Student Perceptions of 'Flipped' Microbiology Laboratory Classes

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Keywords: flipped classroom, microbiology laboratory, digital technology, pre-recorded lecture

International Journal of Innovation in Science and Mathematics Education, *24*(1), 24-35, 2016.

Abstract

Digital education technology is a key component of the contemporary student learning experience and often underpins 'flipped classrooms'. Flipped classrooms reverse classroom content and homework by assigning students instructional content as preparation for class and consequently free class time from lecture for other activities. While they are adopted with relative ease in traditional classroom settings, the science laboratory presents more challenges due to infrastructure and safety considerations. This study investigated the utility of flipped classrooms in a University undergraduate microbiology laboratory. Introductory lectures formerly delivered in class were pre-recorded and made available in advance. Quantitative and qualitative data from a student survey revealed that the pre-recorded introductory lectures used to flip the microbiology laboratory engaged and benefited many students. Students considered that the flipped laboratory 1) assisted them in preparing for laboratory classes independently and at their own pace; 2) enabled more class time to complete tasks, 3) enabled them to revisit and clarify confusing content; and 4) provided revision material. The study also revealed that if the shift in learning culture required for the flipped classroom approach is not adopted universally it can engender negative peer-to- peer interactions.

Introduction

A new generation of students referred to as 'digital natives' (Prensky, 2001) is receiving much attention in the literature as educators attempt to respond to a perceived need to contemporise their teaching practice (Bennett, Maton, & Kervin, 2010). Integrating technology into the curriculum is a widely adopted strategy to engage 'digital natives' and underpins the technology-driven initiative referred to as the 'flipped classroom'. The flipped classroom is one of many methods adopted in the broader blended learning domain. For example, in Staker and Horn's (2012) blended-learning taxonomy, flipped classroom is considered as one of the four forms of the 'Rotation Model' where students move between learning modalities. For Slomanson (2014), flipped classroom is just one form of blended learning.

In contrast to traditional classrooms where class time is filled with instruction and assimilation followed by homework to consolidate learning, flipped classrooms reverse classroom content and homework (Bergmann & Sams, 2012). Thus 'first exposure' occurs *before* class (Brame, 2013) and work typically done as homework is undertaken *in class* with instructor guidance (Herreid & Schiller, 2013). While numerous descriptions of flipped classrooms abound in contemporary literature, digital technology in the form of pre-recorded lectures is frequently used to ‘flip’ (Brame, 2013; Center for Digital Education, 2012; Hamdan, McKnight, McKnight, & Arfstrom, 2013; Roehl, Reddy, & Shannon, 2013). Technology is clearly not mandatory, however, as flipped classrooms are not new to the humanities (Berrett, 2012; Brame, 2013).

Time is a scarce learning resource (Tucker, 2012) and the most oft cited benefit of flipping classrooms is that it frees in-class time for other activities. In terms of Bloom’s revised taxonomy (Krathwohl, 2002) this too is ‘flipped’, with lower level cognitive work undertaken outside of class and in-class activity focused on higher levels of cognitive work in a peer/instructor supported environment (Brame, 2013). The flipped classroom is thus a student-centred learning approach where in-class time can be dedicated to more effectively engage in active learning of relevant discipline concepts, exploration of topics in greater depth and creating richer learning opportunities (Hamdan, McKnight, McKnight, & Arfstrom, 2013; Zappe, Leicht, Messner, Litzinger, & Lee, 2009). There is increased opportunity for teacher-to-student mentoring and peer-to-peer collaboration (Bergmann & Sams, 2012; Hamdan, et al., 2013; Roehl, Reddy, & Shannon, 2013), providing a human benefit as teachers talk more to students (Tucker, 2012).

Flipped classrooms promote thinking outside the classroom (Herreid & Schiller, 2013) because instruction can occur anywhere: at home, the library or a computer laboratory (Lage, Platt, & Treglia, 2000). Using a continuously available digital resource allows students to access material at their own pace and in their own time (Fulton, 2012; Gregory & Di Trapani, 2012; Hamdan, et al., 2013; Jones & Edwards, 2010; Lage, et al., 2000; Patterson, 2011; Roehl, et al., 2013), and provides opportunities to revisit content to revise, reinforce key concepts or spend more time with problematic material (Fei, Mather, Elmer, Allen, Chin & Chandler, 2013; Lie & Cano, 2001; Roehl, et al., 2013). This model allows them to pause, when needed, in alignment with their attention cycles and those who can process instruction more quickly may even view content at double speed (Bergmann & Sams, 2012). It allows educators to cater to different learning styles and preferences (Lage, et al., 2000; Zappe, et al., 2009) and absent students can stay current (Herreid & Schiller, 2013; Roehl, et al., 2013).

Benefits are not confined to improved student engagement, with increased student achievement also proposed. Some studies report increased student performance from ‘flipping’, notably in Science, Technology, Engineering and Mathematics (STEM) disciplines such as chemistry (Ruddick, 2012), architectural engineering (Zappe, et al., 2009), physics (Deslauriers, Schelew, & Wieman, 2011), statistics (Wilson, 2013) and biology (Moravec, Williams, Aguilar-Roca, & O'Dowd, 2010). It is noteworthy, however, that there are inherent difficulties in obtaining ‘hard data’ to support such claims because it is difficult to find a large cohort enabling direct comparison of flipped to traditional classrooms.

For many educators the flipped classroom is synonymous with use of digital technology (Overmyer, 2012) and this is very attractive due to the ready availability of internet resources on just about any subject (Herreid & Schiller, 2013). It is relatively straightforward to enrich existing course content, customise and update it (Fulton, 2012) and educators experience gains in teaching efficiency, namely through decreased preparation time once groundwork has been completed (Lage, et al., 2000). Creation of shared content can provide resources to other educators (Tucker, 2012) and allow them to be absent, if required, without a loss in teaching continuity (Bergmann & Sams, 2012).

As the flipped classroom learning model enabled through digital technology is a relatively recent model of instruction, the body of evidence to support claims that it has a positive impact on student engagement and achievement is still growing (Bishop & Verleger, 2013; Gregory & Di Trapani, 2012; Yarbro, Arfstrom, McKnight, & McKnight, 2014). Although STEM disciplines are considered to lag behind the humanities with retention of their traditional didactic 'in class' lecture approach, flipped classroom adoption is increasing (Berrett, 2012). A disparity remains, however, between the integration of technology in classrooms and laboratories. Pre-laboratory preparation is considered a necessity by educators (Johnstone & Al-Shuali, 2001) and studies by Jones and Edwards (2010), Gregory and Di Trapani (2012) and Schmid and Yeung (2005) are some of the limited number of studies investigating the impact of using technology-initiated pre-laboratory online resources for improving students' capacity to prepare for laboratory classes. Laboratory settings present a unique challenge for technology integration (Caron, 2011) as many classes are delivered in a manner largely unchanged since the advent of digital technology, i.e. via a laboratory manual containing 'recipe-like' instructions (Cooper & Kerns, 2006), and often in a physically unchanged space. In many teaching laboratories digital technology is either absent or in the form of fixed classroom infrastructure only. A further complicating factor is laboratories that have a physical containment aspect such as medical and microbiology laboratories. These laboratories preclude the use of personalised technology by students due to strict safety requirements (to use technology in these situations all devices must remain in the laboratory and have appropriate safety features such as waterproof and washable keyboards). Thus, unless a teaching laboratory is furnished with sufficient digital technology for each student, it is more usual for educators and students in laboratory classes to be reliant on the use of limited in-class technology or technology outside of the laboratory space.

Proposed Study

This study contributes to research on flipped classrooms utilising digital educational technology in STEM, and in particular in a laboratory setting where such studies are still lacking. The flipped classroom model is investigated for its utility in a second year, undergraduate microbiology laboratory class at an Australian University. Prior to the study, introductory laboratory lectures were delivered in class, with a sub-set delivered via PowerPoint presentations. These lectures were removed from class, content was enriched and the lectures pre-recorded using the recording and delivery platform Echo360 and made available to students in advance. Quantitative data using Echo360 analytics were used to analyse the usage of pre-recorded introductory lectures by students and to investigate the relationship with performance. Effects on student performance have been reported elsewhere (Mellefont & Fei, 2014), with no correlation determined between students with a high level of engagement with 'flipped' lectures and their grade in the associated practical exam. In addition to quantitative data, a survey was administered to students to gauge their perceptions on the utility of a 'flipped' microbiology laboratory class and those results are reported here.

Materials and Methods

Study cohort and selection of 'flipped' classes

A cohort of 96 students participated in the project for one semester (13 weeks). The weekly, three-hour intensive laboratory classes were delivered face-to-face with students seated four per bench. Introductory lectures were delivered at the beginning of class and students used the remaining time to undertake projects in consultation with an instruction-based laboratory manual. Projects required individual, paired or bench-group work and comprised 'recipe-like' instructions and inquiry based exercises. All students received the *same* content for a sub-set of classes (8 weeks) focussed on general ‘bacteriology’, with lectures delivered via PowerPoint presentations. The remaining sub-set of classes comprised ‘specialist’ medical or marine microbiology content (3 weeks), with less structured introductions delivered with whiteboard presentations. All students undertook a revision class (Week 12) in preparation for their final practical exam (Week 13).

The ‘bacteriology’ block was selected for flipping, as all introductory lectures comprised media-rich PowerPoint presentations developed and delivered by the same instructor. The first lecture in the ‘bacteriology’ block was not flipped due to safety considerations so that students could be inducted into generic laboratory safety protocols *in situ*. The following six lectures were considered essential viewing in preparation for laboratory classes and constituted the truly flipped portion of the study (i.e. containing preparatory content). The eighth and final week of the ‘bacteriology’ block contained flipped content considered optional viewing as the material comprised a lecture focussed mostly on review content and a non-compulsory lecture related to a computer-based assessment task that could be completed by consulting the laboratory manual. The existing content in the PowerPoint lectures was enriched through further addition of video, images and hyperlinks, and the lectures were pre-recorded using Echo360 Personal Capture (Table 1).

Table 1: Type and duration of introductory lectures

Lecture Style	Lecture Content	Duration (minutes)
TRADITIONAL: In class	Introductory Lecture WEEK 1	-
FLIPPED: Essential viewing (preparation for laboratory classes)	Introductory Lecture WEEK 2	32
	Introductory Lecture WEEK 3	30
	Introductory Lecture WEEK 4	23
	Introductory Lecture WEEK 5	28
	Introductory Lecture WEEK 6	37
	Introductory Lecture WEEK 7	17
FLIPPED: Optional viewing	Introductory Lecture WEEK 8 (mostly review content for Week 7)	9
	Non-compulsory tutorial for Assignment Task (WEEK 9)	22

Students are expected to prepare for class by reading the introductions and procedures for scheduled projects and completing an aligned weekly assessment task (usually a pre-laboratory on-line quiz). The pre-recorded introductory lectures were intended for viewing in conjunction *with* usual class preparation and although they were not assessed *per se*, the content related to aligned weekly assessment tasks. Recordings were made available five days in advance. As they were removed from the laboratory class itself, students were able to commence work immediately on arrival.

Students were notified face-to-face in their first laboratory class of the upcoming change in delivery style of introductory laboratory lectures for Weeks 2-8, i.e. from ‘traditional in-class’ to ‘flipped’, and that flipped content was considered an essential preparation tool. Each student was provided with a hard copy of the project information sheet that detailed how the ‘flip’ worked, which lectures were flipped and a schedule of their availability. This information was also available through the unit online learning environment. Students were reminded to view the flipped lectures via emails and an online news tool in Weeks 3, 6 and 7.

Survey data

To investigate student perceptions of the pre-recorded introductory lectures an online questionnaire survey, adapted from another research group (Fei et al. 2013), was administered to all students with four sections:

A. Student access
B. Perceived benefits
C. Perceived utility
D. Open ended question

Section A comprised simple factual questions requiring a single response and Sections B and C were opinion/attitudinal questions measured with a five-step Likert Scale (Strongly Disagree through to Strongly Agree). Ethics approval (H13989) was obtained from the University's Human Research Ethics Committee. Participation was voluntary, with students advised there was no penalty for not undertaking the survey, and all responses were non-identifiable. The survey was administered via Survey Monkey at the end of semester so students could reflect on the flipped 'bacteriology' block in comparison with the traditionally delivered 'specialist' block. Descriptive analysis was conducted using SPSS (v.21) to understand students' perceived utility and benefits of pre-recorded lectures for the 'bacteriology' block. A thematic approach (Braun & Clarke 2006; Joffe 2011) was used by the authors to analyse the comments collected from the open-ended question.

Results and Discussion

From 96 students, 56 valid survey responses were received. This response rate (58%) is similar to the average number of unique views of *essential* flipped content determined from Echo360 analytics, with 55% of students accessing the pre-recorded introductory lectures in Weeks 2-7 (Mellefont & Fei, 2014). .

How students accessed flipped content

The survey results revealed that the majority of respondents usually accessed lectures once a week (91%), with many viewing them on the weekend (30%) or the day before class (46%). The majority viewed the lectures on-line (70%) rather than downloading. Viewing patterns varied, with 57% viewing the lectures in their entirety and the remainder pausing multiple times to access information. As viewing lectures at home (88%) on a personal computer (93%) was preferred, this likely resulted in the majority viewing lectures by themselves (82%) rather than in a study group. These data support statements that flipped content provides freedom of access to materials as students are not restricted by place (Lage, et al., 2000) or time of access (Roehl, et al., 2013) and can pause when needed (Bergmann & Sams, 2012).

Readily accessible digital technology can be utilised for revision purposes (Herreid & Schiller, 2013). When asked if they engaged with the pre-recorded laboratory lectures as preparation and/or revision tools, 79% of respondents indicated they viewed them each week *and* to revise for the practical exam. A small proportion (16%) viewed them weekly but did not use them for revision, with the remainder sporadic viewers who did, however, use them for revision purposes (5%). This contrasts to the usage data collated from Echo360 viewing analytics reports, which suggested that the pre-recorded laboratory lectures were viewed mainly as a preparation tool and not for revision (Mellefont & Fei, 2014). However, it should be noted that the course statistics data only reported viewing pre-recorded laboratory lectures *live*; when a student downloaded a pre-recorded laboratory lecture no further interactions were recorded. The survey revealed that 30% of respondents did indeed download the pre-recorded laboratory lectures and saved them on their personal devices and thus had them available for revision purposes. It should be noted, however, that the survey question was structured to only reveal *if* the pre-recorded laboratory lectures were used for revision, not *the way* in which they were used. It is likely that students adopted a variety of strategies to utilise content from live viewing for revision, e.g. taking notes while lectures streamed, or taking screen captures of slides and converting to hard copy (observed in class for at least one student).

Perceived benefits to students

A series of survey questions were administered to determine if students perceived flipped content in a microbiology laboratory setting as beneficial (Figure 1). Percentage agreement for each answer option was calculated by adding the number of Agree and Strongly Agree responses and are presented in descending order.

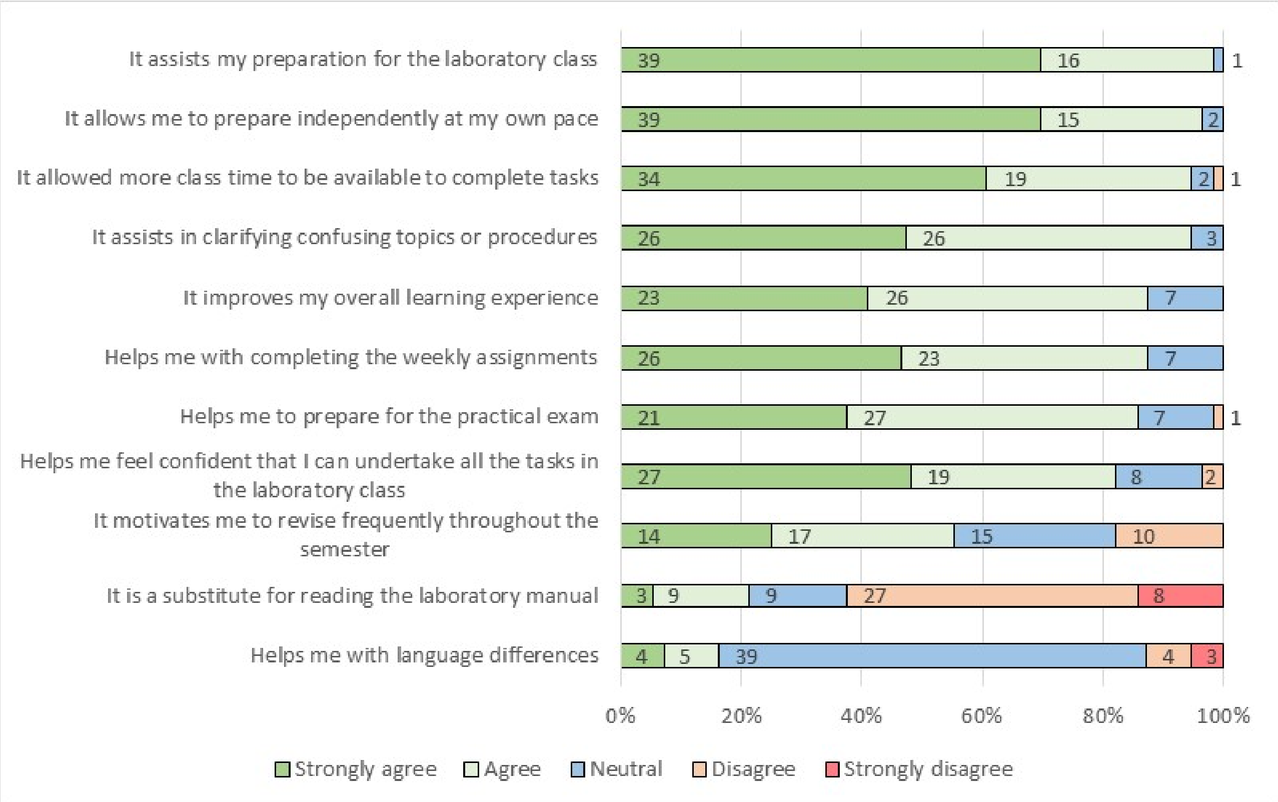

Figure 1: Students' perceived benefits of pre-recorded lectures (number of responses and overall percentage)

The data presented in Figure 1 indicate that respondents considered the pre-recorded laboratory lectures beneficial for their laboratory classes, with the majority of the proposed benefits rated highly with over 80% agreement. Student perceptions showed particularly high agreement, over 90%, for benefits that accorded with literature reports that flipped content assists them with their preparation for class independently and at their own pace (Jones & Edwards, 2010; Fulton, 2012; Roehl, et al., 2013), they have more class time to complete tasks (Tucker, 2012; Zappe, et al., 2009) and clarification of confusing content is possible (Fei, et al. 2013; Lie & Cano, 2001). They felt more confident in the laboratory class itself and in undertaking the aligned assessment tasks, and that their overall learning experience was improved. While approximately half of the respondents agreed that pre-recorded laboratory lectures were a motivating factor for revision, some respondents disagreed (17.9%) or were neutral in their opinion (26.8%). These varied responses, however, may just reflect a diversity of study and revision habits within a class, with not all students electing to revise frequently throughout the semester. The pre-recorded lectures were intended to complement, rather than replace, the laboratory manual. Pleasingly, respondents agreed with this intention as only a minority suggested the pre-recorded lectures were a substitute for reading the laboratory manual (16.1%).

Perceived utility of flipped content

Figure 2 presents student perceptions on the utility of the pre-recorded laboratory lectures, including aspects of quality, preference of delivery style and relevance.

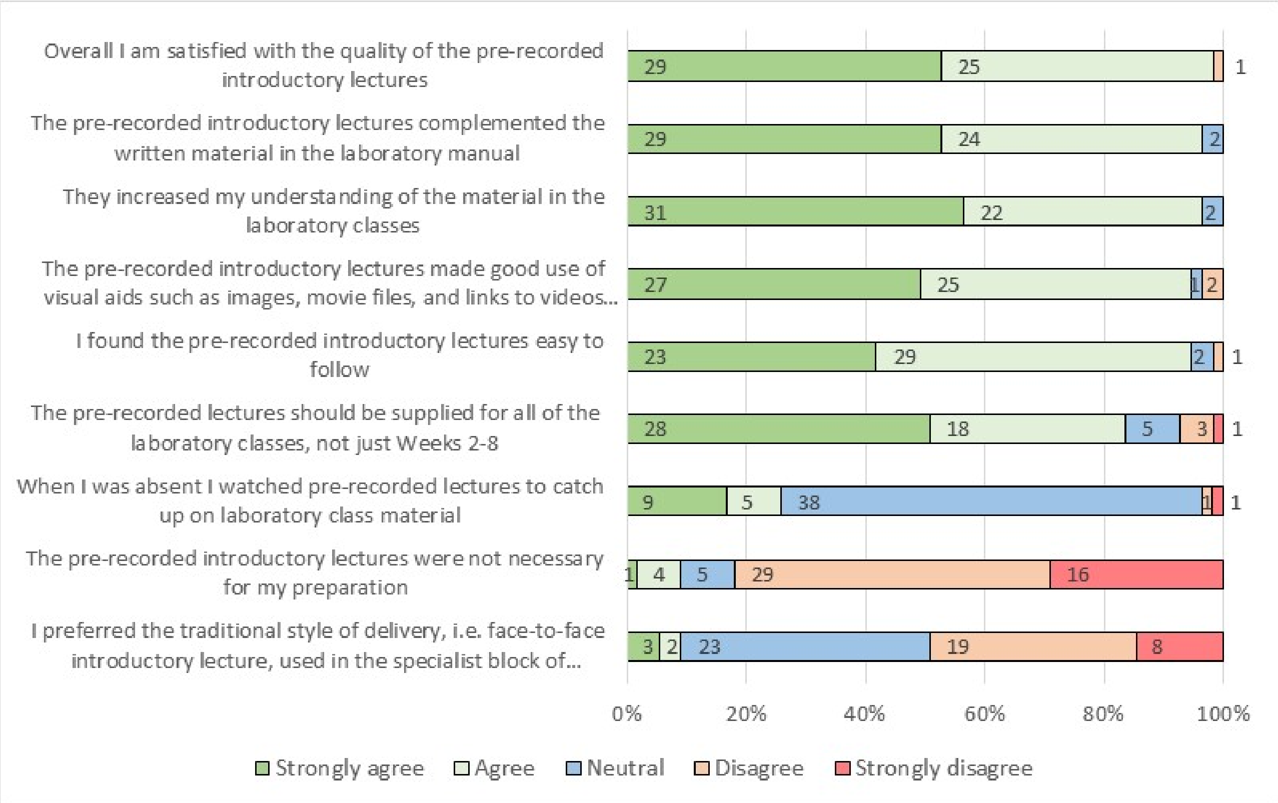

Figure 2: Students' perceived utility of the pre-recorded lectures (number of responses and overall percentage)

Respondents considered the pre-recorded laboratory lectures fit for purpose, with the majority of statements regarding the quality of the pre-recorded laboratory lectures rated very highly (>90% agreement). The pre-recorded laboratory lectures were considered to be suitably enriched with media tools and easy to follow. More importantly, from an educator standpoint, they agreed that content complemented that presented in the laboratory manual and student understanding of the laboratory classes was enhanced. Only a sub-set of the laboratory classes were flipped, the 'bacteriology' block, and it appeared that most students preferred this delivery style (83.6%), in comparison to more traditional in-class instruction utilised in the 'specialisation' block (9.1%). Based on this initial reception by students, future delivery of the laboratory classes could be optimised by transforming *all* introductory laboratory lectures into the flipped format. Flipped classrooms are purported to allow absent students to stay current (Roehl, et al., 2013). Absenteeism in the laboratory classes was monitored, with a required attendance rate of 80%, likely accounting for the low agreement that flipped content allowed absent students to stay current as high attendance occurred. Students were in low agreement (9.1%) that the pre-recorded laboratory lectures were *not* necessary for laboratory class preparation. This aligns with observations reported in Figure 1, with 98.2% considering the pre-recorded laboratory lectures assisted their preparation.

Student reflections

Open-ended comments were received from 36 of 56 respondents and were largely consistent with numerical scores from the survey instrument and reflect a positive response to the introduction of flipped content in the microbiology laboratory class. The most oft-cited benefits support the data presented in Figure 1 and literature reports, namely freeing class time from lecture, increased preparedness, the opportunity to pace their own learning and using content as a revision tool. Representative statements include:

> *"…. I had more time to 'digest' the requirements for the coming practical class and because it can be played multiple times, I was able to make sure I got all the necessary information required before attending the class as well as when I was revising for my practical exam…."*
>
> *"…. The thing I liked most about them was that you could walk into the Prac class and start straight away. It felt like time was used efficiently this way and that I was prepared for the tasks each week. The recording were concise as well, which is not the case in some face-to-face scenarios in other laboratories I've taken."*
>
> *"They were very helpful as I could stop the recording and take notes, rewind if I was confused/there was something in the quiz about the online lecture. It helps save time in the practical as well. Face-to-face is good for understanding, but sometimes it is just too fast and I cannot take adequate notes."*
>
> *"They allowed me to get straight into the pracs when I arrived as I had an excellent understanding of what I had to do and how to do it. I could go over parts of the recording if required and take down excellent notes to assist me in the prac….'*

Bishop and Verleger (2013) surveyed research into flipped classrooms and concluded that student perceptions are generally positive overall. The results from this study corroborate their findings, with students very supportive of the introduction of flipped lecture content in the microbiology laboratory. The preponderance of literature concerning flipped classrooms focuses on the benefits of this learning model. As a consequence, almost all the survey questions presented in Figure 1 are posed as positive statements and perhaps introduce bias accordingly as perceived negatives are not well represented. This, in conjunction with some aforementioned questions that lack explicit wording, indicates that the survey instrument requires refinement.

Despite the many proponents in the literature, and the positive reception from students reported here, there is a growing voice of detractors of flipped classrooms. Flipped classrooms require a shift in learning culture by students as they must assume more responsibility for their individual learning experience (Roehl, et al., 2013; Strayer, 2012). They can be perceived by students as an offloading of responsibility by faculty as they think 'they are just teaching themselves' (Talbert, 2014). The cognitive strain associated with flipped classes engenders resistance in reluctant learners and when students are unable to passively receive content in class, i.e. those who prefer the ‘empty vessel’ approach, they dislike its removal (Ash, 2012; Berrett, 2012). Chowdhury (2014) considers ‘isolation' to be inherent in flipped classrooms as students may not have access to intervention in moments of need and may be deprived of the inherent passion and personality of an engaged educator if this is not successfully translated into the digital experience. Isolation may be exacerbated in ‘digital immigrants’, i.e. those not born into the digital world (Prensky, 2001), as they are presented with a steep learning curve; a situation shared by some members of faculty (Berrett, 2012). Financial limitations must also be considered as this model often relies on the availability of computers and access to the internet outside of class (Lage & Platt, 2000; Roehl, et al., 2013). Technical issues around access, streaming and downloading digital content can impact students (Enfield, 2013) and the development of material can be costly and time/labour intensive for educators (Lage, et al., 2000).

Of the potentially negative aspects described above, none were *directly* represented in any responses collated by the survey. Interestingly, however, one purported benefit of flipped classrooms was not always perceived so by the students surveyed. Increased opportunity for peer-to-peer collaboration is a reported advantage of flipped classrooms, with students helping each other learn (Bergmann & Sams, 2012; Hamdan, et al., 2013; Roehl, et al., 2013). Anecdotally, lecturers concurred as they noted a higher level of peer-to-peer interaction with some students leading others through project tasks. However, while an educator considers peer-to-peer collaboration an opportunity for students to reinforce their learning through instructions of others, students may have a divergent view. Four respondents noted that lack of preparation by laboratory partners/ groups, i.e. those who had *not* viewed the pre-recorded introductory lectures, hindered and frustrated them. Excerpts include:

> *“My lab partner usually did not watch them which put pressure on me to explain the material. The one week I forgot neither of us had any idea what to do at the beginning which required us to read through the lab manual in detail.”*

> *“….Some people on my bench did not watch the pre labs and then would ask me or my lab partner to explain everything. When people do not watch the pre labs it can slow the progress of the group during group tasks…..”*

> *“….one downside is if your lab partner consistently refused to watch the lectures and has no idea what he was doing at the beginning of each class. This lead to a multiple mistakes being made as they tried to bumble through without instruction….”*

> *“I watched them every week, but others on my bench did not and it was frustrating having to tell them what to do every week….”*

Thus it appears that the required shift in learning culture advocated by Roehl et al. (2013) was *not* adopted by all students in the flipped laboratory classes. This highlights that educators in flipped classrooms must clearly articulate that a change in learning culture is required by all students to improve their own learning experience as well as that of others, particularly in laboratory classes where a collaborative work ethic is requisite. Further, they must also continuously monitor and assess the type of student interaction occurring and, if needed, intervene in such interactions to optimise the learning experience for all students.

Open-ended comments through survey can provide instructive feedback that can be utilised to improve the student learning experience. One respondent articulated a unique approach to utilising the pre-recorded introductory lectures for the microbiology classes as follows:

> *"…. Myself and my lab partner would view the lecture recordings individually and then meet up for a short session (ie. 20 mins) before the lab began, to make sure we were both confident and understood the material. This allowed us to be more efficient during the course of the lab, and plan out the order in which we could complete the tasks."*

This approach fosters peer-to-peer collaboration and could be used to alleviate the earlier cited frustration experienced by some students, particularly if it was extended beyond a laboratory pair to that of the bench group. This feedback will be used as an exemplar for future cohorts in flipped microbiology classes as a potential model for preparation.

Conclusion

The flipped classroom provides a flexible, appropriate for '21st century learning' experience (Fulton, 2012) and while commonly used in traditional classrooms, some laboratory classes lag behind. In this study the flipped classroom learning model was implemented in an undergraduate microbiology laboratory class through the provision of pre-recorded introductory laboratory lectures for a 'block' of teaching that was previously delivered in-class. While acknowledging that it is difficult to accommodate the diversity of learning styles and preferences in the classroom, flipping the microbiology laboratory class by utilising digital technology appeared to have engaged and benefited many students, particularly those willing to take more responsibility for their learning. The most significant benefits for students arose through the provision of more class time to complete laboratory tasks and increased capacity to prepare for class in a manner that was not restricted by location or time, and a resource for revision. Not all students, however, embraced this new approach to learning and preparation. This resulted in some negative student interactions in cases where students had not viewed the pre-recorded laboratory lectures in preparation for class. The survey results benefited teaching staff as it identified areas where more support and direction is needed for students adapting to this new learning culture. More actively promoting the benefits of the flipped classroom approach, providing clearer expectations for the role of students in their own learning and emphasising the collaborative work ethic required may collectively minimise such problems in future. While the open-ended commentary revealed potential learning approaches that can be utilised to improve the student learning experience, the study may benefit from a mixed methodology to include interviews of students.

The results from this initial study provide preliminary evidence that the flipped classroom model can be used successfully in a microbiology laboratory class. The challenge of integrating digital technology in the laboratory space was circumvented by simply externalising it, and generally students responded positively to the change in learning culture. However, there is significant scope for further research to investigate how students perceive the flipped microbiology laboratory as this study establishes baseline data only. As adoption of any new pedagogy is an iterative process, collectively the data will be used to inform teaching practice and to refine and optimise future delivery of flipped microbiology laboratory classes.

Acknowledgments

This work was supported by the University of Tasmania Teaching Development Grant scheme.

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