Review

Just-in-time Teaching and Peer Instruction in the Flipped Classroom to Enhance Student Learning

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Abstract
The 'flipped classroom', also known as 'lecture flipping' or the 'inverted lecture' is becoming more prevalent as an approach used to engage students in their own learning and as an alternative to the 'didactic' lecture. In the 'flipped classroom' students study material (for example online screencasts, a recorded lecture or directed reading) before an interactive session that replaces the traditional lecture. This latter session is based around problem solving and/or discussions and collaborative learning. This review focuses on and appraises the two methods that are commonly used in the 'flipped classroom' approach: (i) 'Just-in-Time Teaching' (JiTT) is used alongside the preparatory material which is tested in online quizzes and students can post questions online to clarify aspects that they did not understand; (ii) 'Peer Instruction' (PI) is used in the interactive session, and enables students to generate knowledge through discussion with their peers, to actively participate in the subject which they are studying and to clarify topics that they find difficult. When combined, these approaches provide the students with clear opportunities to learn individually and collaboratively, and to obtain rapid feedback. This review highlights the clear advantages of the 'flipped classroom' approach over the traditional lecture that lead to enhanced student learning, and also considers the challenges for staff and students in undertaking these approaches.

Introduction

The 'Flipped Classroom' (Bergman & Sams, 2012) is a blended-learning approach (that is it uses a combination of face-to-face teaching and learning with digital and online learning) that is becoming more widespread in higher education as a way to engage students in their own learning and as an alternative to the 'didactic' lecture (Bishop & Verleger, 2013; Butt, 2014; Sharples *et al.* 2014; Tune, Sturek & Basile, 2014; Millard, 2012; Hereld & Shiller, 2013; Enfield, 2013). The traditional lecture is predominantly a passive event for students; they may take notes but valuable face-to-face time is often not used effectively for student learning. Lectures can be made interactive if, for example, questions are asked or multiple choice questions linked to personal response systems ('clickers') are used (Lasry, Mazur & Watkins, 2008; Watkins & Mazur, 2010). In 'flipped teaching' or the 'flipped classroom', traditional lectures are replaced, sometimes entirely, by interactive sessions. Students study material prior to the session; this can take the form of short online screencasts (10–20 minutes), entire recorded lectures or directed reading (Sharples *et al.* 2014). The screencasts and recorded lectures can be produced by the lecturer, but there is also a large resource of material available on the web that can be used for this purpose.

To complete the preparation for the interactive session, the 'Just-in-Time Teaching' (JiTT) approach is often used, in which the preparatory material is tested in online quizzes, and students can also post questions online to clarify aspects that they did not understand. The JiTT exercises have a deadline a few hours before the class, which allows the teacher time to incorporate material based on the comments and questions raised by the students (see Figure 1). These activities taken as a whole encourage students to take ownership of their learning and they can work at their own pace, ensuring better understanding of the material (Simkins & Maier, 2010).

The interactive session that replaces the lecture is generally based around problem solving and/or discussions and collaborative learning. A key aspect of these sessions should be that students work together and learn from each other. These sessions typically involve a period of reflection on the pre-lecture material during which questions posted by the students online can be addressed directly by the lecturer in the interactive session. Problem solving and/or data interpretation linked to multiple choice questions and the use of personal response systems ('clickers') are also typically used. This can also be achieved using the students' own mobile devices and these approaches stimulate active engagement by students in their learning and allow the teacher to judge student understanding. Data and/or text can also be provided in the interactive session for students to interpret and/or critically analyse and they can also construct essay plans. All of these activities can start as exercises to be done by students thinking and working individually followed by students working collaboratively in small groups.

Once students have made an attempt at an answer to a question or challenge, a common next step is to use Peer Instruction (PI). Peer Instruction requires students to work collaboratively either in pairs or in larger groups. It encourages interactivity in classes to engage students and address topics which students find difficult. For example, the students are asked to respond to a question, based on the material they

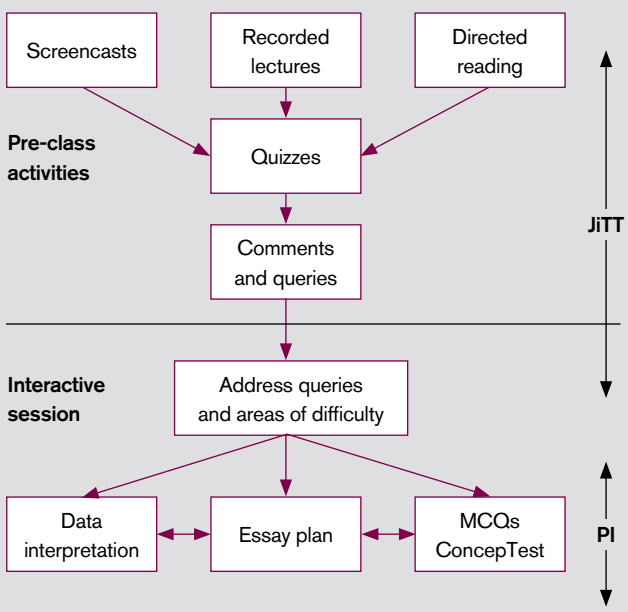

Figure 1: The 'flipped classroom' showing how JiTT and PI are used in the pre-class activities and interactive session.

have studied pre-lecture, using personal response devices. Students are then requested by the lecturer to discuss their answers with a neighbour or in small groups. After several minutes the students vote again after which the lecturer goes through the correct answer (Lasry, Mazur & Watkins, 2008; Watkins & Mazur, 2010). This approach therefore uses assessment for, or as, learning (i.e. uses formative work), provides rapid feedback and enriches the learning experience of students.

This brief review focuses on the two established methods of Just-in-Time Teaching and Peer Instruction that are frequently used in the 'flipped classroom' approach and describes the methodology and pedagogy for these techniques and evaluates the effectiveness of these methods for student learning and the acquisition of knowledge and skills.

Just-in-Time Teaching

The Just-in-Time Teaching approach (Novak, Patterson, Gavrin & Christian, 1999; Gavrin, 2006; Novak & Patterson, 2010; Novak, 2011; Simkins & Meier, 2010) was originally developed to help students to organise their work out-of-class and to gain more from valuable in-class student-teacher time. The approach is founded on some of the *'Seven Principles For Good Practice in Undergraduate Education'* (Chickering & Gamson, 1987). JiTT has evolved over a number of years and its users have enhanced the technique by drawing on a number of modern learning theories and educational techniques (Novak, 2011; Bransford, Brown & Cocking, 2000). Of particular importance are research into teaching for conceptual change (Scott, Asoko & Driver, 1991) and into assessing students' motivational beliefs (Beghetto, 2004).

The main concept behind the JiTT approach is to create a direct link between the pre- and in-class activities by making use of introductory web-based assignments, commonly referred to as *'JiTT exercises'* (Novak & Patterson, 2010). In these exercises students usually have to read, watch or carry out an activity and then answer questions related to the task. As much of the student learning takes place outside of class, those who use the JiTT approach regard their pedagogical methodology as a feedback loop between pre- and in-class experiences (see Figure 2).

JiTT exercises can be short quizzes (for example multiple choice questions) or more challenging questions that require a response in the form of text (Novak & Patterson, 2010). JiTT assignments have a deadline a few hours before class, thereby allowing the teacher sufficient time to adapt the forthcoming class, taking the students' responses into account. Often exemplar student responses are shown at the start of class thus prompting small group or full class discussions. Student misunderstandings or areas of difficulty are also identified in the pre-class responses and these are used to determine the appropriate choice of classroom activities.

JiTT classes are different from traditional lectures for two important reasons: firstly, students enter class having very recently completed the pre-class assignment and so are prepared for the in-class activities; secondly, the students have a sense of ownership towards the classes as the activities are tailored towards their specific understanding of the topics (Novak & Patterson, 2010). The exact format of classes varies depending, for example, on the number of students, the learning space, the personalities of both the students and their teacher. Examples of in-class activities include whole-class discussions, demonstrations, or group-based learning activities to facilitate cooperative learning. JiTT can be used in conjunction with other pedagogic techniques and innovations, it can be used to motivate student learning and is applicable at different levels and in a wide range of disciplines for example Biological Sciences, Geosciences, Physical Sciences, Economics, History and the Humanities (Simkins & Maier, 2010).

Figure 2: The JiTT feedback loop (adapted from Novak & Patterson, 2010).

It has been demonstrated that successful use of JiTT can result in cognitive gains ranging from moderate to quite significant (Novak, 2011). As an example, in a first semester introductory Physics course, the Force Concept Inventory (FCI) is the assessment instrument typically employed (Hake, 1998). Through the FCI identical multiple choice questions are used on the first and last days of class and any improvement is measured in terms of *'average normalised gain'* ((post-test percentage score)-(pre-test percentage score))/(100 - pre-test percentage score). On traditional courses improvements are generally 10–20% but teachers using JiTT cite gains of between 40 and 70% (Hake, 1998). These gains can be even greater when JiTT is used in conjunction with other interactive engagement techniques such as Peer Instruction or collaborative learning (Crouch & Mazur, 2001). Similar gains have also been reported in an introductory Biology course (Marrs, 2010). The average normalised gain where both JiTT and in-class cooperative learning were used was 63.6% compared to JiTT only (56%) and cooperative learning only (45%). Using either JiTT or cooperative learning led to an average normalised gain of 52% but classes using neither JiTT nor cooperative learning had average normalised gains of 17–21%. In addition, the use of JiTT in Biology has been shown to lead to positive assessment results, decreased attrition rates, increases in student attitudes, interactivity and study habits (Marrs & Novak, 2004).

Peer Instruction

Peer Instruction (PI) is an interactive method of teaching delivery which encourages in-class interactivity to engage students and address topics which students find difficult (Mazur, 2014; Watkins & Mazur, 2010; Crouch, Watkins, Fagan & Mazur, 2007; Crouch & Mazur, 2001). PI facilitates peer learning by enabling students to discuss concepts in class. For the technique to work optimally, however, students need to have a basic understanding of the concepts when they come to class, so JiTT complements the technique well. JiTT organises students' pre-class preparation and enables teachers to receive feedback from their students in advance of class. Teachers can therefore select the PI questions used in-class to address the specific difficulties encountered by students.

PI uses short, multiple choice questions in class which probe students' conceptual understanding, known as *'ConcepTests'* (Watkins & Mazur, 2010), for example Physics (Mazur, 2014), Chemistry (Ellis *et al.* 2000, Landis *et al.* 2001), Astronomy (Green, 2002), Mathematics (Hughes-Hallett *et al.* 2006; Terrell, Connelly, Henderson, & Strichartz, 2005), Geoscience (Steer & McConnell, 2011) and Philosophy (Bigelow, Butchart & Handfield, Undated).

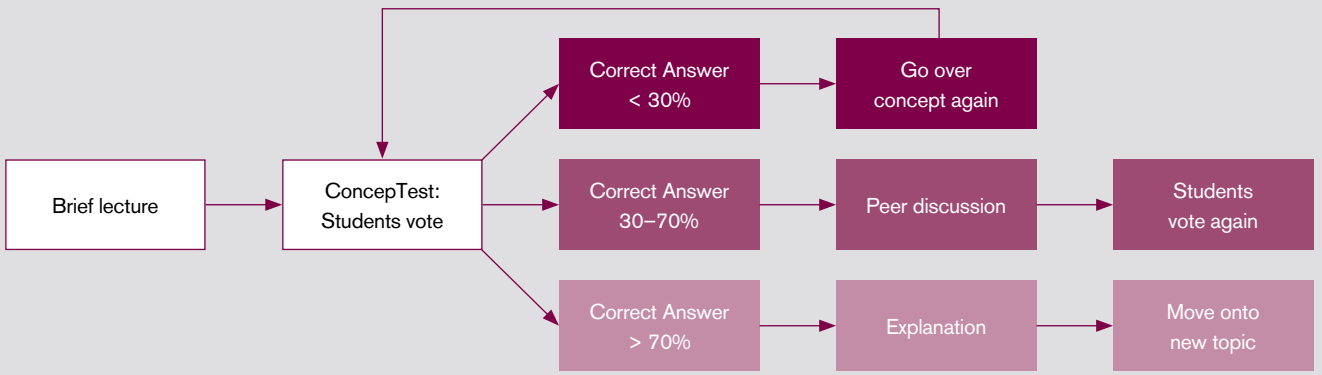

Fig 3: The ConcepTest-Peer Instruction Implementation Process (adapted from (Lasry, Mazur and Watkins, 2008)).

To implement ConcepTests and PI (Watkins & Mazur, 2010) the teacher briefly presents on a topic after which the students reflect on what they have learnt through a ConcepTest (see Figure 3). After thinking about the question for a couple of minutes students vote individually on an answer. If *ca.* 30–70% of students answer correctly the teacher asks them to turn to their neighbours and discuss their answers, in pairs or small groups, preferably with someone who voted differently. The teacher moves around the class promoting active discussions and to direct student thinking. After several minutes the students vote again after which the teacher goes through the correct answer. Depending on the student responses, the teacher may ask another ConcepTest on the same topic or move onto a different topic.

There are different types of question format which can be used in PI, for example, questions on general theories and definitions, application of concepts in varying contexts and questions which inter-relate different ideas (Watkins & Mazur, 2010). PI can not only be used with questions for which there is a 'correct' answer but also to stimulate discussion amongst students where there is no definitive answer. PI facilitates students improving their critical listening skills as well as the ability to create solid arguments. Whatever the discipline, PI supports students in the creation of knowledge through discussion with their peers and in active participation in the subject which they are studying.

At Harvard University, PI courses in introductory Physics have demonstrated greater average normalised gains than traditional courses (Crouch & Mazur, 2001). Other research has shown positive results with PI in a variety of disciplines, for example Biology, Engineering, Psychology, Medicine, Philosophy and Mathematics (Watkins & Mazur, 2010).

Conclusions

Lectures can encompass a range of approaches, from the traditional, didactic presentation of material, to sessions that incorporate interactive activities and the fully flipped classroom. The flipped classroom has two key elements: (i) pre-class activities, including the use of resources, attempts at quizzes and posting comments and queries online and (ii) interactive sessions that replace the traditional lecture, often including the use of personal response systems and mobile devices and that encourage peer and collaborative learning. JiTT links the pre-lecture study with the interactive session. Peer Instruction linked to ConcepTests and/or multiple choice questions engages students in their own learning and encourages them to work collaboratively; it also provides rapid feedback to students. PI can be used in the context of a lecture that incorporates interactive exercises but, as has been described above, works most effectively when combined with the JiTT methods that take advantage of online provision of learning resources. This blended approach releases more time for active learning and interaction with the instructor in the 'lecture' session.

This short review has cited evidence in support of both the JiTT and PI approaches. The 'success' of such approaches requires an appraisal of student engagement (for example do the students use the resources and try the online quizzes? Do students take an active part in the classroom activities?), the student experience (for example do they enjoy and value these approaches?), student performance (for example is there an improvement in tests and assignments?) and the acquisition of key skills (for example working collaboratively, interpretation of data and critical thinking). This review has shown that there is an increasing body of evidence that suggests that all these criteria are met to some extent. Probably the most challenging aspect of these approaches is to ensure that all of the students are engaged – in the experience of the authors, there is usually 10–20% of the class who do not take advantage of the pre-class resources and quizzes. The evidence presented here is also important in demonstrating explaining to some teachers the benefit of these approaches for student learning. Facilitating the interactive sessions can be an extremely rewarding experience for the teacher, but preparation of the resources and quizzes takes time and the unpredictability of the interactive sessions can cause problems for some staff, while being stimulating to others. The flipped classroom, JiTT and PI depend on digital technology – the internet, VLE, mobile devices and these need to function optimally for an effective experience. In the approaches described in this review, the virtual learning environment needs to be in place, but also the physical space can restrict the type of interaction that's possible. Large lecture theatres are not ideal for peer learning, and collaborative activities involving students working in groups of maybe 6–8 members work best when they can sit around a table. All of these factors, staff, students, the virtual and physical learning environment as well as the quality of the resources, quizzes and interactive exercises need to be taken into consideration when considering the flipped classroom. The payoff is a more challenging experience for both teachers and students that encourages active learning and the acquisition of skills not easily attained in a conventional lecture.

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