Flipped classroom learning in a large introductory undergraduate engineering course

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CONTEXT

The flipped-classroom model is a recent educational development that is prominent in the literature on learning. The typical flipped class scenario involves students looking up information, reading printed materials or watching videos prior to gathering in a classroom to apply the knowledge through problem solving activities with guidance from the teacher. However, there is little research available about the effects of the flipped class on students' learning in large introductory engineering courses with a strong lab component that must be conducted in multiple streams. This current research is based at one New Zealand university with engineering student enrolments of typically 150 students. In the past few years, prior to the introduction of the flipped class, the course lecturers have been refining the teaching of the course through a focus on threshold concepts (TCs) and the introduction of online tutorials.

PURPOSE

This paper aims to address the question: Does flipping a first year electronic engineering class and changing the traditional role of the lecturer to a "learning guide" offer better value for money in terms of the lecturer's time, resources, and student satisfaction than the traditional face-to-face lecture model?

APPROACH

We adopted a design-based research approach to develop and trial a flipped class approach to help students learn the TCs and related concepts in electronic engineering. We will report on the design of the flipped class involving lecturer developed online videos and student collaborative problem solving activities. Data collected from lecturer reflections, student focus group interviews and student evaluation of the course will be reported and discussed.

RESULTS

Of the 64 students who responded to the midterm survey, over 80% found the videos helpful in learning key course ideas. About 70% of respondents indicated that the problem solving sessions helped them understand concepts covered in videos, 43% found them useful in allowing them to explain what they know so far in the course, and, about a quarter found them useful for applying their knowledge in real life and to practice team work skills. The course lecturers observed that as compared to previous years, students are more on- task in the labs, and that the problem solving activities worked well despite some students reporting that some of the exercises were a bit challenging. Regardless, the lecturers felt that the problem solving activities helped to complement the online video lectures.

CONCLUSIONS

The results suggest that flipping the class provides students with a more active student-centred learning context. Lecturers become learning facilitators or guide to address student queries when needed. Subsequently when lecturers and students get together in face-to-face class or lab sessions, these allow for more productive, group problem solving activities, and bolster the "esprit-de-corps" of the student cohort. It is our experience that without these changing roles and learning contexts, the flipped class loses more than it gains.

KEYWORDS

Flipped classroom, engineering education, threshold concepts learning, blended learning, university

Introduction

This study addresses the question of whether flipping a first-year electronic engineering class—that is, replacing lectures with a suite of selected or specifically-produced video lectures and with increased interactive class activities—lead to greater satisfaction and better value for money in terms of the staff time and resources than the traditional face-to-face, lecture-centric model. This current research is based at one New Zealand university with engineering student enrolments of typically 150 students. In the past few years, the course lecturers have been refining the teaching of the course through a focus on threshold concepts (TCs) and the introduction of online tutorials. These efforts have been extended to encompass a flipped classroom intervention to better support and facilitate student learning in the course. Several aspects of the modern engineering-teaching environment bear on and motivate this study.

The Common Large-Class Model in Engineering

In first-year engineering classes numbers are frequently quite large, with class sizes of one to several hundred students being common. The "broadcast" style of teaching via lectures copes satisfactorily with such groups, but tutorials and laboratory classes are only practical with smaller numbers of students, typically 20 to 40 in each class. This necessitates that the cohort be broken into multiple streams. The streams are scheduled to have their tutorial or lab classes at different times and days, over a period of one or occasionally two weeks. A pedagogically undesirable circumstance arises in this scenario, which we call "The Phase Problem". Most significant is that lectures pertinent to a given lab or tutorial (small) class must precede that class to be useful to the students, and so must occur before the *first* such small class. Those lectures will then occur days or weeks ahead of when their content will be used by the *last* stream in the set, displacing the broadcast from the application, with potentially undesirable pedagogical impact (White et al., 1995). For example, in a course with 5 parallel streams occurring on 5 afternoons of the week, and three lectures on three consecutive days, the first usage in a small class of a broadcast lecture is displaced by 3 to 5 days and the last usage by 8 to 10 days. An assessment that should follow a small class suffers the same variable delay.

Cost Pressure and the Promise of Online Learning

Universities are under considerable pressure to control costs. Modern technologies are seen as offering the chance to increase pedagogical efficiency and enhance student learning. However, international literature indicated that there is limited rigorous literature and research that points to the actual effects on workload in online and blended higher education teaching environments (Tynan, Ryan, & Lamont Mills, 2013). The wide availability of broadband connections, public sources of information such as Wikipedia and Youtube, personal computing devices with colour screens, electronic whiteboards and lightboards, and learning-management systems such as Moodle or OpenEdX are touted to reduce staff and student effort. However, with an increase of new technologies in university life in a recent article, Rumble (2011) acknowledges the additional workload that the development of online teaching requires and points to a lack of agreement on how such costs should be included and calculated. "Teaching costs" might include but are not limited to information communication technology infrastructure, redevelopment of content, supporting students, managing assessment online and other service costs.

Threshold Concepts

Emerging evidence exists for the value of structuring curricula around threshold concepts (Male, & Baillie, 2011; Peter & Harlow, 2014). Meyer and Land (2003; 2006) introduced the notion of threshold concepts (TCs) as those concepts that students need to master in order to think like a subject specialist. However, students often find TCs troublesome, and this is where they often ‘get stuck’. By designing their pedagogy to target the teaching and learning of specific TC content, lecturers can optimise student learning outcomes.

This research builds on our previous study which found support for the effectiveness of a TC-based pedagogy and assessment with engineering students. Students in the previous study also reported a preference for learning the course content through online tutorials that they could work through independently in their own time and pace (Peter et al., 2013).

The Flipped Classroom

The flipped-classroom is a student-centred educational development that is prominent in the recent literature on learning. The typical flipped class scenario involves students finding and reading books or papers, or watching videos, in order to gain basic information in their own time, and then gathering in a classroom to apply the knowledge through problem solving activities with guidance from the teacher (Strayer, 2012). Overall, the existing literature shows findings from flipped class research appear consistently positive (Bishop & Verleger, 2013) and suggest that students are differentially predisposed to be somewhat suited to a flipped teaching environment (e.g., Anderson et al., 2013), and many have found that students tend to prefer flipped to traditional teaching environments (e.g., Bates and Galloway 2012).

Flipping the focus of class time allows students to take increased responsibility for their own learning through active investigation both in and outside of class time. This changes the class time focus and dynamics from the transmission of knowledge to one involving collaborative, interactive learning and just-in-time teaching (Bonk & Khoo, 2014). It provides more flexibility for lecturers and students to participate in discussion and collaborative and guided problem solving activities in ways that are known to address student misconceptions and support the mastery of threshold concepts (O’Toole, 2013).

Research Design

We adopted a design-based research (DBR) approach to develop, trial and evaluate the TC-based flipped class approach to help students learn the TCs and related concepts in electronic engineering. A DBR approach can provide insights into teaching practices, deepen theoretical thinking, and contribute to better understanding of student learning processes within technology-enhanced teaching contexts (Reeves, McKenney, & Herrington, 2011).

In our work, we have been involved in three iterations and refinement of the TC-based flipped pedagogical intervention involving practitioner-researcher led cyclical process of planning, design (including development work), and implementation to understand the process and impact of the intervention. The expectation was that by flipping the class, students would have more opportunities to be active knowledge constructors with the lecturer facilitating students to achieve deeper levels of thinking and higher levels of knowledge application.

Research Context

Participants

Of the 144 students enrolled in the course 64 students completed the midterm survey and 106 students completed the end of semester survey. Six students attended the focus group meeting. The study received ethical approval from the University’s Human Ethics Committee and all participants participated in the study on a strictly voluntary basis.

The course

The course in this study has traditionally consisted of three one-hour long lectures, an hour-long tutorial session, and one weekly three-hour laboratory session. Each student was expected to attend all lectures and one of 5 parallel laboratory (lab) streams, which run once a day on each day of the week. Since 2013, the face-to-face tutorial sessions had been replaced by online tutorials allowing students to solve tutorial problems at their own pace. The switch to online tutorials was welcomed by the majority of students, and resulted in a significant improvement in both learning and satisfaction.

In our TC-based flipped-class approach the weekly lectures were replaced with a suite of short lecturer-developed "Khan-Academy-style" videos (Khan Academy, 2015). The instructional videos targeted two TCs in the course (circuit modelling in the form of Thevenin's theorem, and linear approximation in the case of dynamic resistance). These had to be specially developed as TCs are rarely addressed in the publically-available online materials. Where addressed, the material was usually a video of a traditional blackboard lecture, typically an hour in duration.

As these TCs are mostly taught using circuit diagrams, graphs, and equations, the videos recorded and allowed the lecturer to draw, modify and elaborate using a drawing tablet and eventually a Lightboard to replicate the way he usually teaches in his face-to-face class. Smoothdraw and Quicktime were used for the video screen capture. Sorden's (2005) principles guided the development of the instructional videos. The videos were created over two lots of 3-month period during which the lecturer worked intensely with educational researchers and a professional video-production technician to achieve a high standard.

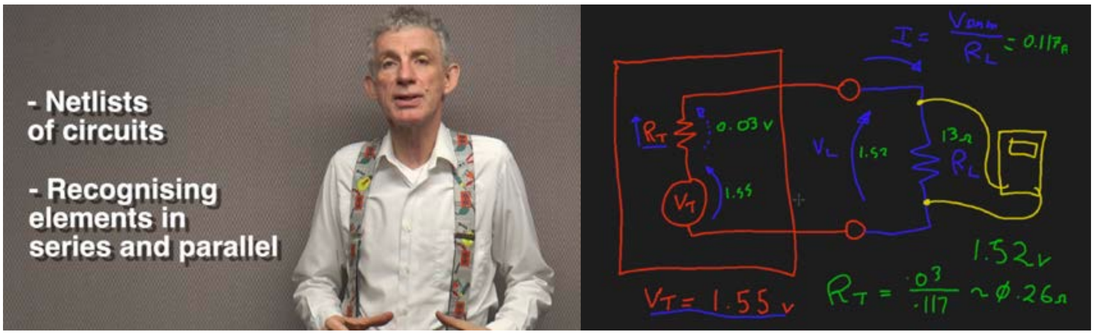

Figure 1: Screenshots from a lecturer-developed video

Materials and Procedure

Altogether, 75 videos between 3 and 15 minutes long were designed, recorded, edited and made available to students from the course's university online learning management system (Moodle). Links to another approximately 30 publically-available videos hosted on Youtube were included in the course Moodle site as supplementary material where appropriate.

Students were regularly reminded to watch the weekly assigned videos prior to attending the face-to-face class sessions. The course was taught by two lecturers (L1 and L2). In addition to watching the lecturer-prepared course videos, students were expected to participate in the following activities: Once a week working in pairs to solve problems from a worksheet; completing online tutorials (marks were allocated for completing the tutorials); a 3-hour hands on lab session where students work in pairs and can ask questions of the lecturers and lab demonstrators (marks were allocated for work completed in the labs); an online forum for students to ask questions when needed; occasional optional lecturer-led session to assist students with a difficult topic or preparation before an assessment; and a bi-weekly assessment (there were no midterm or final exams).

We report on lecturer reflections, student focus group interviews and student evaluation of the course (mid-semester survey and end-of-semester survey) collected from the third iteration of the intervention. The survey data was analysed using SPSS software while the focus group interview data was thematically analysed to identify emerging themes.

Findings

Findings from the student survey and focus group interviews will be reported first followed by the lecturers' reflections.

Student Perceptions

Mid-semester survey

Over 80% of students indicated that the lecturer developed videos were helpful in learning key course ideas. About 70% of respondents reported that the problem solving sessions helped them understand concepts covered in videos, 43% found them useful in allowing them to explain what they learnet in the course, and, about a quarter found them useful for applying their knowledge in real life and to practice teamwork skills.

End-of-the-semester survey

Figure 1 summarises the findings on student learning. About half of students (51%) said that they watched assigned videos before their labs, 16% watched them before weekly problem solving activities, and 24% watched before both weekly problem solving activities and their respective weekly labs. Importantly 24% of students felt that the flipped class contributed very much to their learning of TCs, 58% said that it somewhat contributed to their learning and 12% felt that it did not contribute at all to their learning. About half of responding students (51%) felt that fortnightly assessment help them learn very much, 42% said that they somewhat helped and 7 students student said that they did not help at all.

About a third of students said that they took notes all the time, 56% said they took them sometimes and 11% said they never took notes while watching videos.

When asked if they preferred flipped class or traditional approach 47% of respondents said they preferred or strongly preferred flipped approach, 20% had no preference and 15% preferred the traditional approach.

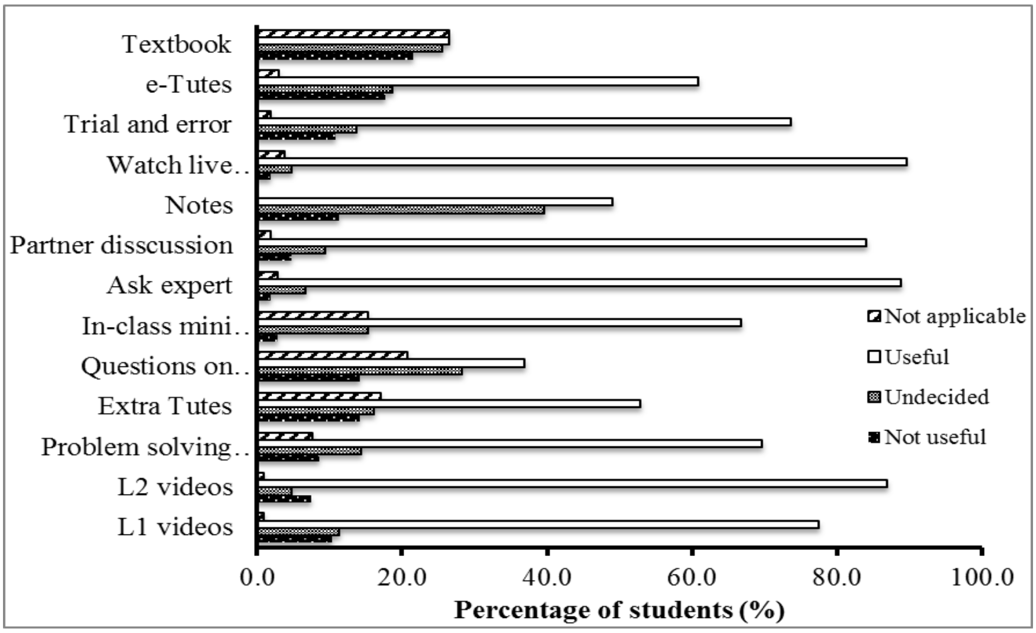

Figure 1. Students' rating of the usefulness of various teaching-learning strategies

Focus group interview

The student focus group interview corroborated the survey findings in that students generally enjoyed learning from videos and the flipped class approach, they felt that they learnt more than they would have in the traditionally taught class, and would recommend a flipped class model of teaching and learning to their friends.

One student explained the advantage of learning from videos to understand basic course introductory ideas:

> *I liked the video and e-tutorials, it was quite helpful, especially early on in the course, 'cause it gave me a lot of chance to practice the things that were quite fundamental to the rest of it. And in particular like when you're stuck on a question it's quite good to have a Youtube video or a video [lecturer developed video] that kind of helped explain that concept. I thought that was really good at the start.*

Students commented that they benefitted from taking notes while watching the videos to identify questions for later clarification in class:

> *This is a really good way of running a class… I like watching videos, it's so much more helpful than just sitting in a lecture room... For a video you can – you can take notes, and try pausing it if you have a question. It's sometimes easier to lose track [in a lecture], and also, you can make a list of questions from the video, and just go to your professor and ask him.*

Students emphasised that the overall course elements needed to come together coherently for the TC-based flipped class approach to be effective. One student commented how the course videos supplemented the other course activities effectively to help him learn the TCs identified in the course:

> *The videos were straightforward. They even explained step-by-step how to solve any circuit using Thévenin's Theorem. And we had a lot of questions using the quizzes, the e-tutorials, they're all talking about them. And even when he moved to another subject, we still talked about Thévenin and used it too. For example for the dynamic resistant, we still used Thévenin. So after all that [practice] we should understand it.*

Once students have watched the videos, working in pairs during the problem solving sessions helped them clarify their ideas and share their learning:

> *I think it helped because [my lab partner] and I really found out where each other's strengths and weaknesses were. So we could use that to our advantage…It was like peer teaching as well. If I didn't understand something, she did. We'd show each other.*

Students preferred the biweekly assessments to a final exam to affirm prior understanding and consolidate their learning:

> *Like the fortnight was a good length of time to have—like a large amount of new learning. Not only both weeks, some questions rely on your understanding of the first week, or the second week. Even though the quiz[assessment] is on the third, third and fourth weeks.*

Students unanimously agreed they learn more from the flipped class approach than attending lectures:

> *There's some [other course] lectures that are actually boring. I don't get anything. Because most of them, they are just slides, available in PowerPoint..., and he just comes in and reads from those slides---student 1.*

> *I find that quite often it's difficult to pay attention during a lecture, because if you've missed some important bit of information that you can't get outside of that lecture [from outside resources], you're going to have a lot of difficulty paying attention to lecture because you don't quite get what's going on---student 2.*

Importantly, students felt that more face-to-face support to supplement the online course resources would be helpful to get assistance with questions they have identified from the online videos and tutorials:

> *The ideal would be to have [both] online tutorials and face-to-face tutorials in a smaller environment, a smaller classroom.*

Lecturer Reflections

It took 10-12 weeks for each lecturer to record the video materials, have them “professionally edited” by a multimedia student as part of our university student Summer Research Scholarship scheme, and then upload them through the Panopto system to the Moodle content management system used at this university. Time was also spent on developing and refining the in-class problem solving activities. This time was in addition to the development of the content and delivery environment for the online tutorials in 2013, carried out by the lecturers and a part-time, graduate-student developer.

In terms of the lecturers’ time, the lecturers felt that the initial large time investment in reconsidering the materials for videos, designing and preparing the videos, and finding additional video materials online improved the quality of the paper and their teaching. The effort created a great resource. All of the created materials will be reused, and used by a new lecturer first in a compact version of the paper delivered in T-semester 2016, and then again in the full delivery in A-semester of 2017.

According to the course lecturers, compared to previous years, students were more on-task in the labs. The problem solving activities worked well despite some students reporting that some of the exercises were “challenging”. Nevertheless, the lecturers felt that the problem solving activities helped to complement the online video lectures. The lecturers’ observation paralleled that of students’ in that they felt that the ideal teaching/learning model would incorporate both pre-recorded videos and an amount of face to face lectures.

Both lecturers were subjectively convinced that student learning was significantly more effective. Both formed the impression that this video-supported, fully-flipped mode “reduced the tails” in the spread of learning, pulling up the low-end of the distribution but not supporting the special endeavours of the highest-performing students.

One of the lecturers believes that although the outcome has been very positive for students and their learning, the process is not necessarily “worthwhile”. Creation and curation of the videos took 20 to 24 man-weeks of academic time; development of the online tutorial content system (not including the questions themselves) took half a man-year of a senior tutor; design of the re-worked paper with IT support and integration into the university timetable involved a number of people for various periods. It has been estimated elsewhere that the online tutorial system would take over five years to pay back in terms of graduate student and academic staff time. Some of these costs could be shared across multiple papers, but the practice is not yet widespread enough in New Zealand universities to facilitate this. Given that many of the students would be equally satisfied with the old-fashioned, face-to-face lecture mode of delivery, the improvement of learning came at a considerable cost that most universities would not wish to bear. It is possible that the program is proving worthwhile in boosting learning, but less so in terms of “IQ-points per dollar”.

Discussion and Conclusion

This study investigated students’ perceptions of the extent to which a TC-based flipped class approach facilitated their learning in a first year undergraduate course in electronics. It addressed the question of ‘Does flipping a first year electronic engineering class and changing the traditional role of the lecturer to a “learning guide” offer better value for money in terms of the lecturer’s time and resources than the traditional face-to-face lecture model?’

Findings revealed that students were generally positive about learning TCs through the lecturer-developed instructional videos. In addition to having videos that are deemed to be enjoyable, students valued that the course activities (e.g., problem solving exercises, labs, biweekly exams) and resources (online videos, online tutorials) complemented one another. Importantly, students indicated a preference to have a real person (teachers, demonstrators, peers) available---especially when they have questions related to material in the videos and tutorials. This aligns with findings from other studies that found support for using the technology to expand the variety of educational activities possible in the classroom (Strayer, Hart, & Bleiler-Baxter, 2016). Importantly, students had to get used to the change of role from lecturer that of a facilitator. Our results were that just under half the class preferred the flipped class approach. This corroborated other findings (e.g., Nguyen, Japutra, & Chen, 2016) and highlight that as lecturers change their roles, there is a need to prepare students in terms of expectations of their active participation in learning.

The development of all materials for the flipped class required investments of time for planning and implementation. This will need to be taken account when other practitioners decide to develop their own flipped class. In our case, the lecturers progressively built, refined and implemented the flipped teaching over a 2-year period through successive iterations of various versions of the flipped class (i.e., from 3-week partly flipped pilot to fully-flipped 12 week course). Further, our results support findings that active learning requires students to engage in meaningful learning activities that allow them to think about what they are doing. Students perceived the continuous assessment-driven flipped classroom design as being more useful to their learning than a flipped classroom where summative assessment is not integrated with the flipped aspect of the teaching. Even though we did not report on the results on student achievement, the initial findings do not offer any conclusive evidence to support that using a fully flipped model for the entire course has better learning outcomes for students than traditional classroom. Improvement in grades was no more than the variation experienced year-on-year in the decade leading up to this study. In sum, when developing and evaluating the effects of a fully flipped classroom, lecturers have to be cognisant of the interplay of many factors and that it takes time and effort to finely tune the flipped class model appropriate to their context. Even after these efforts, not all students may appreciate or benefit from the flipped classroom environment.

References

Anderson, H. G., Krstenansky, J. L., Anderson, S. L., Gillette, C., & Koc, H. (2013). *Holistic interview predictors of first semester performance in the flipped classroom environment*. Paper presented at the 114th annual meeting of the American Association of Colleges of Pharmacy, Chicago, IL.

Bates, S. P., & Galloway, R. K. (2012). *The inverted classroom in a large enrolment introductory physics course: A case study*. Paper presented at the 2012 Higher Education Academy STEM conference, London, UK.

Bishop, J. L., & Verleger, M. A. (2013). *The flipped classroom: A survey of the research*. Paper presented at the 120th American Society of Engineering Education Annual Conference & Exposition, Atlanta, GA.

Bonk, C. J. & Khoo, E. (2014). Adding some TEC-VARIETY: 100+ Activities for motivating and retaining learners online. Retrieved from http://tec-variety.com/ Khan Academy (2015). Khan Academy. Available at https://www.khanacademy.org/

Khan Academy (2015). Khan Academy. Available at https://www.khanacademy.org

Male, S. A., & Baillie, C. A. (2011). Engineering threshold concepts. In *Proceedings of SEFI Annual Conference, Lisbon*. Retrieved from http://www.sefi.be/wp-content/papers2011/T7/24.pdf

Meyer, J.H. F., & Land, R. (2003). Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines. In C. Rust (Ed.), *Improving student learning, improving student learning theory and practice - 10 years on* (pp. 412–424). Oxford, England: OCSLD. Retrieved from http://www.tla.ed.ac.uk/etl/docs/ETLreport4.pdf

Meyer, J., & Land, R. (2006*). Overcoming barriers to student understanding: Threshold concepts and troublesome knowledge*. Oxon, England: Routledge.

Nguyen, B. Yu, X. Japutra, A., Chen, C. H. S., (2016). Reverse teaching: Exploring student perceptions of “flip teaching”. *Active Learning in Higher Education, 17*, 51-61

O'Toole, R. (2013). Pedagogical strategies and technologies for peer assessment in Massively Open Online Courses (MOOCs). Discussion Paper. University of Warwick, Coventry, UK: University of Warwick. (Unpublished)

Peter, A. & Harlow, A. (2014). Re-envisioning tertiary teaching and learning of difficult concepts: How “threshold concepts” afford understanding of problematic ideas. Retrieved from http://www.tlri.org.nz/tlri-research/research-progress/post-school-sector/re-envisioning-tertiaryteaching-and-learning.

Peter, M., Harlow, A., Scott, J., Balsom, T., & Round, H. (2013). On the threshold: Affordances of online tutorials in the learning of threshold concepts. In Proceedings of the International Conference on Perception and Action (ICPA). Lisbon, Portug

Reeves, T.C., McKenney, S., & Herrington, J. (2011). Publishing and perishing: The critical importance of educational design research. *Australasian Journal of Educational Technology, 27*(1), 55–65.

Rumble, G. *(*2011*).* Flexing costs and reflecting on methods*.* In L. Burge*,* C. Campbell Gibson *&* T. Gibson *(Eds),* Flexible pedagogy, flexible practice: notes from the trenches of distance education *(pp.* 243–255*).* Athabasca*: Athabasca University Press.*

Sorden, S. D. (2005). A cognitive approach to instructional design for multimedia learning. *Informing Science: International Journal of an Emerging Transdiscipline*, 8, 263-279.

Strayer, J. F., Hart, J. B., & Bleiler-Baxter, S. K. (2016). Kick-starting discussions with the FLIPPED CLASSROOM. *The Mathematics Teacher, 109*(9), 662.

Strayer, J.F. (2012). How learning in an inverted classroom influences cooperation, innovation and task orientation. *Learning Environments Research, 15*(2), 171–193.

Tynan, B., Ryan, Y., & Lamont-Mills, A. (2013). Examining workload models in online and blended teaching. *British Journal of Educational Technology, 46*(1), 5-15.

White, R., Gunstone, R., Elterman, E., Macdonald, I., McKittrick, B., Mills, D., & Mulhall, P. (1995). Students' perceptions of teaching and learning in first-year university physics. *Research in Science Education, 25*(4), 465-478.

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