consider the timing and extent of student engagement with online resources both before class and before assessments.

This study was novel by examining how the same students engaged with two differently structured versions of a flipped classroom. For all students, there was earlier pre-class engagement when online materials involved videos, rather than when they were text based. However, even the prepared cluster of students engaged in a late and limited way when the resources were texts. The FC involved a fourth-year final semester course where it might be assumed students would possess stable learning strategies. However, this study found that such students were still quick to modify learning strategies in response to changes in the FC structure. This may be partly due to the novel nature of the FC to students that were more used to traditional methods. More studies are needed that consider the stability or malleability of learning strategies among the same group of students, ideally as they encounter differently structured FCs.

While assessments reduce procrastination, their timing is important. This study considered how students responded to differently timed assessments. Regular weekly post-class assessments encouraged students use of online resources. However, while placing the assessment after-class enabled higher-order skills to be assessed it also resulted in the assessment-focused cluster not preparing for the class session that developed the very skills that were going to be assessed. When classes were even a few weeks in advance of the assessment, class preparation decreased. Low-stakes regular assessments support the regulation of student behaviours aligned with the FC method. A question for future research is whether assessment over-use inhibits students' ability to self-regulate.

CRediT authorship contribution statement

John N. Walsh: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

Data availability

The authors do not have permission to share data.

References

- Al-Samarraie, H., Shamsuddin, A., & Alzahrani, A. I. (2020). A flipped classroom model in higher education: A review of the evidence across disciplines. *Educational Technology Research & Development*, 68, 1017–1051. <https://doi.org/10.1007/s11423-019-09718-8>
- Al-Zahrani, A. M. (2015). From passive to active: The impact of the flipped classroom through social learning platforms on higher education students' creative thinking. *British Journal of Educational Technology*, 46(6), 1133–1148. <https://doi.org/10.1111/bjet.12353>
- AlJarrah, A., Thomas, M. K., & Shehab, M. (2018). Investigating temporal access in a flipped classroom: Procrastination persists. *International Journal of Educational Technology in Higher Education*, 15(1), 1–18. <https://doi.org/10.1186/s41239-017-0083-9>
- Aznar-Díaz, I., Hinojo-Lucena, F.-J., Cáceres-Reche, M.-P., & Romero-Rodríguez, J.-M. (2020). Pedagogical approaches in the knowledge society: The flipped classroom method for the development of creativity and dialogical learning. *International Journal of Emerging Technologies in Learning*, 15(3), 4–14. <https://doi.org/10.3991/ijet.v15i03.11664>
- Boevé, A. J., Meijer, R. R., Bosker, R. J., Vugteveen, J., Hoekstra, R., & Albers, C. J. (2017). Implementing the flipped classroom: An exploration of study behaviour and student performance. *Higher Education*, 74, 1015–1032. <https://doi.org/10.1007/s10734-016-0104-y>
- Brown, C. A., Danvers, K., & Doran, D. T. (2016). Student perceptions on using guided reading questions to motivate student reading in the flipped classroom. *Accounting Education*, 25(3), 256–271. <https://doi.org/10.1080/09639284.2016.1165124>
- Carvalho, A. (2013). Students' perceptions of fairness in peer assessment: Evidence from problem-based learning course. *Teaching in Higher Education*, 18(5), 491–505. <https://doi.org/10.1080/10562517.2012.753051>
- Chan, S.-Y., Lamb, Y. K., & Ng, T. F. (2020). Student's perception on initial experience of flipped classroom in pharmacy education: Are we ready? *Innovations in Education & Teaching International*, 57(1), 62–73. <https://doi.org/10.1080/14703297.2018.1541189>
- Cheng, L., Ritzhaupt, A. D., & Antonenko, P. (2019). Effects of the flipped classroom instructional strategy on students' learning outcomes: A meta-analysis (Vol. 67, pp. 793–824). *Educational Technology Research & Development*. <https://doi.org/10.1007/s11423-018-9633-7>
- Choa, M.-H., Park, S. W., & Leec, S.-e. (2021). Student characteristics and learning and teaching factors predicting affective and motivational outcomes in flipped college classrooms. *Studies in Higher Education*, 46(3), 509–522.
- Choi, J., & Lee, Y. (2018). To what extent does 'flipping' make lessons effective in a multimedia production class? *Innovations in Education & Teaching International*, 55(1), 3–12. <https://doi.org/10.1080/14703297.2015.1123105>
- Chuang, H.-H., Weng, C.-Y., & Chen, C.-H. (2018). Which students benefit most from a flipped classroom approach to language learning? *British Journal of Educational Technology*, 49(1), 56–68. <https://doi.org/10.1111/bjet.12530>
- Cilliers, L., & Pylman, J. (2022). South African students' perceptions of the flipped classroom: A case study of higher education. *Innovations in Education & Teaching International*, 59(3), 296–305. <https://doi.org/10.1080/14703297.2020.1853588>
- Davies, R., Allen, G., Albrecht, C., Bakir, N., & Ball, N. (2021). Using educational data mining to identify and analyze student learning strategies in an online flipped classroom. *Education Sciences*, 11(11), 668–679. <https://doi.org/10.3390/educsci11110668>
- Davies, R. S., Dean, D. L., & Bal, N. (2013). Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course. *Educational Technology Research & Development*, 61, 563–580. <https://doi.org/10.1007/s11423-013-9305-6>
- Del Valle, R., & Duffy, T. M. (2009). Online learning: Learner characteristics and their approaches to managing learning. *Instructional Science*, 37, 129–149.
- Dianati, S., Iwashita, N., & Vasquez, C. (2022). Flipped classroom experiences: Comparing undergraduate and postgraduate perceptions of self-regulated learning. *Issues in Educational Research*, 32(2), 473–493. www.iier.org.au/iier32/dianati.pdf
- Díaz, M. J. S., Antequera, J. G., & Pizarro, M. C. (2021). Flipped classroom in the context of higher education: Learning, satisfaction and interaction. *Education Sciences*, 11, 416–433. <https://doi.org/10.3390/educsci11080416>
- Divjak, B., Rienties, B., Iniesto, F., Vondra, P., & Žizak, M. (2022). Flipped classrooms in higher education during the COVID-19 pandemic: Findings and future research recommendations. *International Journal of Educational Technology in Higher Education*, 19(9), 1–24. <https://doi.org/10.1186/s41239-021-00316-4>
- Dong, Y., Yin, H., Du, S., & Wang, A. (2021). The effects of flipped classroom characterized by situational and collaborative learning in a community nursing course: A quasi-experimental design. *Nurse Education Today*, 105, Article 105037. <https://doi.org/10.1016/j.nedt.2021.105037>
- Elmaadaway, M. A. N. (2018). The effects of a flipped classroom approach on class engagement and skill performance in a Blackboard course. *British Journal of Educational Technology*, 49(3), 479–491. <https://doi.org/10.1111/bjet.12553>

- Fan, Y., Matcha, W., Uzir, N. A., Wang, Q., & Gasevic, D. (2021). Learning analytics to reveal links between learning design and self-regulated learning. *International Journal of Artificial Intelligence in Education*, 31, 980–1021. <https://doi.org/10.1007/s40593-021-00249-z>
- Fisher, R. L., LaFerriere, R., & Rixon, A. (2020). Flipped learning: An effective pedagogy with an Achilles' heel. *Innovations in Education & Teaching International*, 57(5), 543–554. <https://doi.org/10.1080/14703297.2019.1635904>
- Gasevic, D., Dawson, S., & Siemens, G. (2015). Let's not forget: Learning Analytics are about Learning. *TechTrends*, 59(1), 64–71.
- Haagsman, M. E., Scager, K., Boonstra, J., & Koster, M. C. (2020). Pop-up questions within educational videos: Effects on students' learning. *Journal of Science Education and Technology*, 29, 713–724. <https://doi.org/10.1007/s10956-020-09847-3>
- He, W., Holton, A., Gu, H., Warschauer, M., & Farkas, G. (2019). Differentiated impact of flipped instruction: When would flipped instruction work or falter? *International Journal of Teaching and Learning in Higher Education*, 31(1), 32–49. www.ijetl.org/ijetl/
- Hendrik, H., & Hamzah, A. (2021). Flipped classroom in programming course: A systematic literature review. *International Journal of Emerging Technologies in Learning*, 16(2), 220–236.
- Hsia, L.-H., & Hwang, G.-J. (2020). From reflective thinking to learning engagement awareness: A reflective thinking promoting approach to improve students' dance performance, self-efficacy and task load in flipped learning. *British Journal of Educational Technology*, 51(6), 2461–2477. <https://doi.org/10.1111/bjet.12911>
- Hwee, J., & Koh, L. (2019). Four pedagogical dimensions for understanding flipped classroom practices in higher education: A systematic review. *Educational Sciences: Theory and Practice*, 19(4), 14–33. <https://doi.org/10.12738/estp.2019.4.002>
- Hyttinen, M., & Suhonen, J. (2022). Using the flipped classroom and learning diary to enhance learning in higher education: Students' experiences of flipping the basics of law course. *International Journal of Teaching and Learning in Higher Education*, 33(3), 446–464.
- Jakobsen, K. V., & Knetemann, M. (2017). Putting structure to flipped classrooms using team-based learning. *International Journal of Teaching and Learning in Higher Education*, 29(1), 177–185.
- Jang, H. Y., & Kim, H. J. (2020). A meta-analysis of the cognitive, affective, and interpersonal outcomes of flipped classrooms in higher education. *Education Sciences*, 10, 1–16. <https://doi.org/10.3390/educsci10040115>
- Judson, K., & Aurand, T. W. (2021). Student perceptions of the flipped classroom: An evaluation of hybrid pedagogy in the marketing classroom. *Journal of Higher Education Theory and Practice*, 21(5), 13–26.
- Kazanidis, I., Pellas, N., Fotaris, P., & Tsinakos, A. (2019). Can the flipped classroom model improve students' academic performance and training satisfaction in Higher Education instructional media design courses? *British Journal of Educational Technology*, 50(4), 2014–2027. <https://doi.org/10.1111/bjet.12694>
- Kreber, C., Castleden, H., Erfani, N., & Wright, T. (2005). Self-regulated learning about university teaching: An exploratory study. *Teaching in Higher Education*, 10(1), 75–97.
- Lee, J., & Choi, H. (2019). Rethinking the flipped learning pre-class: Its influence on the success of flipped learning and related factors. *British Journal of Educational Technology*, 50(2), 934–945. <https://doi.org/10.1111/bjet.12618>
- Li, S., & Suwanthep, J. (2017). Integration of flipped classroom model for EFL speaking. *International Journal of Learning and Teaching*, 3(2), 118–123.
- Limaymanta, C. H., Apaza-Tapia, L., Vidal, E., & Gregorio-Chaviano, O. (2021). Flipped classroom in higher education: A bibliometric analysis and proposal of a framework for its implementation. *International Journal of Emerging Technologies in Learning*, 16(9), 133–149. <https://doi.org/10.3991/ijet.v16i09.21267>
- Lo, C. K. (2018). Grounding the flipped classroom approach in the foundations of educational technology. *Educational Technology Research & Development*, 66, 793–811. <https://doi.org/10.1007/s11423-018-9578-x>
- Long, T., Cummins, J., & Waugh, M. (2019). Investigating the factors that influence higher education instructors' decisions to adopt a flipped classroom instructional model. *British Journal of Educational Technology*, 50(4), 2028–2039. <https://doi.org/10.1111/bjet.12703>
- Lu, O. H. T., Huang, A. Y. Q., Huang, J. C. H., Lin, A. J. Q., Ogata, H., & Yang, S. J. H. (2018). Applying learning analytics for the early prediction of students' academic performance in blended learning. *Educational Technology & Society*, 21(2), 220–232.
- Lundin, M., Rensfeldt, A. B., Hillman, T., Lantz-Andersson, A., & Peterson, L. (2018). Higher education dominance and siloed knowledge: A systematic review of flipped classroom research. *International Journal of Educational Technology in Higher Education*, 15, 1–30. <https://doi.org/10.1186/s41239-018-0101-6>
- Luo, H., Yang, T., Xue, J., & Zuo, M. (2019). Impact of student agency on learning performance and learning experience in a flipped classroom. *British Journal of Educational Technology*, 50(2), 819–831. <https://doi.org/10.1111/bjet.12604>
- Masland, L., & Gizdarska, S. (2018). 'Then what Am I paying you for?' Student attitudes regarding pre-class activities for the flipped classroom. *International Journal of Teaching and Learning in Higher Education*, 30(2), 234–244.
- McCallum, S., Schultz, J., Sellke, K., & Spartz, J. (2015). An examination of the flipped classroom approach on college student academic involvement. *International Journal of Teaching and Learning in Higher Education*, 27(1), 42–55.
- McNally, B., Chipperfield, J., Dorsett, P., Fabbro, L. D., Frommolt, V., Goetz, S., Lewohl, J., Molineux, M., Pearson, A., Reddan, G., Roiko, A., & Rung, A. (2017). Flipped classroom experiences: Student preferences and flip strategy in a higher education context. *Higher Education*, 73, 281–298. <https://doi.org/10.1007/s10734-016-0014-z>
- Mirriahi, N., Liaqat, D., Dawson, S., & Gasevic, D. (2016). Uncovering student learning profiles with a video annotation tool: Reflective learning with and without instructional norms. *Educational Technology Research & Development*, 64, 1083–1106.
- Pattanaphanchai, J. (2019). An investigation of students' learning achievement and perception using flipped classroom in an introductory programming course: A case study of Thailand higher education. *Journal of University Teaching and Learning Practice*, 16(5), 1–17.
- Perera, D., Kay, J., Koprinska, I., Yacef, K., & Zaiiane, O. R. (2009). Clustering and sequential pattern mining of online collaborative learning data. *IEEE Transactions on Knowledge and Data Engineering*, 21, 759–772. <https://doi.org/10.1109/tkde.2008.138>
- Pérez, A., Collado, J., Salmones, M. M. G., Herrero, Á., & Martín, H. S. (2019). An empirical exploration of the perceived effectiveness of a 'flipped classroom' in a business communication course. *The Journal of Scholarship of Teaching and Learning*, 19(2), 47–65. <https://doi.org/10.14434/josotl.v19i1.22842>
- Prashar, A. (2015). Assessing the flipped classroom in operations management: A pilot study. *The Journal of Education for Business*, 90, 126–138. <https://doi.org/10.1080/08832323.2015.1007904>
- Price, C., & Walker, M. (2021). Improving the accessibility of foundation statistics for undergraduate business and management students using a flipped classroom. *Studies in Higher Education*, 46(2).
- Rahman, A. A., Zaid, N. M., Abdullah, Z., Mohamed, H., & Aris, B. (2018). *Social constructivism learning through project based Learning with Scaffolding in flipped classroom international conference on learning and teaching in computing and engineering (LaTICE)*. Auckland, New Zealand.
- Salehudin, I., & Alpert, F. (2022). A deeper understanding of student preferences for in-class video use: A segmentation analyses of needs, group differences and preference clusters. *Education & Training*, 64(4), 476–490. <https://doi.org/10.1108/ET-02-2021-0045>
- Sarkar, N., Ford, W., & Manzo, C. (2020). To flip or not to flip: What the evidence suggests. *The Journal of Education for Business*, 95(2), 81–87. <https://doi.org/10.1080/08832323.2019.1606771>
- Sezer, B., & Abay, E. (2019). Looking at the impact of the flipped classroom model in medical education. *Scandinavian Journal of Educational Research*, 63(6), 853–868. <https://doi.org/10.1080/00313831.2018.1452292>
- Shahnama, M., Ghonsooly, B., & Shirvan, M. E. (2021). A meta-analysis of relative effectiveness of flipped learning in English as second/foreign language research. *Educational Technology Research & Development*, 69, 1355–1386. <https://doi.org/10.1007/s11423-021-09996-1>
- Sohrabi, B., & Iraj, H. (2016). Implementing flipped classroom using digital media: A comparison of two demographically different groups perceptions. *Computers in Human Behavior*, 60, 514–524.
- Sommer, M., & Ritzhaupt, A. (2018). Impact of the flipped classroom on learner achievement and satisfaction in an undergraduate technology literacy course. *Journal of Information Technology Education: Research*, 17, 159–182. <https://doi.org/10.28945/4059>
- Steen-Utheim, A. T., & Foldnes, N. (2018). A qualitative investigation of student engagement in a flipped classroom. *Teaching in Higher Education*, 23(3), 307–324. <https://doi.org/10.1080/13562517.2017.1379481>
- Stöhr, C., & Adawi, T. (2018). Flipped classroom research: From “black box” to “white box” evaluation. *Education Sciences*, 8(1), 1–4. <https://doi.org/10.3390/educsci8010022>

- Stover, S., & Houston, M. A. (2019). Designing flipped-classes to be taught with limited resources: Impact on students' attitudes and learning. *The Journal of Scholarship of Teaching and Learning*, 19(3), 34–48. <https://doi.org/10.14434/josotl.v19i2.23868>
- Sun, J. C.-Y., Wu, Y.-T., & Lee, W.-I. (2017). The effect of the flipped classroom approach to OpenCourseWare instruction on students' self-regulation. *British Journal of Educational Technology*, (3), 713–729. <https://doi.org/10.1111/bjet.12444>, 2017.
- Swart, W., MacLeod, K., Wengrowicz, N., & Paul, R. (2021). Flipped classrooms and COVID-19 disruption: Empirical results. *Journal of Higher Education Theory and Practice*, 21(3), 131–143.
- Turan, Z., & Goktas, Y. (2016). The flipped classroom: Instructional efficiency and impact on achievement and cognitive load levels. *Journal of E-Learning and Knowledge Society*, 12(4), 51–62.
- vanderVelde, R., Blignaut-vanWestrhenen, N., Labrie, N. H. M., & Zweekhorst, M. B. M. (2021). 'The idea is nice... but not for me': First-year students' readiness for large-scale 'flipped lectures'—what (de)motivates them? *Higher Education*, 81, 1157–1175. <https://doi.org/10.1007/s10734-020-00604-4>
- vanLeeuwen, A., Bos, N., vanRavenswaaij, H., & vanOostenrijk, J. (2019). The role of temporal patterns in students' behavior for predicting course performance: A comparison of two blended learning courses. *British Journal of Educational Technology*, 50(2), 921–933. <https://doi.org/10.1111/bjet.12616>
- Walsh, J. N., O'Brien, M. P., & Costin, Y. (2021). Investigating student engagement with intentional content: An exploratory study of instructional videos. *International Journal of Management in Education*, 19(2), Article 100505. <https://doi.org/10.1016/j.ijme.2021.100505>
- Walsh, J. N., O'Brien, M. P., & Slattery, D. M. (2019). Video viewing patterns using different teaching treatments: A case study using YouTube analytics. *Research in Education and Learning Innovation Archives, REALIA*, 22(6), 77–95.
- Walsh, J. N., & Rísquez, A. (2020). Using cluster analysis to explore the engagement with a flipped classroom of native and non-native English-speaking management students. *International Journal of Management in Education*, 18, Article 100381. <https://doi.org/10.1016/j.ijme.2020.100381>
- Wang, Y., Huang, X., Schunn, C. D., Zou, Y., & Ai, W. (2019). Redesigning flipped classrooms: A learning model and its effects on student perceptions. *Higher Education*, 78, 711–728. <https://doi.org/10.1007/s10734-019-00366-8>
- Wu, Y. T., Chai, C. S., & Wang, L. J. (2022). Exploring secondary school teachers' TPACK for video-based flipped learning: The role of pedagogical beliefs. *Education and Information Technologies*, 27, 8793–8819. <https://doi.org/10.1007/s10639-022-10977-x>
- Xiu, Y., & Thompson, P. (2020). Flipped university class: A study of motivation and learning. *Journal of Information Technology Education: Research*, 19, 41–63. <https://doi.org/10.28945/4500>
- Yang, L., Sun, T., & Liu, Y. (2017). A bibliometric investigation of flipped classroom research during 2000–2015. *International Journal of Emerging Technologies in Learning*, 12(6), 178–186. <https://doi.org/10.3991/ijet.v12i06.7095>
- Yilmaz, R. M., & Baydas, O. (2017). An examination of undergraduates' metacognitive strategies in pre-class asynchronous activity in a flipped classroom. *Educational Technology Research & Development*, 65, 1547–1567. <https://doi.org/10.1007/s11423-017-9534-1>
- Zainuddin, Z., & Halili, S. H. (2016). Flipped classroom research and trends from different fields of study. *International Review of Research in Open and Distance Learning*, 17(3), 313–340.
- Zheng, L., Bhagat, K. K., Zhen, Y., & Zhang, X. (2020). The effectiveness of the flipped classroom on students' learning achievement and learning motivation: A meta-analysis. *Educational Technology & Society*, 23(1), 1–15.