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A flipped classroom in communication systems: Student perception and performance assessments

Aksay Fatih Öncel[1] and Ali Kara[2]

[1]Department of Electrical and Electronics Engineering, Middle East Technical University, Ankara, Turkey[2]Department of Electrical and Electronics Engineering, Atilim University, Ankara, Turkey Corresponding author:
Ali Kara, Department of Electrical and Electronics Engineering, Atilim University, Incek, Ankara 06836, Turkey.
Email: ali.kara@atilim.edu.tr

Abstract

Flipped classroom is an emerging course delivery method, where the traditional in-class and out-of-class activities flip places. The lectures are given out-of-class with electronic resources and in-class time is reserved for group activities and discussion with the instructor. In this study, we present our implementation of a flipped classroom in a senior level undergraduate engineering course. An extensive perception analysis was carried out with anonymous surveys and face-to-face interviews with students. Performance analysis of the flipped class was carried out by comparing the achievement level in the course learning outcomes of previous years' traditional classes and recent year's flipped class. The out-of-class lectures were implemented as machine-voice- narrated presentations. The effect of machine voice on the flipped classroom is also examined. Students' perception and reaction to various aspects of the flipped class are documented. Performance analysis showed a significant improvement in one categoryof course learning outcomes. Student perception was positive overall.

Keywords

Flipped classroom, inverted classroom, perception assessment, performance assessment, text-to-speech, synthetic voice

Introduction

Flipped classroom is a newly popular course delivery method, where, as the name suggests, the traditional in-class and out-of-class activities flip places, so that the lecture retention is carried out out-of-class, and in-class time is reserved for mostly interactive activities such as group-based discussions or problem solving and quizzes. It is a learner-centered method where learners are expected to participate actively in order to fully benefit from the course. Recent studies showed promising results in student performance in flipped classes com- pared to traditional ones.1–6 Bates and Galloway4 also reported increase in content coverage.

The degree of flipping and, consequently, the flipped classroom structure can vary greatly by implementation.6 Generally, the out-of-class lecture delivery is carried out with narrated self-study materials, i.e. video lectures or presentations. There can also be supplementary exams, i.e. online quizzes to track and encourage lecture participation. The in-class activities can be small group discussions, prob- lem solving, and discussion with the instructor.

At the Department of Electrical and Electronics Engineering of Atilim University, where this flipped classroom study is conducted, there has been an

ongoing effort on enhancing the courses with new and emerging methods.7–9 In O€ ncel and Kara,7 the authors have published some preliminary findings of the flipped classroom study, which is the subject of this letter.

In this study, we implemented a flipped classroom for an undergraduate electrical engineering course: communication systems. It is a one-term course, given in the third year of the four-year regular program time. The flipping degree was full, viz. the lecture delivery was carried out out-of-class with nar- rated presentations and was supplemented by online quizzes, and in-class time was partitioned to discussion with the instructor, small-group problem solving and individual problem solving. The students' perception of the flipped class- room was assessed in detail; for this purpose, with high participation, surveys and face-to-face interviews were carried out. Rich and conscious qualitative responses were obtained, which enabled a healthy and precise assessment of various aspects of the flipped classroom. Students' performance was also evaluated by their exam results.

The out-of-class lectures were prepared with a synthetic voice text-to-speech (TTS) software, which was a new experience for many of the students. The effect of synthetic voice narrative is also analysed.

The remainder of the paper is organized as follows. In the Course Content section, the course content of the flipped and previous years' traditional class are presented. In the Assessment Methods section, the assessment methods of students' perception and performance are presented. The TTS section is reserved for the TTS. Results section gives the final results of our study. In Discussion, discussion of our findings is carried out; and finally there is Conclusion.

Course content

In this section, the content of the previous years' traditional class and the recent year's flipped classroom are presented.

The said communication systems course is an obligatory course in the electrical engineering curriculum. Regularly it is given as a one-term course in the second semester of the third year (electrical engineering is programmed as four years). It has three lecture hours a week, and biweekly lab sessions, where hardware as well as Matlab-aided software hands-on experiments are performed. The course book is S. Haykin, and M. Moher's "Communication Systems", 5th ed., John Wiley & Sons, 2010.10 Traditionally, the students are graded by mainly classical written exams, but in the flipped classroom, this was changed to half of the grading being achieved from flipped classroom activities. The medium of education is English in the department, where the students are mostly Turkish native speakers. On average, 50 students take the course per semester, with recent year's (2014– 2015 term) regular student population being 39.

Traditional classroom

In the traditional classes of previous years, the lectures were given in the class by the instructor via computer-aided presentations. The grading was done mainly by two midterms and one final. Also, the lab sessions and other auxiliary activities contributed minorly.

Flipped classroom

The lecture delivery in the flipped class took place out-of-class by machine-voice- narrated computer presentations published online weekly. On average, each pre- sentation had 20 slides, but some marginal ones with twice that number also existed, and the total runtime took between 10 and 30 min. Students were given the course materials in two formats, (1) machine-voice-narrated presentation slides and (2) video versions of the machine-voice-narrated slides. The online presenta- tions were based on the instructor's presentations prepared for traditional classes. They were narrated with a synthetic voice TTS software, as otherwise they would be narrated by the instructor himself in the class. Details of the TTS are given in the next subsection. A separate transcript of the voice recording was not provided. Students were

expected to study this material as many times as necessary to under- stand the lecture, as there was no encouragement to seek the lecture reten- tion elsewhere.
After having seen the lectures, the students were expected to fill in some feed-
back forms. A form was provided for asking the instructor content-related ques- tions about the lecture. These questions were compiled and answered each week in the class. Other forms were created for students to give feedback about that week's lecture material itself. Students had the opportunity to evaluate the lecture in terms of sound, visual quality, etc., volume/scope of the presentation and the quality of
the material of the presentation. These feedback forms were compiled each week and, when applicable, immediate actions were taken by altering the presentations and republishing them online; also, attitudes and long-run suggestions were eval- uated periodically.
A couple of days after the publication of the lectures, an online quiz solely derived from the recent lecture was performed. The quiz took place at evening, in one single session for all students. There were approximately 10 questions in each quiz. The questions were kept at a very basic level: the aim was to track and encourage the student participation in the lectures. The questions were multiple- choice and students could learn their results immediately after the session ended. Following day of the online quiz, a class hour was scheduled for discussion with the instructor. In this discussion hour, the questions asked by students in the feed- back forms were answered. Having read the feedback forms and seen the quiz results, the instructor had a relatively accurate idea about which parts of the lecture needed further discussion, and focused on these parts in the discussion hour; and at the same time went through as many questions as possible systematically, so that
each student had an opportunity for their questions to be answered.
Two days after the discussion hour, the in-class collaborative problem solving (CPS) and individual quiz took place. In CPS, the instructor randomly assigned small groups of at most three students, and they were given a moderately complex problem about that week's lecture to solve in an hour. The following hour of CPS, the students took the individual quiz, which consisted of a very similar problem to that of CPS.
There was only one midterm and one final in the flipped class as compared to two midterms and one final in traditional class. Half the grade came from flipped classroom activities, the main source being the individual quiz and CPS. All flipped classroom activities were graded depending on the effort that was expected from the students to spend on them.

TTS

We used an American English accented voice for our Turkish native speaker audience. The TTS software was a commercial product that is widely used and accepted in the field.
The only control we had on TTS was its speed, which we kept intentionally slower than that of average human speech to make it more audible. TTS speech is mono- tonic by its nature. The effect of TTS use is elaborated in detail in results' section and also in a previous work.7 Attention of the student was kept alive by continuing activities as discussed above (quizzes, discussion hour, feedback forms, etc.).
The ideas behind using the TTS instead of recording the instructor's voice narrative were, (1) to speed up the process of transition to flipped classroom, as it can take over 100 h to prepare the lectures that way,2 and (2) to create a generic lecture preparation environment, where changes to lectures can be made without much effort, viz. a change in the lecture text can be re-narrated with ease using TTS. Our work with TTS will also guide the future researchers who intend to use it in their flipped classes.

Assessment methods

The assessment of the implemented flipped classroom was done in two parts: (1) students' perception of flipped classroom, and (2) students' performance as com- pared to traditional classes. The former made use of qualitative as well as quan- titative assessment, whereas the

latter was purely quantitative. TTS assessment is also included here. Assessment methods are summarized in Table 1.

Student perception

There were two ways of assessing student perception: (1) Likert-like surveys filled anonymously (called flipped classroom survey from thereon to differentiate it from the university-wide survey), and (2) face-to-face interviews conducted with a selected group of students. The university also had its own university-wide course assessment survey, and although it was not specific to the flipped classroom, its results are also presented.

Surveys

There were two flipped classroom surveys conducted by us throughout the semester.[7] They were carried out on paper during midterm (the first) and final exam times (the second). They asked, in general, the students' satisfaction level, on a scale of five, five being the maximum satisfaction, of the following items: course workload; course materials; presentation content, audio and video quality; online quizzes; in-class activities: discussion hour, CPS, and individual quiz; overall view. They also had an option to fill in an open-ended question regarding their other

Interviews

Three interviews were carried out throughout the semester, approximately at the beginning, middle, and the end of the semester. The questions were open-ended and the participation was face-to-face. Ten students were selected to participate in the interviews and the same 10 students attended all the interviews. The students were selected for their initial diverse view of the flipped classroom, as observed from the feedback forms, and for their high participation level in the class and flipped classroom activities. The diversity was preferred in order to achieve an unbiased view in aggregation. The same questions were asked in each interview, which also tracked the change in students' mood.

In addition to the things asked in the surveys, students were also asked to name what they most like and dislike in this new system. The answers were rich and diverse; there were many implications of certain tendencies and attitudes towards various aspects of the implemented flipped classroom. Full questions and some sample answers are provided in Öncel and Kara.[7]

Performance evaluation

The performance of the students of flipped classroom was evaluated by their achievement level in predefined course learning outcomes (CLOs), shown in Table 2. These CLOs are in existence in the department since few years in accordance with ABET certification process.[11] They help the instructor and department to evaluate individual and class performance.

There are two ways of measuring the CLO achievement levels: (1) students' self-declaration, and (2) exam results. For the first type of self-declared results, students are asked their ability level on a scale of one to five for each CLO. These scores are then normalized to one for comparison with achievement levels derived from exam results. For the second type of achievement evaluation from exam results, questions from written classical exams are matched to CLOs by the teaching staff and students' scores in these questions are regarded as their achievement in that

particular CLO. Exam questions are partially graded, moderately long, problem-solving questions.

Performance evaluation via CLOs is an already working process in the department, so for this year's flipped classroom performance evaluation, the existing previous two years' scores were compared with recent year's scores.

TTS assessment

To assess the TTS effect alone, we carried out a comparative intelligibility and perception test. In the test, we asked the students to transcribe and answer some basic questions about a TTS fragment and a narrative by the instructor. Their accuracy was then compared. Also, they were asked about their perception of the two different narratives.

Results

In this section, the results of the assessments are presented.

The open-ended responses, for both surveys and interviews, are given when they indicate a certain tendency and shared by a majority or point out to an interest- ing fact.

Although quantitative analysis was carried out for TTS as well, it is not presented directly; rather, the qualitative results driven from it are presented.

Flipped classroom surveys

A total of 37 and 35 students participated in the first (midterm time) and second (final exam time) surveys, respectively. Results are given in Table 3[7] as mean scores

Table 3. Survey results.[7]

Item asked	I. Mean (SD)	II. Mean (SD)
Course workload	2.92 (1.28)	3.46 (1.36)
Course materials	3.86 (1.30)	3.71 (1.26)
Lecture content	3.56 (1.09)	3.49 (1.20)
Lecture audio	3.00 (1.29)	3.43 (1.27)
Lecture visuals	3.67 (1.03)	3.88 (1.02)
Online quiz	3.41 (1.03)	3.36 (1.39)
Discussion hour	2.46 (1.35)	2.67 (1.49)
CPS	3.74 (1.25)	3.85 (1.31)
Individual quiz	3.29 (1.32)	3.36 (1.30)
Overall satisfaction	3.03 (1.06)	3.21 (1.39)

and standard deviations (SDs) of the first and second surveys on the first and second column, respectively. Full questions are provided in the Appendix of Öncel and Kara.[7] The results show a moderately positive perception of the flipped class except for the "Discussion Hour," as discussed below.

Student's *t*-test is a commonly used method for statistical evaluation purposes. Its effectiveness has been demonstrated in the educational literature. Although the group size is somewhat moderate (maximum 37) in our case, which might not guarantee a normal distribution required for the *t*-test, we have applied the *t*-test anyhow to give an idea of the significance of the statistical changes.

Between two surveys, the "Course Workload" item improved from 2.92 to 3.46, with $p < 0.05$ statistically significant under *t*-test. This is attested to the fact that, as also pointed out in interviews, the students have got familiar with the new system in time, so the time needed to spend on the course was decreased. We did not decrease the course workload in between in any manner. Also, the "Lecture Audio" item had improved from 3.0 to 3.43 with $p¼ 0.08$. This is partly due to students getting familiar with the TTS and partly to our improvements on the TTS.

In the first survey, in the open-ended question, there were several complaints about a decreased level of interaction with the instructor. Some students wanted the discussion hour to be longer and out of purpose so that the lecture be given traditionally. These students completely missed or rejected the main point of flipped classroom. There was also a comment noted that this system would be extremely hard for students that do not study regularly. In fact, the students who wanted traditional lectures stated their average time spent for this course weekly as at most 1–2 h, which is below the average of 3 h; also, they gave at most two points out of five to the "Course Workload" item. This shows that the flipped classroom is highly likely to negatively discriminate the students that do not have a regular study habit or are not active learners.

In the second survey, only a few negative marginal comments were left, which clearly stated preference of traditional class over the flipped.

University-wide survey

A total of 35 students participated in recent year's university-wide survey. The previous years' participation was approximately the same.

The university-wide course evaluation did not show any significant change in any aspect between the traditional classes and the flipped class, when the previous two years' traditional classes' evaluation scores were aggregated and compared with recent year's flipped class and put under *t*-test. Anyhow, the scores were already one of the highest faculty-wide.

In qualitative responses, students reacted to the flipped class diversely. One thing almost all responses agreed on is that this new method of flipped class forced them to study more, which is seen as positive by the majority and negative by some minority. Also, the majority found the new method successful.

Interviews

The main things the students talked about in the interviews are grouped under the following sections.

Workload

In the first interview, the students stated that they at least spend 3 h on the course weekly. For most of them, this course was the most time-demanding course they were taking and flipped system was the reason. Coming to the second interview, the time spent had decreased, as they have got familiar with the system.

TTS

The most negative views towards the system were aimed at the synthetic voice of TTS. Students had an uneasy time trying to listen to and understand the unfamiliar machine voice. One of them, with a musical background, even stated that this voice was "killing his ears". For this reason mainly, many of them ceased following the lecture through narratives and started going through the textbook in the guidance of the presentations.

In response to the negative feedbacks, some improvements on the voice were made by slowing the pace and improving the intonation; however, many still did not listen to the narratives. Many stated they would prefer the recorded sound of the instructor.

Feedback forms

Although in the beginning, the feedback forms were welcomed as means of participating, feeling involved, and easy grade acquiring, over time they started to feel redundant and to some extent lost their functionality as the quality of the responses got lower. Students stated they were filling the forms just for formality. Some feedback form samples can be found in Öncel and Kara.[7]

Discussion hour

Many students expected the instructor to give a traditional lecture hour in the discussion hour. This would, taken as it is, imply a partially flipped class, which was not our intention. Some wanted a longer discussion hour with the same motive as above.

CPS and individual quiz

The most-liked part of the flipped class was the CPS. Many stated that it helped them learn by discussion with peers. The idea of similar questions asked in CPS and individual quiz was also liked: as some stated, when they come to class unprepared, instead of taking the individual quiz directly and fail, they had an opportunity to learn by group discussion. Even the prepared students benefited by validating their ideas in discussion.

Some students complained about the random pick of groups, whereas others liked it, because, as they stated, in the industry, where they would work after graduation, they would not be able to pick their colleagues. This was an effective justification used by the instructor in CPS sessions, and it mostly convinced the students.

Overall

Overall, the interviewed students did not object to the flipped classroom emphatically, though they were not zealous about it either, except for a few marginal cases. The majority liked the increased importance of self-study, because they had never studied so intensely for a course before.

The sharp transition from the traditional in-class lecture to the flipped class left a vague feeling of uneasiness at some students. Although they could not well support with firm arguments, they felt that something was missing and they would feel themselves more comfortable in a traditional class. At the least, they expected a guidance from the instructor on the course of their self-study, even though they were supported with the TTS-narrated lectures, whose aim was exactly that. Some students implied that they did not trust the new system, although it was prepared by the instructor; and they would prefer the instructor to give the lectures himself traditionally, but keep the rest of the flipped class intact, e.g. online quizzes, in-class discussion. In a nutshell, they liked the new activities in the class but either lacked the capabilities to or preferred not to retain the lectures through presentations on their own.

A suggestion some shared was to rather have been asked for their consent to participate in the flipped class before the beginning of the class and be more informed about it, even though they would have given their consent anyhow.

Performance evaluation

The performance of the students was evaluated by their achievement scores in CLOs. The questions in exams, in subquestion level, were matched to CLOs,

and aggregated achievement in CLOs in the past two years' traditional classes and recent year's flipped class were compared. Also, the self-declared CLO scores are presented, but not included in the instructor's evaluation.

In Table 4, the CLO achievements measured from exams in traditional classes and flipped class are given as mean scores and SD. The scores are normalized to unity. Only in the fourth CLO, there was a meaningful change in the positive direction. The other CLOs did not change considerably. The last two CLOs that listed in Table 2 are not relevant to the exam questions, therefore they are not included.

In Table 5, the self-declared CLO achievements normalized to unity are presented. At least 15 students attended this evaluation each year. The last two years' traditional scores were aggregated and compared to recent year's flipped class. In every CLO, there is improvement. Note that, there is a considerable gap between the CLO achievement measured by exam results and the self-declared ones, because the students tend to misjudge or vaunt their own achievement.

TTS

A group of 10 native Turkish speakers and a native English speaker participated in the TTS test. The speech given to the audience to be transcribed was of approximately 3 min length, course related, and technical. The TTS read the text in the

Table 4. CLO scores by exam results.

CLO number	Traditional (SD)	Flipped (SD)
1	0.37 (0.42)	0.34 (0.39)
2	0.37 (0.38)	0.38 (0.37)
3	0.24 (0.34)	0.2 (0.32)
4	0.16 (0.24)	0.34 (0.29)

CLO: course learning outcome.

Table 5. CLO scores self-declared.

CLO number	Traditional class	Flipped class
1	0.74	0.86
2	0.69	0.86
3	0.73	0.74
4	0.61	0.82
5	0.69	0.82
6	0.62	0.78

CLO: course learning outcome.

same configuration as in the lecture presentations; and the instructor read a very similar text matched in length and pace to TTS.

The native English speaker transcribed both speeches accurately and answered all the questions correctly. However, he stated that he had difficulty in following the TTS, because its intonation was very monotonic and it required him to give a lot more attention to understand it. Also, some technical terms' pronunciation was wrong according to him. The Turkish native speakers could not transcribe neither text accurately, however they did slightly better on the instructor's speech. This overall low performance is attested to the students' general lack of language skills, which was also reported by the instructor in his 15 years of teaching in the university. Though slightly, they scored better in the questions about the instructor's speech. Native Turkish speaking students' perception of the TTS was absolutely negative, and they all rated it almost at minimum. On the other hand, they liked the instructor's speech better, giving moderately high scores to it in comparison.

Discussion

Putting aside the TTS, the flipped classroom was overall welcomed as seen in all assessments. Perception and performance evaluation showed mainly posi- tive results.

Besides the assessments above, one thing observed by the instructor is that it allowed for more content coverage, also seen in Mason et al.[2] and Bland.[12]

Perceptive evaluation pointed out that the most liked thing in the flipped class-room was the in-class activities, especially the group discussion, also reported in Kim et al.[1] It indicates that regardless of the course being taught traditionally or flipped, the students benefit much from a controlled discussion with peers.

One thing almost all students agree on is that this flipped method of course delivery compels the students to study more and regularly as compared to in a traditional class. First of all, the lectures must be retained actively by the students. They must navigate through and understand the lecture by themselves, as opposed to having the instructor at their disposal to ask questions in the class at any time. This is well documented in the flipped classroom surveys subsection, as the students that opposed flipped class-room emphatically spend less time on the course than the average of the class. Flipped classroom negatively discriminate these non-active learners and they are the main source of negative perception of flipped classroom.

Some flaws in our implementation did exist, the most prominent one being the TTS. Although not an essential part of a flipped class, it hindered the capability of the out-of-class lecture delivery of our flipped classroom implementation. Some students, unfortunately, identified the flipped classroom with the machine voice, therefore developed a strong dislike to the whole system. This, combined with lack of students' self-study discipline as evident from perceptive assessments, resulted in the opinion of some students that the lectures were not adequately received by them.

Some students also complained about the lack of a solid study guideline. Actually, the instructor provided a guide at the beginning of the course and

students were supplemented with instructions as frequently as possible through the online learning system. This complaint can be attested to the fact that some stu- dents were very conservative about the traditional class and did not believe in this new method of course delivery; therefore, as stated in the interviews, they felt themselves afloat. These types of students should be convinced somehow, for their own sake, to the feasibility and benefits of the flipped classroom. The need for a solid guideline is also reported in Mason et al.,[2] Strayer,[13] and Fredrickson et al.[14]

Conclusion

In this study, we implemented a flipped classroom in a senior engineering course. The flipping degree was full. The lectures were delivered by machine-voice-narrated pre- sentations. An online quiz tracked and encouraged students to watch and under- stand the presentations. Several feedback forms were generated for students to ask content questions; and for us to obtain information about the quality of the presen- tation material. The in-class time was reserved for discussion with the instructor, group-based problem solving, and individual problem solving. The course grade came halfly from the flipped class activities and halfly from traditional written exams. The assessment of the flipped classroom was carried out perceptively and perform- atively. Anonymous surveys and face-to-face interviews enabled us to evaluate the system perceptively. The performative analysis was done by examining students' exam results of two previous years' traditional classes and of recent year's flipped class.

Overall, the results were positive. The students, at the least, did not absolutely object to the new system. Although, there was a skepticism at the beginning, by the end most liked the new system. The TTS was a major drawback, which resulted in a prejudice against the flipped class. The performance evaluation did not show any deterioration, and in one category, the success of the students was increased.

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References

Kim MK, Kim SM, Khera O, et al. The experience of three flipped classrooms in an urban university: an exploration of design principles. *Intern High Educ* 2014; 22: 37–50.

Mason GS, Shuman TR and Cook KE. Comparing the effectiveness of an inverted classroom to a traditional classroom in an upper-division engineering course. *IEEE Trans Educ* 2013; 56: 430–435.

Kim GJ, Patrick EE, Srivastava R, et al. Perspective on flipping circuits I. *IEEE Trans Educ* 2014; 57: 188–192.

Bates SP and Galloway RK. The inverted classroom in a large enrolment introductory physics course: a case study. In: *Proceedings of the HEA STEM learning and teaching conference*, London, United Kingdom, 12 May, 2012.

O'Flaherty J and Phillips C. The use of flipped classrooms in higher education: a scop- ing review. *Intern High Educ* 2015; 25: 85–95.

Bishop JL and Verleger MA. The flipped classroom: a survey of the research. In: *ASEE national conference proceedings*, Atlanta, GA, 23 June, 2013.

Oncel AF and Kara A. Students' perception of and attitude towards transition to flipped classroom: a communication systems course in engineering. *Int J Eng Technol* 2016; 13: 1–6.

Cigdemoglu C, Kapusuz KY and Kara A. Heterogeneity in classes: cooperative problem-solving activities through cooperative learning. *Croat J Educ* 2014;4: 999–1029.

Kara A, Cagiltay NE and Dalveren Y. An enhanced course in digital communications. *Int J Eng Educ* 2014; 30: 1048–1059.

Haykin S and Moher M. *Communication systems*. 5th ed. Hoboken, NJ, USA: John Wiley & Sons, 2010.

Criteria For Accrediting Engineering Programs, 2015 – 2016, www.abet.org/accredita tion/accreditation-criteria/criteria-for-accrediting-engineering-programs-2015-2016/ (accessed 5 July 2018).

Bland L. Apply flip/inverted classroom model in electrical engineering to establish life-long learning. In: *Proceedings of ASEE annual conference and exposition*, Chicago, IL, USA, 18 June, 2006.

Strayer J. *The effects of the classroom flip on the learning environment*: *a comparison of learning activity in and traditional classroom and a flip classroom that used and intelligent tutoring system*. PhD Dissertation, Department of Education, Ohio State University, Columbus, OH, USA, 2007.

Fredrickson N, Reed P and Clifford V. Evaluating web-supported learning verses lec- ture-based teaching: quantitate and qualitative perspectives. *High Educ* 2005; 50: 645–664.