High or low tech approaches to teaching and learning?: The value of pedagogical soundness

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Abstract*:* This paper looks at the application of peer instruction via in-class concept questions, an approach based on a constructivist conception of learning (as opposed to a 'transmissionist' model) that facilitates the engagement of learners through active learning opportunities (Smith et al, 2009). This approach has been adopted using both 'high tech' (clickers) and 'low tech' (flashcards) approaches (Mazur, 1997, 2009), whereby crucially, 'no significant differences were found in conceptual learning gains' between either approach (Lasry, 2008).

The current paper considers the use of flashcards to facilitate peer discussion and learning in a fluid mechanics module and elicits learner reflections on how this approach better facilitates learning relative to a 'traditional' lecturing approaches. It also reflects on how this approach compares with other technological innovations aimed at supporting learning. Conclusions are drawn around the need to place the pedagogical horse ahead of the technological cart when considering teaching approaches.

Introduction

In-class peer learning or peer instruction has shown to be an effective means of class based student learning (Mazur, 1997). It represents a considerable enhancement on the traditional lecture format based on a model of knowledge transmission as it promotes active learning, which both coheres with how students learn - through active engagement (Felder and Brent, 2003) and feedback (Felder and Brent, 1999). As practiced in the context of this paper and by Mazur, it also invokes commonly used and useful active learning mechanisms such as introducing student activity into the lecture, promoting student engagement and collaborative learning (Prince, 2004). It is employed based on 'an understanding of teaching as encouraging deep approaches to learning' whereby 'dialogue, structured goals and activity that is expressly linked to the content to be learned are typical concomitants.' (Ramsden, 2003, p.159). This paper describes the application of peer instruction among a group of undergraduate chemical engineering students through the use of conceptual multiple choice questions throughout the lecture and reflects on their experiences of this compared with the more traditional forms of lecturing that they are more generally exposed to. It then more broadly compares the approach taken, which might be characterized as a low tech version of peer instruction, to a range of other available initiatives which might be considered 'high tech' to see these initiatives compare among students on their conceptions of learning. Some more general reflections follow on the appropriate use of technological tools in education in relation to pedagogical soundness.

Peer Instruction

'Peer Instruction' is a term coined by Harvard physicist and educationalist Eric Mazur and is described and promoted in an eponymous book (Mazur, 1997). Mazur claims that the days of the lecture, or at least those of the traditional lecture are numbered, as its format is based on an outmoded model of 'knowledge transmission' which merely 'reduces education to a transfer of information', and is thus no longer tenable (Mazur, 2009). He declares that he has on this basis turned the 'information transfer model of education upside down' to the extent that 'instead of teaching by telling', he is 'teaching by questioning' (Mazur, 2009). The approach taken by Mazur is described as follows (Mazur, 2009):

- The responsibility for gathering information now rests squarely on the shoulders of the students.
- They must read material before coming to class, so that class time can be devoted to discussions, peer interactions, and time to assimilate and think.
- I now structure my time during class around short, conceptual multiple-choice questions.
- I alternate brief presentations with these questions, shifting the focus between instructor and students.
- The questions address student difficulties in grasping a particular topic and promote thinking about challenging concepts.
- After posing the question, I give the students 1 to 2 minutes to think, after which each must commit to an individual answer.
- They do this by submitting their answers using handheld devices called “clickers”.
- The devices transmit the answers to my computer, which displays the distribution of answers.
- If between 35% and 70% of the students answer the question correctly, I ask them to discuss their answers and encourage them to find someone in the class with a different answer.
- Together with teaching assistants, I circulate among the students to promote productive discussions and guide their thinking.
- After several minutes of peer discussion, I ask them to answer the same question again. I then explain the correct answer and, depending on the student answers, may pose another related question or move on to a different topic.
- This approach has two benefits: It continuously actively engages the minds of the students, and it provides frequent and continuous feedback (to both the students and the instructor) about the level of understanding of the subject being discussed.

There is evidence too that even by facilitating peer discussion through the above process that student understanding can be improved compared with situations where students simply reflect on the material individually, even when they don’t know the correct answer (Smith at al., 2009)

Application of ‘Peer Instruction’

The author of this paper has always employed various methods which would seek to instigate both active and interactive learning in the lecture room situation through asking questions in class and invoking class discussions. However, coming across Eric Mazur’s formal and rigorous application of interactive and peer learning through his development and application of ‘peer instruction’ at an engineering education conference (Mazur, 2012) was revelatory. Mazur employed his teaching technique to great effect among delegates at the conference, and made a thoroughly convincing case while emphasizing the pedagogical underpinnings for the technique as opposed to just demonstrating a use for an existing technology: ‘it is not the technology but the pedagogy that matters. Unfortunately, the majority of uses of technology in education consist of nothing more than a new implementation of old approaches, and therefore technology is not the magic bullet it is often presumed to be.’’ (Mazur, 2009). Moreover, while I would wholly support Mazur’s thesis regarding the invalidity of the transmission model of education and by extension the demise of the traditional lecture, I would not go so far as to say that this spells the demise of the lecture; I’d prefer to conceive it as merely lecturing (i.e. using the allotted time and space available) in a way that better coheres with contemporary best practice in pedagogical practice through the application of, in effect a new (i.e. broader, less constrained and more innovative and creative) approach to lecturing. As Ramsden (2003, p. 148) suggests ‘lecturing itself .. does not lead to poor learning. You can use any teaching method in an information transmission way or in a way that makes learning possible. It is how lecturing is used - the underlying approach adopted - that determines its effectiveness.’’

Being suitably convinced of the merits of applying a peer instruction approach to achieve both active and ultimately deep learning outcomes, I thus resolved to formally apply this approach to a third year undergraduate module I taught which focused primarily on fluid mechanics (PE3001 Applied Thermodynamics & Fluid Mechanics) from the following and subsequent years. The application was as described by Mazur earlier, though given the relatively small class sizes (typically in the range circa 25-35), there was no need for a step involving teaching assistants. Instead after students had paired off and conversed, discussed, argued and (dis)agreed following their initial answer, and then 'voted' again following this crucial stage of engagement, peer interaction and feedback and learning, I would instigate a general class discussion on the problem at hand. This discussion was a key part of the learning process, as regardless of whether students had ultimately answered the question correctly or not (most of the questions happened to be closed questions with definitive answers given the nature of the topic at hand, though this can work equally well, and even better in the context of open ended questions (Schell, 2012)), students were crucially, by now actively engaged with the topic at hand, and in doing so were being (consciously or subconsciously) led to (co-/re-/)construct their own personally conceived models of reality in the domain of fluid mechanics and applied thermodynamics; and by engaging in this process they were (effectively) learning. Another key difference with the method taken by Mazur was that the more low tech option of flashcards was chosen ahead of the use of clickers/software. These consisted of sets of four variously coloured square laminated cards (made by the author using some card and laminate) which are distributed to all students at the beginning of every class (Figure 1).

Figure 1: Set of flashcards used for in-class peer instruction

Rationale for using flashcards

Even though clickers were available to the author in his institution (and hence represented no additional capital cost), flashcards were chosen as the preferred 'technology' for the application of peer instruction for a number of reasons. For a start, they were fast to set up, easy to use and understand, were non-intimidating and did not require any technical training or know-how and were utterly reliable. They were also very portable and could be distributed and collected with minimum fuss before and after the lecture. Moreover, they were suited to the class size, which was quite small and thus allowed for a more intimate and personable classroom setting (and student-lecturer interaction) than a large class in a vast lecture theatre, while not necessitating the collation of large amounts of data as would be the case with a clickers-software scenario. Finally, it has been shown that the effectiveness of a 'low tech' option such as flashcards can be just as good as more 'high tech' approaches involving clickers and collated data, since studies have shown that 'no significant differences were found in conceptual learning gains' between either approach (Lasry, 2008).

How it worked

The approach, on the basis of experiential knowledge and informal student feedback, was a resounding success right from the beginning. Students appeared more alert and engaged throughout the class and really appeared to enjoy an altogether richer (learning) experience.

Moreover, there appeared to be virtually no resistance or cynicism among the students to this new approach; they all seemed to embrace it.

In practical terms from the lecturer's perspective, the course delivery had to be reconfigured. Whereas before students were provided with a comprehensive set of notes containing explanatory material, workbook style class exercises, sample and exam questions and solutions, plus a suite of accompanying in-class overhead Powerpoint slides, the new approach involved all the above with the exception that the notes were not generally covered in class (apart from in some specific circumstances), but instead the old slides were replaced by a new set which, while wholly based on all the material in the notes, included only a series of concept questions, typically with four possible answers. While this took considerable preparatory time to put together, and required a good degree of consideration to come up with both questions and answers which would maximize the degree of engagement and learning for the students, the end result was transformative in terms of active engagement, which it is hoped, had a knock-on positive effect on the overall quality of learning. Figure 2 displays a number of the slides used throughout the module where students were invited to dwell on possible answers to a posed question (or do a small calculation if required) before selecting their answer and displaying one of their four coloured cards.

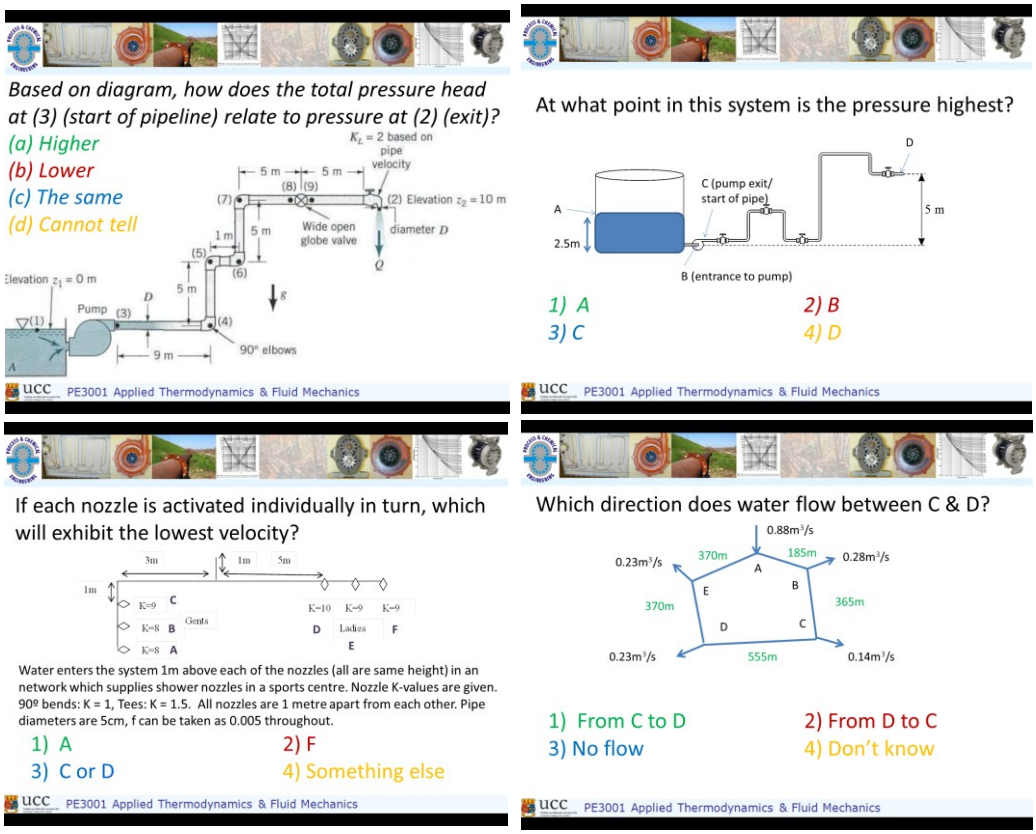


Figure 2: Selected screen shots from overhead lecture slides for PE3001

Formal Feedback

The incorporation of a peer instruction (inter)active learning approach was instigated during 2012-2013, and repeated over the following years. Formal module based feedback taken on the module in general provided evidence that the students felt that they gained from the experience and strongly supported the initiative during both 2012-2013 and 2013-2014. Any changes in module grades in the continuous assessment and final exam over time could not be correlated with an alteration in the level or depth of student learning on the module since there are a large number of variables at play in what is a complex and iterative process. However, the new approach did facilitate the development of conceptual type exam

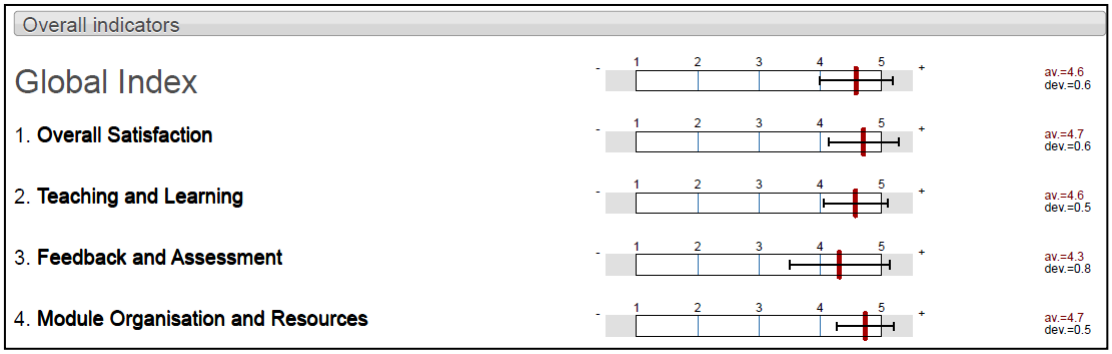
questions which could better probe for deeper learning and to try to gauge subject understanding among students as opposed to simple reductive questions which only required a greater extent of shallow and rote learning.

For the 2014-2015 iteration, the university-wide module survey gathered feedback on the module as a whole (along with all other undergraduate modules being offered by the university at that time). However, in addition it was decided to survey the students' in-class specifically on the use of peer instruction with flashcards as a teaching approach. Given that there are a number of technological teaching tools being promoted at present both within the university and more generally across the education sector, it was decided to calibrate students' subjectively perceived learning experience through the use of the flashcards (which while representing educational innovation, are also a low tech option) against a number of the (higher) tech related innovations that are currently available.

Feedback Results

The university-wide module based feedback (undertaken online and out of class over a two week survey period subsequent to the completion of relevant modules) elicited a healthy response rate of 73% for the module, as 19 out of 26 registered students for 2014-2015 completed the survey. On the survey as a whole, feedback was overwhelmingly positive regarding the module. Table 1 provides a snapshot of the overall quantitative indicators (on a 1-5 scale, with 5 as best). One sub question asked whether students felt the module challenged them to think more critically. Reassuringly all responded with a 4 or 5 to this question, while 13 out of 19 (68%) responded with a five.

Table 1: University wide module survey indicators for PE3001 (2014-2015)



While it might be guessed that the interactive peer instruction approach might have helped fuel such an overwhelmingly positive response rate, confirmation of this came in the qualitative freeform feedback section. Here students were asked two questions. The first queried whether they could identify any elements of the module or its delivery that they found particularly helpful, while the second asked if they might have any suggestions as to how the module or its delivery might be improved.

Table 2: University wide module survey freeform feedback for PE3001 (2014-2015)

- Coloured cards were helpful in thinking about the questions asked and the logic behind each answer.
- Great variation between reading of course documents and interaction with students through a card system. Excellent method of getting students to think and maintain concentration. All lectures should incorporate this where possible
- I thought the use of the coloured cards really helped as it made it more interactive.
- Quiz's very very useful. Forces you think. Much deeper level of understanding. Layout of notes very structured, very clear.
- The cards were excellent, prevented my interest from waning and also gave me risk-free opportunities to be wrong. General lecturing style and substance were of the highest standard
- The class involvement with the flash cards included the class and made us listen and think about the problems.
- The use of the coloured cards was particularly helpful because it required students to think about the content in class, which enhances retention of material. I think the majority of students felt this way because it was the best attended of our modules.
- The coloured cards were very helpful as it forced you to think about the problems. makes the lecture go by much

quicker.

Of the six respondents who answered the latter question, four of them mentioned the flashcards, all of these mentioning that the cards should be used throughout the whole of the module 'to increase the in class learning of the material' or to 'help the student body to learn and understand the content easier'. This was in response to the one section of the module which I hadn't used flashcard due to time constraints involved in developing appropriate questions. Of the 13 comments made in relation to the helpful aspects of the module, all 13 mentioned the peer instruction/flashcard approach in a positive light. A representative selection of responses is presented in Table 2.

The bespoke in-class survey on the peer instruction approach also took place upon completion of the module during 2014-2015 (Semester 1). There were 24 respondents to this survey (where responses sum to a smaller number this was due to non-completion of certain questions/parts). The first set of questions asked students about their experiences of flashcards as well as the opportunities for peer interactive learning, and how they might compare the use of flashcard with a higher tech mode such as clickers (Table 3).

Table 3: In-class Peer Instruction survey for PE3001; Facilitating learning questions (2014-2015)

*In your own experience/opinion, to what extent do the following (PE3001) initiatives **better facilitate learning**?*	Significantly poorer	Somewhat poorer	About the same	Somewhat better	Significantly better
Using **flashcards**	0	0	0	4	20
Peer interaction and learning (discussing/debating problems with peers)	0	0	0	5	19
Use of (low tech) **flashcards** versus (higher tech) **clickers** (multi-coloured buttons on remote control device)?	0	0	3	7	14

Perhaps surprisingly, the good majority elected with the low tech option that they were familiar with ahead of the (perhaps) unfamiliar more high tech mode option for peer instruction, while less surprisingly (and certainly in light of the module survey) there was unanimity with respect to the respective peer instruction methods over more 'traditional' default modes of lecturing.

A second set of questions related to the question of how the students (all were undertaking a full time programme) would compare the face-to-face classroom lecture experience with an online mode of remote/distance learning in terms of relative perceived ability to facilitate learning (Table 4). This was in the context of a general move towards the development of increased online and distance learning opportunities with the increased availability of computing power and appropriate software, as well as the possibility and promotion of lecture recording software (for subsequent upload for student viewing) within the university locally.

Table 4: In-class Peer Instruction survey for PE3001; lecture mode questions (2014-2015)

In your opinion, in terms of ***better facilitating learning***…	Significantly poorer	Somewhat poorer	About the same	Somewhat better	Significantly better
In general, how would an online **recorded lecture** compare with **in-class lectures** (delivered in the	7	7	6	2	0

'traditional' manner)?					
How would online **recorded lectures** (of PE3001) compare with **in-class lectures incorporating flashcards and peer learning opportunities** (as in PE3001)?	11	8	3	0	0
How would a ***live* online lecture *(with interactive capabilities)*** compare with a (PE3001) **in-class lecture?**	6	12	4	0	0

The results were pretty resounding. The good majority felt that the 'traditional' (though possibly endangered?) information transmission mode of lecturing was still better than a (transmission mode) recorded lecture, possibly as a result of some perceived benefits through face-to-face interaction. However, when a peer instruction mode of learning is presented alongside a recorded lecture, the former wins out conclusively. And even a technology facilitated distance learning mode of peer instruction fails to win favour over a similar approach mediated by a live in-person lecturer alongside a class of face-to-face peers. Thus it would seem that, as far as the students are concerned, that particularly when one moves beyond a reductionist mode of conceiving learning as a linear process of accumulating knowledge (where knowledge is simply made up of atomistically resolved bytes of information) as entailed by the traditional transmissionist model, and instead sees it as a complex iterative social process precipitating 'a qualitative change in a person's view of reality' (Ramsden, 2003, p.7), then there is an inherent value envisaged in the physical lecture (albeit in flipped or new form) as an occasion for a unique learning experience. The fact that student have to be motivated to care enough to physically present at a lecture also presents its own dynamic and openness for learning.

The final set of questions related to comparing this (low tech) pedagogical innovation with a range of technologies that are currently potentially available to students (apart from possibility of live interactive lectures) at the university, to see how students envisaged each innovation actually supported their learning relative to each other (Table 5). The peer instruction approach was by far the most popular. The next two favoured options (online videos and electronic provision of notes/slides) were extensively used in the module, though there was little support for either recorded or live lectures as a learning support mechanism.

Table 5: In-class Peer Instruction survey for PE3001; technology facilitated learning (2014-2015)

In terms of better facilitating learning, please rank each of the following technical teaching innovations (i.e. 1 = best, 2 = 2nd best, etc.). Omit any which you consider does not make any significant improvement in facilitating learning.	**1**	**2**	**3**	**4**	**5**	**6**
In class flashcards (of clickers) used in conjunction with peer interaction [1st]	19	3	2			
In class use of online videos and/or images [2nd]	1	8	4	2	7	2
Online live lecture (viewed remotely) with interactive opportunities		4	1	3	1	7
Online provision of electronic versions of lecture notes/slides [3rd]	2	5	8	5	2	1
Online quizzes posted on Virtual Learning Environment (e.g. Blackboard) [4th]		1	5	6	4	2
Recorded lectures accessible online	2	2	5	5	4	2

Finally, qualitative feedback on the survey offered resounding support for this approach as a perceived mechanism for facilitating enhanced learning over the traditional approach, as demonstrated by the following selected comments:

Table 5: In-class Peer Instruction survey for PE3001; How learning was facilitated (2014-2015)

- Most enjoyable and effective lecture by a long distance. Lecturer is streets ahead of colleagues who persist with the "traditional lecture".
- Much easier to understand material. Discussion allows people to see how others think, but also makes material more memorable, reducing – possibly – the time given to study later.
- Much better, the students learn and understand much more in lectures. So the student has to spend less time outside of lectures trying to comprehend subject matter and can try questions sooner.
- You tend to learn and retain more information over just traditional lectures.

- It is far superior. I am listening more in class and finding the material a lot easier to absorb as I am thinking about the problem more.
- So much better, not falling asleep in lectures, learning far quicker, gaining true understanding of material.
- Flashcards make what could be seen as a boring topic exciting.

Conclusions

Peer instruction is an approach to lecturing which promotes active learning mechanisms such as student engagement, collaborative learning and feedback. It can be applied equally effectively in terms of learning through either high tech (clickers and live software) or low tech (flashcards) modes (Lasry, 2008). In this study, flashcards were used and were universally embraced as a significant aid to both improved engagement and understanding by students. Students also indicated that they saw more value in this approach ahead of a range of available technologies.

While these findings do not (nor cannot hope to) 'prove' anything, they do align with a broadly held hypothesis (held too by this author) that while technology in itself is neither 'good' nor 'bad', it can be used to either effect, and the key question is how it is used on a sound pedagogical basis to facilitate deep(er) student learning. Technology too, once introduced, cannot be seen as simply a means of transmission, but by necessity, it becomes a c-constructing player as part of a complex learning process. It can thus be transformative in enhancing the learning process when underpinned by sound pedagogical rationale (Säljö, 2010). This may have been the case in this study (based on evidence provided by the students as well as through personal experiential knowledge), whereby the use of a low tech pedagogical initiative in the guise of flashcards, concept questions and peer learning, may have had a transformational effect on the students' learning of fluid mechanics, and certainly on their learning experience. As Ramsden (2003, p.161) has suggested, peer learning 'correctly applied, is an extremely powerful method involving students teaching each other.'

The application of technology for the sake of simply promoting say, a smart learning environment or to participate in the digital revolution while maintaining a transmissionist model is a sure way of achieving 'technology-enhanced non-learning' (Kinchin, 2012). However, when (either low or high) tech initiatives are applied on a pedagogically sound manner (e.g. to encourage and facilitate (inter)active learning and reflective opportunities) and the is transformative result in terms of depth of learning, then this represents technology enhanced learning *par excellence*. As Laurillard (2002, p. xvi) put it: 'A university is defined by the quality of its academic conversations, not by the technologies that serve them.'

References

Felder, R.M. and Brent, R. (1999). FAQS II: (A) Active learning vs. covering the syllabus; (B) Dealing with large classes, *Chemical Engineering Education,* 33(4), 276–277.

Felder, R.M. and Brent, R. (2003). Learning by doing. *Chemical Engineering Education,* 37(4), 282-283.

Kinchin, I. (2012). Avoiding technology-enhanced non-learning. *British Journal of Educational Technology*, 43(2), E43-E48.

Lasry, N. (2008). Clickers or Flashcards: Is There Really a Difference? *The Physics Teacher,* 46, 242-244.

Laurillard, D.M. (2002). Rethinking University Teaching, 2nd Ed., London: RoutledgeFalmer.

Mazur, E. (1997). *Peer Instruction: A User's Manual.* Upper Saddle River: Prentice Hall.

Mazur, E. (2009). Farewell, lecture? *Science,* 323(5910), 50-51.

Mazur, E. (2012). Educating the Innovators of the 21st Century, *4th International Symposium for Engineering Education (ISEE 2012),* Sheffield: ISEE. 19 July 2012.

Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education,* 93(3), 223-231.

Schell, J. (2012). How to transform learning-with teaching. *Leaders of Learners.* June 2012, pp.3-6.

Ramsden, P. (2003). *Learning to teach in higher education.* 2nd Ed. Oxon: RoutledgeFalmer.

Säljö, R. (2010). Digital tools and challenges to institutional traditions of learning: technologies, social

memory and the performative nature of learning. *Journal of Computer Assisted Learning,* 26, 53-64.

Smith, M. K., Wood, W. B., Adams, W. K., Wieman, C., Knight, J. K., Guild, N., & Su, T. T. (2009). Why peer discussion improves student performance on in-class concept questions. *Science,* 323(5910), 122-124.