Pre-lecture Online Learning Modules in University Physics: Student Participation, Perceptions and Performance

Matthew Hill[a], Manjula Sharma[a], Yingying Xu

Corresponding author: m.hill@usyd.edu.au

aSchool of Physics, University of Sydney, Sydney, Camperdown NSW 2006, Australia

Keywords: online learning, physics, student participation

International Journal of Innovation in Science and Mathematics Education, *25*(1), 14-32, 2017.

Abstract

In our earlier paper published in this journal, we described short-weekly online learning modules (OLMs) that were carefully created to supplement a first-year university physics course (Hill, Sharma, & Johnston, 2015). Where the previous paper was focussed on the merits of the content of the OLMs, this paper is focussing on the student uptake to allow for fellow practitioners to benefit from our experience. Online learning is often tried, but less often tested. For practitioners, it is useful to understand when and how students participate, why do or don't students participate, and what are students' opinions of online learning. Here we present the frequency and duration of student engagement with OLMs based on data collected automatically by the learning management system, and results of a survey. Over 75% of students who completed the final exam were deemed to have actively participated in the OLMs for an average of approximately 15 minutes each week. Despite the flexibility of having almost four days to complete the modules, the majority of students completed them 24 hours before the deadline. Students reported that they completed the modules as they found them helpful for learning and for the 1% contribution to the final course mark regardless of correctness of answer. Students reported that the modules improved their understanding, prepared them for lectures, and provided other benefits such as motivating regular participation. When considering performance, students who achieved high distinctions completed the most OLMs at an average of 10.7 ± 1.4 modules, while students who failed the course only completed 4.1 ± 3.8 modules on average. As each grade level increases, so does the average number of OLMs completed. From another perspective when comparing students who completed more than eight OLMs with those who completed less than four using an established physics concepts test (the Force & Motion Concept Evaluation), students who completed more modules had higher learning gains across the semester. Results from this study assist educators in understanding the dynamics of introducing online learning in face-to-face courses and contribute to the growing body of literature into the efficacy of blended learning. For the practitioner often baffled by the significant amount of data that can be queried through learning management systems, this paper offers an analysis using these data to consider what blended learning looks like for the students.

Introduction

The Move towards Online Learning

Online environments have been used for learning for over 40 years (Harasim, 2000). More recently, particular forms of education have emerged which often make extensive use of online learning; examples are MOOCs (Massive Open Online Courses) and many implementations of flipped classroom teaching. Despite an apparent consensus, as stated in Oncu & Cakir (2011), that learning through an online learning environment may be superior to classroom instruction, researchers have pointed out the lack of rigorous efforts to demonstrate how learning in an online environment can achieve its potential (Chen, Wang, & Chen, 2014; Lack, 2013; Oncu

& Cakir, 2011). Integrating online instruction with face-to-face teaching is popular in university courses. This is known as blended learning (Black, 2002; Swan, 2009).

Types of Blended Learning

As is the case for online learning in general, there is mixed evidence and a lack of rigorous research studies into the effectiveness of blended learning (Means, Toyama, Murphy, Bakia, & Jones, 2009; Zhao & Breslow, 2013). Despite this, there are many instances where blended learning has been shown to be effective, often more so than traditional classroom instruction (Black, 2002; Chen, Stelzer, & Gladding, 2010; Day & Foley, 2006; Day, Foley, Groeneweg, & Van der Mast, 2004; Lumsden, 1976; McFarlin, 2008; Moore, 2014; Neumann & Hood, 2009; Pargas, 2006; Seery & Donnelly, 2012; Stelzer, Brookes, Gladding, & Mestre, 2010; Stelzer, Gladding, Mestre, & Brookes, 2009; Utts, Sommer, Acredolo, Maher, & Matthews, 2003).

Several ways of considering the extent to which the different learning opportunities integrate, and the anticipated student time on particular activities are available, two of which are mentioned here. Twigg (2003) describes four models of blended learning:

1. Supplemental: adding extra online instructional activities to an existing course;
2. Replacement: replacing activities in an existing course with online instruction;
3. Emporium: mainly online with some classroom instruction; and
4. Buffet: students can choose from a variety of online and in the classroom activities, further elaborated in (Hood, 2013).

This can be compared to Alammary, Sheard, and Carbone's (2014) three approaches; "low-impact blend" (similar to supplemental), "medium-impact blend" (similar to replacement), and "high-impact blend" which includes both emporium" and "buffet". The 'impact' refers to the extent of change that introducing an online component makes to the course. For the practitioner considering blended learning, these descriptions provide ways of articulating the incorporation online learning into the design of the course.

Measuring Student Participation in Online Activities

In their review article, Means et al. (2009) suggest that the positive effects of blended learning (and purely online learning) may often be due to more time on task rather than online learning environments being a better medium (see also (Beer, Jones, & Clark, 2009; Chen et al., 2010; McFarlin, 2008; Stelzer et al., 2010)). Spending extra time on task using online learning environments, through increased student motivation or greater accessibility to resources, is a recognised benefit (Ruiz, Mintzer, & Leipzig, 2006) and therefore it is vital that studies explicitly measure participation related to time students spend on online activities.

Online environments allow for tracking of student usage, however few studies go into details of when, how often, and for how long students use online resources in their learning experience. Often studies in online learning fail to report on retention rates and instead, like many course providers, choose to focus on how many students have enrolled (Means et al., 2009). In contrast to this, one instance of detailed reporting is a large-data study in medical education using log files to track how students accessed online lectures (Craig, Wozniak, Hyde, & Burn, 2009). The researchers found that the frequency of student participation certainly justified the financial cost and instructor effort required to publish the content. Student participation in the many facets of the blended learning course were mapped allowing the administrator to distinguish between self-directed students with regular participation in many learning activities from those who accessed online lectures in the lead up to an assessment. Studies into blended learning can neglect reporting the level of engagement with online activities, possibly implying all students completed them (Chen et al., 2010; Stelzer et al., 2010). Some studies do report on these patterns and have found relatively high levels of participation despite small credit incentives and also that students are likely to complete exercises very close to the due date despite the inherent flexibility of online access (Seery & Donnelly, 2012). This paper will continue to investigate these questions of student engagement, in particular, how often, for how long, and when during the week and over the semester, do students utilize online learning in the case of a blended learning course in university physics. This paper adds to the current research as it is a large scale study within a calculus based first year university physics course using the supplemental model of blended learning.

Student Perception of Online Activities and Blended Learning

Student motivation and self-efficacy are key contributors to time on task and effective learning engagement (via Likert-scale surveys in Lindstrøm and Sharma, 2011), especially when it comes to activities in the less regulated online learning environment (measured using a motivation strategies learning questionnaire in Wang, Shannon, & Ross (2013)). Measuring student satisfaction and student perceptions of online learning activities allows for a deeper understanding of the positive elements of a blended learning course and identification of barriers to effective engagement. Alammary et al. (2014) give warnings and recommendations for blended learning courses (specifically courses of the supplemental model). Specifically, they warn that adding extra online activities can be a burden to students and recommend that online activities should be integrated well with the existing course in order to address a pedagogical need (this was further argued by Wu, Tennyson, & Hsia (2010)). Some studies report that students perceive a benefit to learning from a blended course structure (Black, 2002) and especially that face-to-face time was used more effectively (Day et al., 2004; Moore, 2014). Why students complete online activities differs depending on the type of activity and the distribution of learning activities. To maximize student engagement, it is recommended that students recognise the intended benefit of particular online learning activities as they complete them. Why students chose to, or chose not to, complete online learning activities is another matter for investigation in this paper. It must be briefly noted that engagement is due to a range of factors and has been particularly associated with active learning (for review articles see Prince (2004) and Freeman et al. (2014)). In this paper the focus is on online learning and engagement but for explicit examples of active learning in physics see Georgiou and Sharma (2015) and Sharma et al. (2010).

Purpose of the Study

In light of the current state of research focusing more on design and final outcomes of blended learning courses this paper will focus on student engagement in an online learning environment to supplement learning in a large first year university physics course (supplemental model). The general research question probes the patterns and perceptions of student engagement with weekly pre-lecture OLMs throughout a semester of undergraduate physics education. The specific research questions and facets examined are:

1. What are the patterns in student use of Online Learning Modules (OLMs) in this course?
    - 1.1 What is the pattern of participation across the semester?
    - 1.2 How long do students stay logged onto the OLMs?
    - 1.3 When do students choose to complete the OLMs?
2. Why do/don't students engage with OLMs?
3. Is introducing the OLMs associated with improved learning and experiences?
    - 3.1 Do completing OLMs improve student learning?

3.2 What are student opinions of the OLMs?

The intention is to share our research with practitioners, who are either considering blended learning and unsure of the student response, or those who have already implemented blended learning and may be exploring how to measure and analyse the student response.

Method

This paper presents a case study using a mixed methods approach, more particularly a mixed-model design (as described by Johnson & Onwuegbuzie (2004)). By combining quantitative and qualitative research approaches we can answer a broader "range of research questions because (we) are not confined to a single method" (Johnson & Onwuegbuzie, 2004). In this section, the context is explained through describing the student population, the form and purpose of the OLMs, and the methods that are used to analyse student participation, perceptions, and subsequent performance on an established physics concept test.

Implementing Online Learning Modules

Sets of 12 OLMs were developed for a 1st year calculus-based physics course at the University of Sydney. The students undertaking the course were in their first semester of university. They had studied physics through to the end of their secondary education. The course was the "Regular" physics course as opposed to the "Advanced" course which consisted of high achieving students based on their grades in secondary education. In 2014, the cohort had 656 students who completed the final exam. For timetabling reasons the students were divided into five lecture streams (or sections) with four different lectures covering identical content for three one hour lectures per week.

The OLMs were designed as weekly exercises for students to complete in order to prepare for the upcoming week's lectures. Each week's module was divided into three brief sections,

- Information, where content was presented
- Questions, where students were asked questions related to the content
- Reflection, where students were prompted using metacognitive questions to reflect on their learning.

Figure 1 is a screenshot of the first module deployed using the universities eLearning platform "Learning Management System (LMS)". More details on the development and content of the OLMs are described in Hill et al. (2015). This is not repeated in this paper as the response of students rather than the content of the OLMs is the focus of the investigation. A sample OLM can be found in Appendix 1.

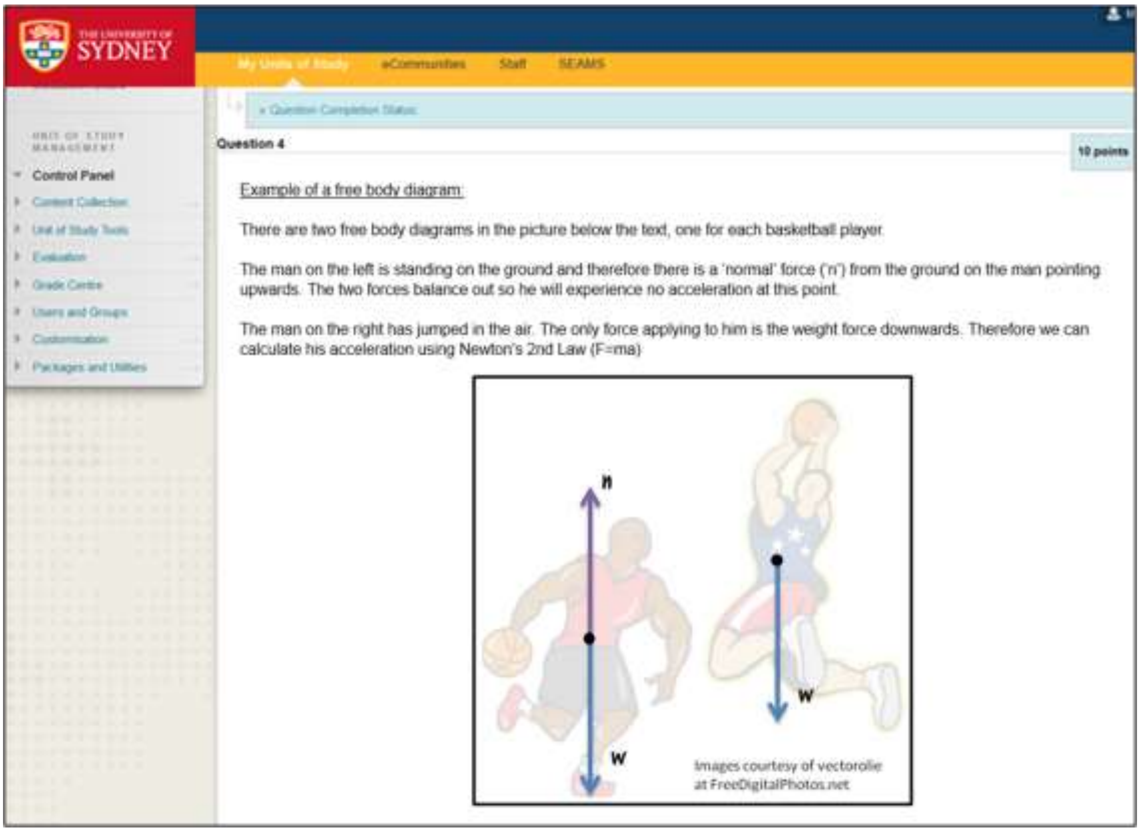

Figure 1: A screenshot of a component of an OLM offered to 1st year university physics students

The OLMs were designed to take 15 minutes with a recommended 30 minute time limit. They were available from 5pm on a Thursday until 10am on the coming Monday when the first lecture of the week occurred. Students were marked for participation, and completion of 11 of the 12 OLMs available through the semester resulted in the student being awarded 1% of the end of semester physics mark.

(The nature of the 1% was due to the culture of the specific institution. Assigning any percentage worth, small or large, for the OLM was important as it validated the activity as a core component of the course. As this was a new and supplemental component of the course only 1% of the end of semester grade was allowed by the course organisers to be awarded for the OLMs. It is possible that varying the percentage may vary the participation but this was chosen in order to present the activity as a core component of the course, but not penalise students for electing not to complete the OLM.)

Students were informed of the OLMs in a variety of ways:

(a) Through the standardised course outline provided online and in the first lecture of the course;
(b) Verbal explanation in the first lecture and hand-out explaining how to access the OLMs;
(c) Verbal reminders in lecture and laboratory classes during the first two weeks of semester;
(d) Weekly emails to students reminding them of their responsibilities for that week; and
(e) Emails to students at time of deployment of the OLMs on four occasions; during the first week, at the beginning of each new topic area, and for the final OLMs.

Measures of Student Engagement with the OLMs

Student engagement with OLMs was measured in four main ways.

Tracking Student Participation in OLMs Online

The LMS recorded the date, time and duration of every student attempt at an OLM. This allowed for most of research question 1 to be answered. We were also able to use these data to determine the number of OLMs completed by each student to answer research question 3 on student learning. The LMS data was transferred to SPSS and analysed by grouping and sorting.

Final Module with Reflection Questions

The final OLM included the following reflection questions:

(a) Likert Scale questions (of strongly agree, agree, neither agree nor disagree, disagree, strongly disagree)
  a. The OLMs were helpful for learning physics this semester
  b. The OLMs were relevant for learning physics this semester
  c. The OLMs were demanding to complete
  d. I put a lot of effort into completing the OLMs each week

(b) Short answer response
  a. What motivated you to complete the OLMs throughout the semester
  b. Name one thing about the OLMs that was helpful for learning physics this semester

Student responses were coded and themes extracted.

Surveys and Focus Groups

The final module (described above) allowed for surveying of students who did regularly complete OLMs. However we wanted to also understand why students who were active participants in the course did not choose to participate in the OLMs. Therefore we surveyed a group of these students and participated in a staff-student liaison meeting to try and ascertain the perspective of non-participating students.

27 students who elected not to complete any OLMs responded to an additional survey administered during tutorials asking “Why did you not complete more OLMs this semester?” At a post-semester staff-student liaison meeting where students shared their experiences of the course in general, a 15 minute focus group was conducted seeking student experiences of the OLMs. Student comments were noted for triangulating with other data.

Student Assessment Marks

Throughout the semester, the students completed a variety of assessments which contributed to their final mark and grade levels of high distinction, distinction, credit, pass and fail. We analysed the number of OLMs completed for each grade level.

Relevant for this investigation, in addition to the above assessments, on two occasions (as a pre-test and post-test) students completed the Force Motion Concept Evaluation (FMCE) (Thornton & Sokoloff, 1997) which is a test on mechanics concepts included in this course. The FMCE has been successfully used to evaluate the effectiveness of other teaching and learning innovations at this institution (Sharma, Johnston, Johnston, Varvell, Robertson, Hopkins, Stewart, Cooper, Thornton, 2010). This therefore provided a quantitative measure of whether the OLMs helped the students to understand physics better over the semester of instruction.

Results

What are the Patterns in Student Use of OLM in this Course?

What is the Pattern of Participation across the Semester?

Of the 656 who completed the final exam, 97% completed at least one module. Furthermore, 45.8% completed more than eight modules, which was deemed as actively participating in the OLMs.

641 students completed the module in the first week and the number of students completing modules decreased across the semester (see Figure 2). During the first week, and in the beginning of semester, there was a large number of students enrolled in Regular Physics and many participated in the OLMs. However, the number of students decreased after week 1. This decline in student enrolment and participation is common across various student learning opportunities (e.g. lectures and tutorials) and is not unique to the OLMs.

After the fifth OLM, the numbers dropped again. This module was available at the end of a week-long mid semester break. A decline is noticed in all aspects of the course. Some students may have been away during the mid semester break, and for some, the break may have altered their regular study routine resulting in a failure to complete that week's OLM.

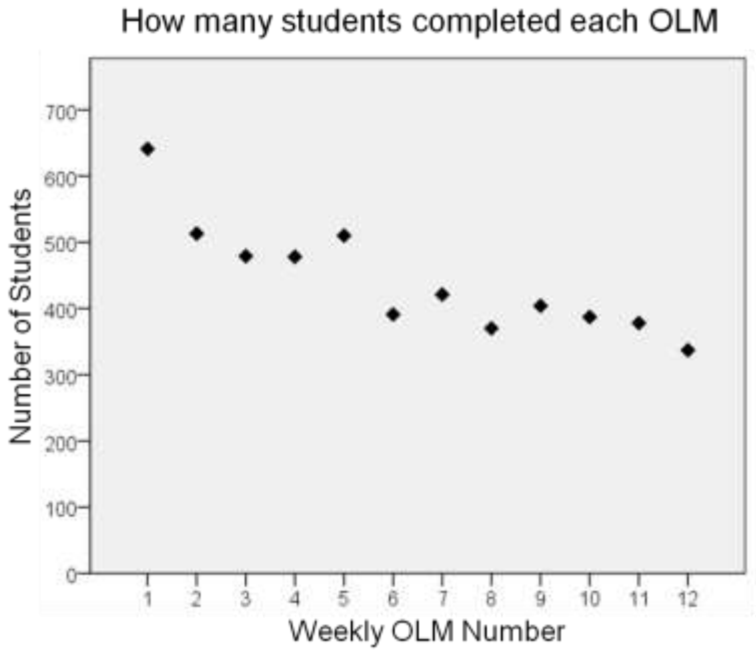

Figure 2: The number of students completing OLMs across the course of the semester.

How Long Do Students Stay Logged onto the OLMs?

The modules were designed to take 15 minutes to complete. The average time across the semester was 14.9 minutes. Figure 3 shows a histogram of the distribution of time students spent on OLMs throughout the semester.

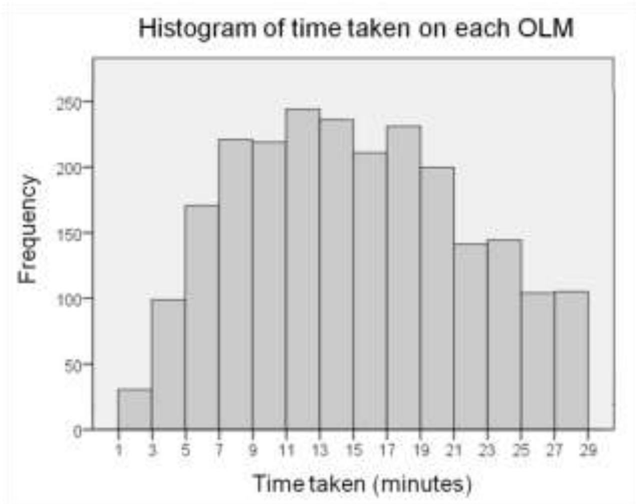

Figure 3: Histogram of time spent on 5101 OLM attempts across the semester excluding the week 13 reflection module which was intentionally shorter.

As Figure 3 indicates there was a wide range of time spent on the OLMs. The data almost appears normal but a Kolmogorov-Smirnov analysis reveals that it is not a normal distribution ($p < 0.001$). While the intended time (and average time) was 15 minutes, many students took up to 30 minutes to complete the modules. It is likely that many students were making use of one of the affordances of online learning – that they can complete activities at their own pace based on their prior knowledge and learning capabilities.

When Do Students Choose to Complete the OLMs?

Another affordance of online activities is that students can complete learning exercises in their own time arranged around other activities. Therefore we may predict that students would complete the modules at all times throughout the four day period given to them each week. The histogram of when students actually completed the modules (split in two hour intervals) is presented in Figure 4.

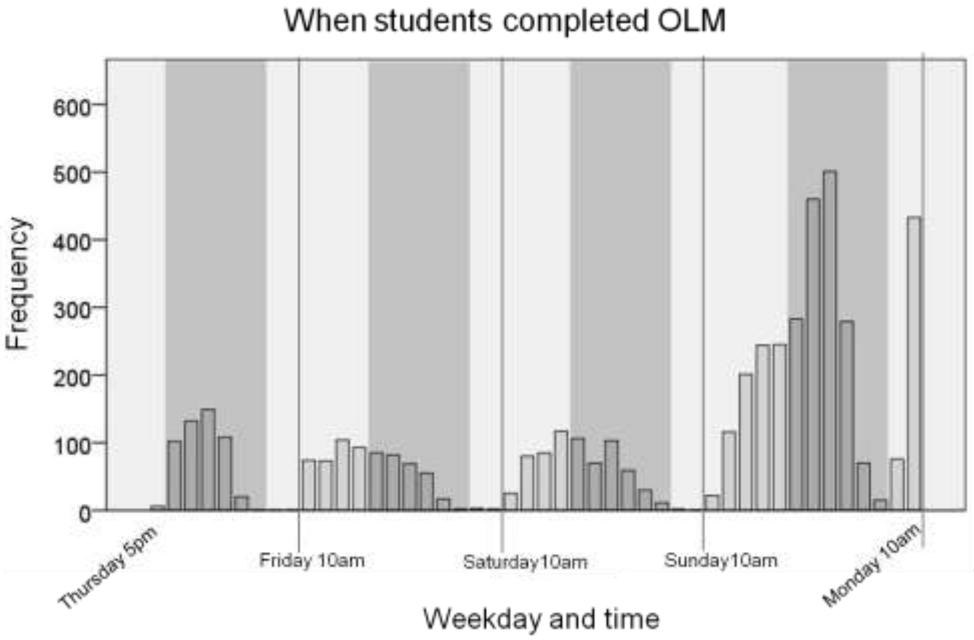

Figure 4: Histogram of when students chose to complete the OLMs between Friday 5pm and Monday 10am. The vertical single lines show 10am as the start of a new day of recording, and the shaded bars represent night time (6pm-6am).

There are three trends to notice from Figure 4. Firstly, students did complete modules right across the weekend indicting that students did the modules when it most suited them. The second trend is that students typically completed the modules between 12pm midday and 3am the following morning suggesting students are willing to engage with online activities later in the night. The final trend is that the majority of students completed the modules immediately prior to the impending deadline of Monday morning, and therefore most students completed the module from Sunday midday onwards. Despite students having the option to choose anytime from 5pm Thursday until 10am on Monday, 63.3% of all modules were completed in the final 24 hours (after 10am Sunday (Figure 5)). We defined four time periods as Thursday (5pm Thursday until 10am Friday), Friday (10am Friday until 10am Saturday), Saturday (10am Saturday until 10am Sunday), and Sunday (10am Sunday until 10am Monday). As the semester went on, a lower percentage of students completed OLM on the Thursday (week 1 had 21%, week 12 had 6%) and more students completed OLM on the Sunday (week 1 had 49%, week 12 had 69%). The overall trend in students completing the OLMs later over the weekend is reflected in the higher standard deviations for the first and last days that the OLM were available.

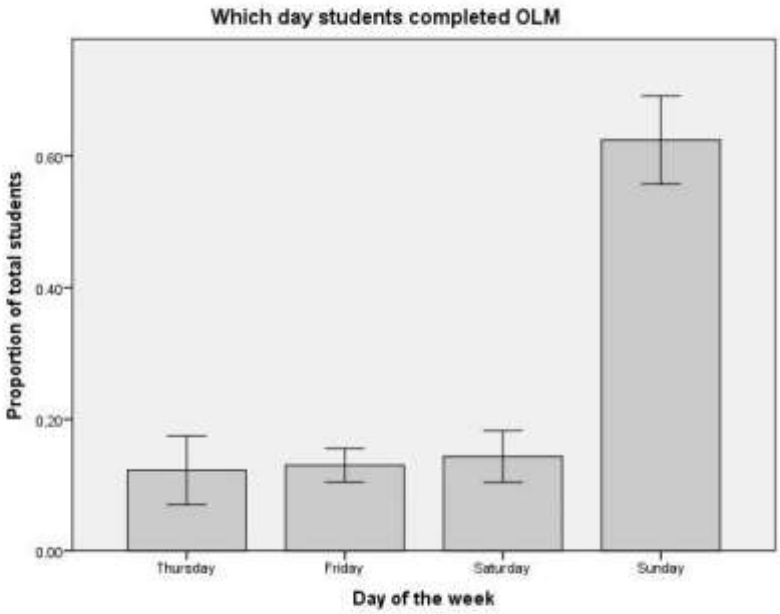

Figure 5: Which day students chose to complete OLMs. Categories extend from 10am of the particular day until 10am the next morning. Error bars represent 1 standard deviation of the proportion of students across the 12 weeks.

Why Do/Don't Students Engage with OLMs?

Why Do Students Choose to Complete OLMs?

326 students responded to the question "What motivated you to continue completing the online learning modules throughout the semester?" The student responses were qualitatively coded into one or more of six categories by one author, which was then validated by another author before together grouping the categories into three themes. These included Theme 1: Finding the OLMs helpful for learning (including categories 1a: Associating OLMs with the lectures, 1b: Referring to helpfulness, and 1c: Referring to learning in a positive), Theme 2: Wanting to attain the associated marks (category 2a: Associated marks), and Theme 3: Completing the modules was a normal part of the course (including categories 3a: Having an "Obligation" to

complete the OLM, and 3b: referring to the OLMs as set work, or a normal exercise). The themes are summarised in table 1.

Table 1: Three identifiable themes to student answers of why they chose to complete the OLMs throughout the semester. Many student answers relate to more than one theme.

Theme	Responses that fit the theme	Representative example
Theme 1: Found the OLMs helpful for learning	61%	"The information gained and summarized by the online learning modules were very helpful in understanding the rest of the course"
Theme 2: Wanted to attain the associated marks	58%	"The 1% mark was easy to get by just completing them. For the little effort, it was worth it"
Theme 3: Completing the modules was a normal part of the course	19%	"It was part of the course"

61% of students indicated that they found the OLMs helpful and useful for learning. Some students felt that the OLMs gave a good overview about the next week's lecture (*The online learning modules provided a very good overview of what we would be learning in lectures and ESPECIALLY in tutorials that week… I would be prepared for the tutorials and be able to contribute to the workshops).* In addition some students saw that the OLMs were a good revision tool (*It helped me reflect on my work*). Therefore many students did the OLMs because it helped them learn.

58% of students indicated that the marks associated with the OLMs were a key motivator. This is despite the total mark attainable only being 1% of the end of semester mark. This indicates that even such a small mark associated with an online activity can be enough to encourage high student participation. Finally 19% of student answers related to the perception that the OLMs were an ordinary part of first semester physics learning. The students were not told that this was a new initiative and so many just took it as a normal requirement.

Why Do Students Choose Not to Complete the OLMs?

We surveyed 27 students who completed less than three OLMs as to why they didn't complete any, or didn't complete more OLMs throughout the semester. They were given space for an open ended response. The three most common reasons were that the students didn't consider engaging in these online activities worthwhile (e.g. *I wasn't bothered*, 8 responses), students forgot about the OLMs (e.g. *I honestly forgot*, 11 responses), and personal/logistical reasons (e.g. *I did not complete the second half as my mother became ill*). This highlights the potential impact of regularly reminding students of the modules and their worth. Only one student indicated technical problems which is positive when trialling a new technological activity. Interestingly two students didn't like the deadline being on Monday with one remarking *If it was (due on) Friday I would do them*. These responses were important for evaluation, in order to try and increase participation in following years.

Is Introducing the OLMs Associated with Improved Learning and Experiences?

Does Completing OLMs Improve Student Learning?

There were two quantitative ways that we present here which can give a measure of student learning. The first is to compare student learning gains on a conceptual test, the FMCE (Thornton & Sokoloff, 1997), completed at the start and end of semester as pre and post tests. Students who completed more than eight OLMs (those who engaged with OLMs) were compared with those who completed less than four (non-participants of OLMs). The average results are presented in table 2.

Table 2: Mean scores and standard deviations on the FMCE raw scores (maximum score is 43) comparing students who engaged in OLMs with non-participants.

	Students who engaged with OLMs (n=261)		**Non-participants (n=53)**	
	Mean	σ	Mean	σ
Pre-FMCE	15.98	8.57	17.37	9.80
Post-FMCE	21.65	11.67	21.13	11.10

Non-parametric tests were used to compare the means as the distributions were found not to be normal (using the Kolmogorov-Smirnov test). Using independent-samples Man-Whitney U Tests, we found that there was no significant difference between the students who engaged with the OLMs and the non-participants for the Pre-FMCE ($p=0.416$) or the Post-FMCE ($p=0.830$). However, for both groups of students the Post-FMCE had a mean that was significantly higher than the Pre-FMCE (non-parametric Related-Samples Wicoxon Signed Rank Test, $p<0.001$). Therefore there was improvement from both groups across the semester.

By calculating the normalised gain, <g>, we are able to easily compare the increases in test scores between the two groups. It is a ratio of the actual gain to the maximum possible average gain for a group of students, i.e.,

$$\langle g\rangle = \%\langle G\rangle/\%\langle G\rangle_{max}=(\%\langle S_f\rangle-\%\langle S_i\rangle)/(100-\%\langle S_i\rangle)$$” (Hake, 1998).

Table 3 shows that the students who engaged with OLMs had a higher gain (.209) than the non-participants (.147) indicating that those who engaged in online learning had greater conceptual physics learning than their fellow students. We note that the pre-FMCE mean is higher for the non-participants while their post-FMCE is no different to that of those who engaged with OLMs. A similar pattern was found in a study in the same institution with students' engagement with tutorials (Sharma, Millar, & Seth, 1999; Sharma, Mendez, & O'Byrne, 2005).

Table 3: Learning gains for the FMCE for students who engaged with OLMs and non-participants.

<g>	**Students who engaged with OLMs (n=261)**	**Non-participants (n=53)**
FMCE	.209	.147

Another measure of the potential impact of the OLMs is comparing the level of student engagement with the OLMs, measured by how many modules were completed by students, and their end of semester physics mark (which is primarily an incorporation of exam, laboratory, and assignment marks). Figure 6 shows that the students who achieved high distinctions on average completed the most OLMs at 10.7 ± 1.4 modules, while students who failed on average only completed 4.1 ± 3.8 modules. As each grade level increases, so does the average number of OLMs completed. This is only a correlation and cannot be reported as a causal link, but when coupled with the results above, that with greater engagement with OLMs also had greater learning gains, it is not surprising that the students who completed more modules, on average, achieved greater success in first semester physics overall. The relationship between OLM participation rates and student success in the course offers administrators another indicator to identify students who may be 'at risk' of failing the course. Not all students who completed few OLM should be classified as 'at risk' as the students who did not complete any modules had no significant difference on the post-FMCE (Table 2), however those who are also found to have a low base-line knowledge would have a high risk of struggling with the course. Students with low or no OLM participation can be contacted by support staff in an effort to help diagnose potential difficulties and where appropriate assist them as they complete the semester.

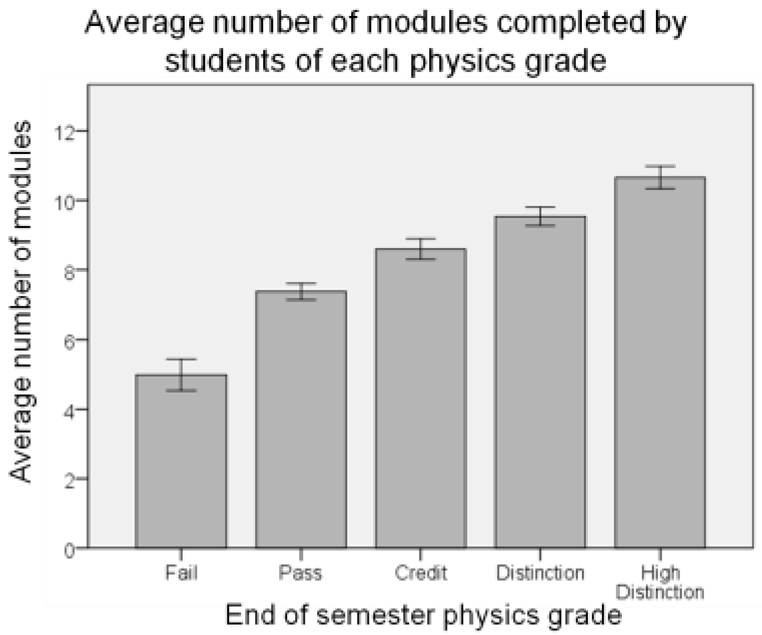

Figure 6: The average number of OLMs completed by students who attained each physics grade (error bars represent the standard error).

What are the Student Opinions of the OLMs?

During the final OLMs students were given an opportunity to reflect on a variety of aspects of the OLMs. Included here are Likert responses and student comments on how the modules helped them in first semester physics. Figure 7 shows four histograms of the students' responses to the final OLM's reflection questions.

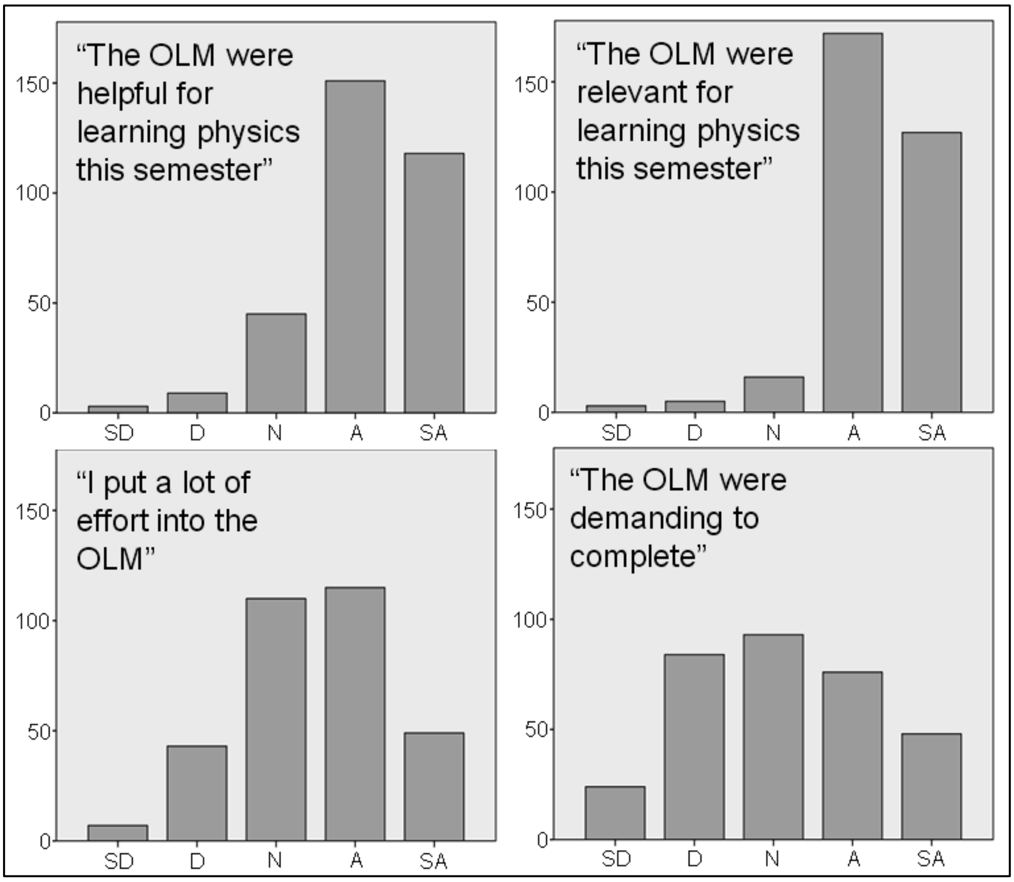

Figure 7: Histograms of student responses to reflection questions on the OLMs. Students could choose from a Likert scale from *Strongly Disagree, Disagree, Neither Agree nor Disagree, agree,* to *Strongly Agree.*

The modules were designed such that the first three questions on the survey would result in most students indicating 'agree' or 'strongly agree' and that the fourth question ("the OLM were demanding to complete") would have a more even spread of student responses. This intent was that modules were not to be too demanding for students. Students on average found the OLMs helpful and relevant for learning physics. The majority of students (51%) either agreed or strongly agreed that they put a lot of effort into the OLMs but many students (34%) answered 'Neither Agree nor Disagree' to this question. While we might have hoped that students had put more effort into the OLMs it is a positive result that students didn't find the extra activity too demanding, but reported its helpfulness and relevance to the course.

As part of the final week's module, the students were asked to "Name one thing about the Online Learning Modules that was helpful for learning physics this semester". Thematic analysis (see Braun & Clarke (2006)) was used to understand and present the open-ended responses. 300 responses were obtained and one researcher identified six sub-themes using a bottom-up approach generating initial codes using a word-count method (see Table 7 of Hill et al. (2015) for the word-count method results). This author proposed three overall themes, and a fourth theme with two student responses stating that they did not find the OLMs helpful in any way. The other authors of the paper validated the analysis by using these now defined themes and sub-themes to categorise a selection of 60 responses (20%). They coded all but one of the responses in an identical way to the original analysis and so the themes are presented below. (The disagreement about the one particular response was resolved after a group discussion.) Table 4 lists the three themes and six subthemes.

Table 4: The themes and sub-themes identified from the 300 online responses to the question "Name one thing about the Online Learning Modules that were helpful for learning physics this semester".

Theme	Sub-theme	% of responses
1. OLMs prepared students for lectures and other learning.	1a. The OLMs made learning in lectures more effective or efficient	44%
	1b. The OLMs assisted preparation for the week's learning (lectures, labs and tutorials)	28%
2. OLMs improved student understanding of physics	2a. The OLMs explained physics or facilitates learning and understanding	24%
	2b. The OLMs introduced physics content, ideas, or representations (graphs, equations or diagrams)	19%
3. OLMs provided other benefits to learning physics	3a. The OLMs encouraged regular physics participation	6%
	3b. The OLMs acted as a review (rather than preview) of the week's material	5%
(4. The OLMs did not provide any benefit)		<1%

Students recognised that completing the OLMs changed the way that they learnt physics [Theme 1]. Either they found physics lectures easier to understand (*by completing the OLMs we are not completely clueless in lectures*) or they felt that the OLMs helped them prepare for upcoming material. Therefore they found that the OLMs integrated well with the physics course. This statement is also supported by theme 3. Many students found that completing the OLMs encouraged regular participation in the physics course (*They made sure I did some physics work each week*).

A final comment is made using comments from the bi-annual staff/student liaison meeting held at the end of each semester which contained a focus group reflecting on the OLMs and the physics course. Here is highlighted three most relevant student comments regarding the increased workload from the OLMs:

- Student A: The quizzes (OLMs) are really helpful for the lecturers in the coming week.
- Student B: The reflection questions are annoying. I know they say they are good for us, but… I don't see the point. The really good part is the information and the questions.
- Student C: There is not too much assessment/activities. It is good to keep motivated.

These three students consider the OLMs helpful (supporting the data obtained from the survey in the final OLM). One provided feedback that a portion of the weekly OLMs were frustrating and from their perspective, unhelpful but was still positive overall for the experience. Finally student C made a direct statement that despite the extra workload this was not a negative. The modules and other activities helped this student to keep motivated. This suggests that there is a limit to the amount of work we can ask of students, but introducing OLMs to a course already with lectures, laboratories, workshop tutorials and assignments has clearly not reached that limit.

Discussion

In comparing voluntary participants and non-participants one must consider the issue that the participants are more likely to put extra effort into all aspects of their learning. While their improved performance from the pre-test to the post-test could be due to the intervention that they voluntarily participated in, it could also be due to their other efforts to learn physics across the semester. However, the results in this paper indicate a clear association between learning gains and OLM participation and suggest that the OLMs may have been one of the differences in the post-test scores of the two groups.

The impact on student performance was only one of the questions that this paper set out to answer. Student participation was measured using data retained through the learning management system platform and engagement with the OLMs was considered through asking when and for how long did the students complete the modules and questioning student perceptions of the OLMs. As a result we have been able to provide practical insight into the benefits of introducing research-based, integrated online learning activities relevant to both researchers and practitioners alike.

Implications for Research

Lack (2013) rued the absence of much rigorous research into online learning. By comparing students who participated in more than eight OLMs (engaged students) with those who completed less than four (non-participants) we have demonstrated that engaging in a significant number of weekly pre-lecture OLMs in physics is associated with conceptual learning gains across the semester. In addition students who attained higher end of semester results for the course on average had completed more OLMs. In addition, student perceptions indicated that they felt that the modules were helpful for learning physics, preparing themselves for lectures, and maintaining progress through the course indicating that the students felt that the implementation of blended learning has a clear positive impact on this first semester physics course.

For one of the first times, student participation was tracked over each weekend and across the semester. The results have shown that the majority of students did engage with the online component of blended learning and that there were some clear patterns in student use. This gives greater understanding of the student attitude towards blended learning and the actual impact rather than just assuming all students who complete all activities given to them regardless of their situations. On average students spent 15 minutes a week on the modules (as intended) but despite giving them almost four days to complete the modules (from Thursday evening until the Monday morning's lecture), 63.3% of modules were attempted in the last 24 hours, and the highest time period of module completion was 9-11pm on the Sunday evening. These results present us with a question: does blended learning allow for students to complete learning activities when it is most convenient for them (potential for greater engagement than face-to-face instruction) or does it simply change the time that students are working to the last 24 hours before the due date (same level of engagement)? That is – did students engage more by participating in an extra task simply because it was an extra task, or was it because the OLMs delivered this content in a format that was conducive to engagement (blended learning). In our course, students saw preparation for the coming week's lectures as a key benefit of the OLMs and therefore it is not surprising that the evening before classes were due to begin for the week would be a peak time in OLMs use as students prepared for the week ahead.

One limitation of the study was that time spent on the OLMs did not necessarily indicate the time that the students spent in front of their computers working through the OLMs. The times used to calculate the average time of 15 minutes was from when they began the module until the time that they submitted it. While OLM sessions that ran overtime were excluded as this indicated that students had simply left their internet browser running, further research would improve the study by tracking clicks or cursor movements to get closer to a true measure of the time the students remained on task.

Further work could also be done in directly asking students why they completed the tasks at the times that they did and how the OLMs fitted into their everyday life. Students could also be asked how OLMs could be structured or delivered in order to make them engage even more. Analysis of specific questions from the exam may also reveal whether the OLMs produce particular benefits with regards to specific sets of knowledge. Finally, data collection could be designed such that students who did participating in OLMs could be matched with students of similar base-line ability who did not participate in OLM allowing for another perspective on the learning gains.

Implications for Teaching

Practitioners are feeling pushed towards increasing the level of online learning in their courses, whether from others in their institutions, or a conviction that it may benefit their students. Many may feel wary about how blended learning can fit with their situation and simply whether the students will participate in learning opportunities when they are placed online. Others may have implemented blended learning and are now looking for ways to measure the student participation and perceptions of the change and its impact on their performance. This paper analyses data retained though a learning management system to consider what blended learning looks like for the students.

This study demonstrates that students do engage in the online learning opportunities of a supplemental model of blended learning (Twig, 2003) in first year university physics. Vitally important was incorporating research into both the design and the evaluation of the OLMs. We followed warnings and recommendations to ensure that the extra activity was not a burden and that the OLMs were well integrated with the course and student data supports this (Alammary et al., 2014). We echo these warnings of ensuring that any additional activity, especially presented through a different medium such as online learning, must be well integrated with the course and students must see the benefit to encourage high levels of participation and engagement. To suit this particular context, an incentive of 1% of the semester grade was ascribed to the completion of the OLM such that the students see the OLMs as a core component of the course.

In particular it needs to be decided whether the online activities are going to be lessons on their own or are designed to improve learning in other settings. By allowing the OLMs to be preparatory and well integrated with the lectures students were able to recognise that the modules helped them prepare and in fact changed the way that they learnt in lectures for the better (consistent with Day et al. (2004) and Moore (2014)).

As well as designing effective modules and convincing students of the educational value of participating in online learning there are a number of logistical factors to consider. Information given to students about online learning at the start of semester, and through the semester, needs to be clear and effective. Our observation is that the current generation of students prioritise course activities when it contributes directly to their final mark. This explains why assigning a participation mark (even if it was only 1%) was effective in encouraging high completion rates (as shown by 58% of students indicating that this was part of the reason why they completed OLMs). In 2015 the institution will be applying standards-based assessment to the first year physics course where, in order to receive a particular grade, students must perform to a minimum standard in *all* learning assessments including laboratory classes, assignments, exams, and OLMs. So rather than 11 out of 12 modules constituting 1% of the physics mark, completion of 10 out of 12 modules will be required for students to attain a high distinction. This is expected to further increase student participation in the OLMs, which are deemed an essential component of the physics course.

Given that part of this is directed to practitioners considering implementing blended learning, we make a final comment reflecting on our experiences. When introducing an online component to a predominantly face-to-face course, especially for a large course, staff need to be available to reply to student emails within short time periods even over weekends to help with technical issues and other questions. Support from IT staff is critical in the start-up phase. As the inclusion of OLMs settles into a normal part of the course, such support needs to be sustained.

Conclusion

This paper demonstrates the integration of blended learning into a large first year university physics course. It was found that there was a high frequency of student engagement, despite a gradual decrease in participation across the semester. A high level of engagement was also found which according to students resulted in positive benefits to their learning in lectures and is associated with overall increases in conceptual understanding. Specifics of student participation such as time of day were tracked and reported. By offering a rigorous investigation into the quality and frequency of student engagement in blended learning, this paper contributes to our understanding of blended learning and provides incentive and an example for educational designers to implement similar blended learning activities to suit their particular context.

Appendix 1

A sample of the OLMs can be found at the following link. Please note, it has been adapted into a worksheet format for easy viewing and therefore some features present in the online environment have been lost.

Online Learning Module: Free-body diagrams:
http://www.physics.usyd.edu.au/super/RFS/Sample%20OLM.pdf

References

Alammary, A., Sheard, J., & Carbone, A. (2014). Blended learning in higher education: Three different design approaches. *Australasian Journal of Educational Technology, 30*(4).

Beer, C., Jones, D., & Clark, K. (2009). The indicators project identifying effective learning: Adoption, activity, grades and external factors. Same places, different spaces. Proceedings ascilite Auckland 2009, 60-70.

Black, G. (2002). A comparison of traditional, online, and hybrid methods of course delivery. *Journal of Business Administration Online*, *1*(1), 1-9.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101.

Chen, Y., Wang, Y., & Chen, N. (2014). Is FLIP enough? Or should we use the FLIPPED model instead? *Computers & Education*, *79*, 16-27.

Chen, Z., Stelzer, T., & Gladding, G. (2010). Using multimedia modules to better prepare students for introductory physics lecture. *Physical Review Special Topics-Physics Education Research*, 6(1), 010108.

Craig, P., Wozniak, H., Hyde, S., & Burn, D. (2009). Student use of web based lecture technologies in blended learning: Do these reflect study patterns. *Same places, different spaces. Proceedings ascilite Auckland 2009*.

Day, J. A., & Foley, J. D. (2006). Evaluating a web lecture intervention in a human–computer interaction course. *Education, IEEE Transactions on*, *49*(4), 420-431.

Day, J. A., Foley, J. D., Groeneweg, R., & Van der Mast, C. A. (2004). *Enhancing the classroom learning experience with Web lectures.* Georgia Tech Library.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410-8415.

Georgiou, H., & Sharma, M. D. (2015). Does using active learning in thermodynamics lectures improve students' conceptual understanding and learning experiences? *European Journal of Physics, 36*(1), 015020.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64-74.

Harasim, L. (2000). Shift happens: Online education as a new paradigm in learning. *The Internet and Higher Education, 3*(1), 41-61.

Hill, M., Sharma, M. D., & Johnston, H. (2015). How online learning modules can improve the representational fluency and conceptual understanding of university physics students. *European Journal of Physics, 36*(4) *(2015)* 045019.

Hood, M. (2013). Bricks or clicks? Predicting student intentions in a blended learning buffet. *Australasian Journal of Educational Technology, 29*(6), 762-766.

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, *33*(7), 14-26.

Lack, K. A. (2013). Current status of research on online learning in postsecondary education. *Ithaka S+ R, zuletzt geprüft am, 3*, 2013.

Lindstrøm, C., & Sharma, M. D. (2011). Self-efficacy of first year university physics students: Do gender and prior formal instruction in physics matter? *International Journal of Innovation in Science and Mathematics Education*, *19*(2), 1-19.

Lumsden, E. A. (1976). The effect of brief, pre-lecture quizzes on performance on regularly-scheduled tests, class participation, and student-evaluation of lectures. *Journal of Instructional Psychology, 3,* 40-44.

McFarlin, B. K. (2008). Hybrid lecture-online format increases student grades in an undergraduate exercise physiology course at a large urban university. *Advances in Physiology Education, 32*(1), 86-91.

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2009). Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies. *US Department of Education*.

Moore, J. C. (2014). Efficacy of multimedia learning modules as preparation for lecture-based tutorials in electromagnetism. *arXiv preprint arXiv:1409.7682*.

Neumann, D. L., & Hood, M. (2009). The effects of using a wiki on student engagement and learning of report writing skills in a university statistics course. *Australasian Journal of Educational Technology, 25*(3).

Oncu, S., & Cakir, H. (2011). Research in online learning environments: Priorities and methodologies. *Computers & Education, 57*(1), 1098-1108.

Pargas, R. P. (2006). Reducing lecture and increasing student activity in large computer science courses, paper presented at the ACM SIGCSE. *Proceedings of the 11th Annual SUGCSE Conference on Innovatioin ad technology in Computer Science Education*, p. 3-7.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*, 223-232.

Ruiz, J. G., Mintzer, M. J., & Leipzig, R. M. (2006). The impact of e-learning in medical education. *Academic Medicine, 81*(3), 207-212.

Seery, M. K., & Donnelly, R. (2012). The implementation of pre-lecture resources to reduce in-class cognitive load: A case study for higher education chemistry. *British Journal of Educational Technology, 43*(4), 667–677.

Sharma, M. D., Johnston, I. D., Johnston, H., Varvell, K., Robertson, G., Hopkins, A., Stewart, C., Cooper, I., & Thornton, R. (2010). Use of interactive lecture demonstrations: A ten year study. *Physical Review Special Topics-Physics Education Research, 6*(2). doi: 10.1103/PhysRevSTPER.6.020119

Sharma, M. D., Mendez, A., & O'Byrne, J. (2005). The relationship between attendance in student-centred physics tutorials and performance in university examinations. *International Journal of Science Education, 27*(11) 1375-1389.

Sharma, M. D., Millar, R., & Seth, S. (1999). Workshop tutorials: Accommodating student centred learning in large first year university physics classes. *International Journal of Science Ed*ucation, *21*, 839-859.

Stelzer, T., Brookes, D. T., Gladding, G., & Mestre, J. P. (2010). Impact of multimedia learning modules on an introductory course on electricity and magnetism. *American Journal of Physics, 78*(7), 755-759.

Stelzer, T., Gladding, G., Mestre, J. P., & Brookes, D. T. (2009). Comparing the efficacy of multimedia modules with traditional textbooks for learning introductory physics content. *American Journal of Physics, 77*(2), 184-190.

Swan, K. (2009). Introduction to the special issue on blended learning. *Journal of the Research Center for Educational Technology, 5*(1), 1-3.

Thornton, R. K., & Sokoloff, D. R. (1997). Assessing student learning of Newton's laws: The force and motion conceptual evaluation and the evaluation of active learning laboratory and lecture curricula. *American Journal of Physics, 66*(4), 338-352.

Twigg, C. A. (2003). Models for online learning. *Educause Review*, *38*, 28-38.

Utts, J., Sommer, B., Acredolo, C., Maher, M. W., & Matthews, H. R. (2003). A study comparing traditional and hybrid internet-based instruction in introductory statistics classes. *Journal of Statistics Education, 11*(3), 171-173.

Wang, C.-H., Shannon, D. M., & Ross, M. E. (2013). Students' characteristics, self-regulated learning, technology self-efficacy, and course outcomes in online learning. *Distance Education*, *34*(3), 302-323.

Wu, J., Tennyson, T., & Hsia, T. (2010). A study of student satisfaction in a blended e-learning system environment. *Computers & Education, 55*(1), 155-164.

Zhao, Y., & Breslow, L. (2013). Literature review on hybrid/blended learning. *Teaching and Learning Laboratory, (TLL),* MIT.