IMPLEMENTATION AND EVALUATION OF THE FLIPPED CLASSROOM APPROACH IN ENGINEERING EDUCATION

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Abstract

Engineering education at the University of the West of England has traditionally followed a conventional approach of large group lectures. This approach has well-known drawbacks in terms of learning. Research has suggested that the flipped classroom approach can help address the issues associated with the traditional delivery method, encourage active-learning and enhance the student experience. This approach was implemented for a module taught to Mechanical Engineering and Automotive Engineering students. Details of the implementation strategy are provided, including how the pre-study educational resources and virtual learning environment supported the flipped classroom approach and how the re-purposed contact-time became a facilitated active-learning environment involving more discourse, group-working, problem-solving and mastery of the topics.

Evaluation of the implementation was collected via the formal end-of-semester module feedback activity. The results demonstrate a strong preference for this delivery method. In 11 of the 13 categories assessed with the Likert scale, over 80% of the students either ‘Agreed’ or ‘Strongly agreed’ with the statements. The student comments were particularly positive, with students highlighting the various benefits of the delivery approach. In addition, the step-change that has occurred in levels of attainment suggest that the approach is working in terms of students’ understanding. This implementation of the flipped classroom approach in engineering education was very successful.

Keywords: engineering education, flipped classroom, inverted classroom, evaluation, implementation

Introduction

Engineering education at the University of the West of England has traditionally followed a conventional lecture-based approach, often accompanied by small group unstructured tutorials. The traditional lecture format has drawbacks in terms of learning: it is predominated by one-way delivery of the content to largely passive audience, with the tutor unable to accommodate for the diversity of the student body and the differences in the way students learn. The students are then required to use unfacilitated out-of-class time to master the content.

In order to address these issues, the flipped (or inverse) classroom approach enables active learning to be embedded within the module. The flipped classroom “means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa” (Lage et al. 2000, p.32). It is thus an approach whereby students use out-of-class educational resources to obtain the content before the teaching session, and the time in class can then become student-centred, dedicated to active learning activities such as problem solving, experiential activities and group work. By applying the new knowledge, rather than merely taking note of it, students are enabled to develop personal ownership of their learning, where they care more about the material they seek to master, and hence have a vested interest in developing a deeper understanding of the material (Gerstein, 2012). In addition, the approach encourages collaborative and peer-assisted learning within the teaching sessions (Foot and Howe, 1998). Lastly, this less didactic approach encourages students to be actively involved in knowledge acquisition (Abeysekera and Dawson, 2015).

Supported by this evidence, the flipped classroom approach was implemented for a third-year undergraduate mechanical engineering module, ‘Vibrational Dynamics’. This paper reports on the method of implementation used, including details of the pre-study material, the use of the virtual learning environment to support this approach, and the structured facilitated sessions. Furthermore, the impact of the approach is illustrated through evaluation conducted as part of the standard formal module feedback activities.

Implementation

Vibrational Dynamics as a 15-credit module (7.5 ECTS) taught over one semester to a cohort of third year students studying Mechanical Engineering and Automotive Engineering. The cohort size for the 2017-2018 academic year was 102 students. It is a highly analytical module, focusing on the theory of vibrating systems, including multi-degree-of-freedom, damped, forced, unforced and non-linear systems, and builds upon the foundations of dynamics taught in the first and second years. In an effort to minimise the impact on timetabling,
the contact time was retained as one two-hour long session per week with the whole cohort, and one one-hour long session per student per week with smaller groups.

The implementation followed the scheme illustrated in Figure 1. Each week, students would conduct independent study on the course content that would be used in the whole cohort teaching session and the small group tutorial sessions; they would then spend time in the facilitated sessions, and follow this up with independent study and the pre-study material for the following week.

![Figure 1: Schematic diagram illustrating the implementation approach.](image)

The pre-course educational resources took a number of forms. A full set of course notes were made available to students. These notes contained all assessed content spread over eight chapters. Each content chapter contained a clear set of learning objectives, and interspersed with the content were dedicated spaces for in-class questions. Also aligned with the content are a number of worked examples, and at the end of each chapter are a set of exercises relevant to that content.

Accompanying these notes were video recordings of the lectures from when this module was delivered in a traditional format. The video recordings were reprocessed into smaller segments (up to 5–10 minutes, generally), aligned with the content, and the slides were inserted over the top of the raw video of the lecture, cutting back to the raw video when appropriate. The slides used for the lecture were integrated with the notes, so students could easily follow the notes as they watched the videos. There is evidence that video lectures are at least as effective as in-person lectures (Zhang et al, 2006; Bishop and Verleger, 2013; Davies, Dean and Ball, 2013) and that technology is an important defining aspect of the flipped classroom, particularly when used for the content delivery aspect of the teaching (Strayer, 2012; Bishop and Verleger, 2013). The videos themselves were optional to watch, as all the content was contained within the notes. They were supportive material, and help address issues associated with a diverse student body, particularly international students and students requiring reasonable adjustments.

The virtual learning environment, Blackboard, was set up to support this delivery approach. The content was broken up by weeks, and each week, a new folder revealed itself to students (using the timed release feature of Blackboard). Within each folder were the educational resources for the pre-study content. This included: the videos for the content; the slides used in the videos; the full-worked solutions to the end of chapter exercises; and a survey which could be used by students to provide feedback on their learning and any particular topics that they would like to cover during the upcoming whole cohort teaching session. Lastly, in an effort to encourage engagement with the content, for the 2017–2018 academic year, an e-assessment test was used on the pre-study content, which was designed to be relatively straightforward to answer correctly had the student engaged with the material. The test was available during the week prior to the associated teaching session, and students had one attempt at answering the question. Marks were given for the correct answer, as well as for engagement with the test. (These ten tests contributed to 20% of the module mark).

The Teaching Sessions

The contact time comprises one two-hour session with the whole cohort, followed by one one-hour session in smaller groups. The two hour-session starts with a quiz using the Turning Point student response system, where multiple choice questions are presented to the class and they participate, anonymously, in answering the questions. This allows both the students and the academic to locate the level of understanding, and potentially highlight any gaps in the knowledge that can be explored during the session. The learning objectives for the topic (as presented in the course notes) are then discussed in more detail, again to help students place their learning and understanding. The session is then facilitated; the academic works through the notes, with the students engaging with the in-class questions, working with each other on the problems, and working through the examples together. The session finishes with a recap of the learning objectives for the topic.

Following the whole cohort session, the group is broken into smaller groups (nominally around 30 students) and the one-hour session takes places in one of the Technology Enhanced Active Learning (TEAL) spaces. These rooms are designed to support active group working, with tables that require students to sit in groups, and each table has a computer terminal on which to use software to support their learning. For this module, the students were all given a question, and the students in these ad-hoc groups work collaboratively on the problem, with the tutor on hand to give advice and provide support as necessary throughout the session. Because this is effectively the third scenario in which the student is experiencing the content, the complexity of the question is at a deep level (i.e. similar to the sort of question they might see in an exam). By visiting the different groups, the tutor gains an insight into the students’ level of understanding and mastery of the content. The end of the session is wrapped up by a presentation of the model solution. For groups that completed the question in good time, they are free to make use of Matlab to aid solution visualisation and validation.

Evaluation Methodology

In this paper, the evaluation of this implementation of the flipped classroom approach is based on the formal module evaluation activity that is conducted at the conclusion of the module. This evaluation has two
sections: the first section contains 13 statements with a 5-point Likert scale, with the respondents choosing whether to ‘Strongly Agree’, ‘Agree’, ‘Neither Agree nor Disagree’, ‘Disagree’ or ‘Strongly Disagree’ with the statements. The 13 statements are:

1. Module teaching staff are good at explaining things
2. Teaching staff make the module interesting and/or engaging
3. The module has challenged me to produce my best work
4. I knew in advance the criteria my work would be marked against
5. The module assessments and marking are fair
6. I’ve received timely feedback on my work submitted for the module
7. Feedback on the module has helped me improve my academic performance
8. The Library has enabled me to access the resources on my reading list
9. I’ve received sufficient advice and support on the module
10. I can contact module staff when I need to
11. I understand how the module fits within, and supports, my wider studies
12. The module is well organised and has run smoothly
13. I am satisfied with the module

The second section of the evaluation form affords the students to provide qualitative comments. The questions for this section are:

- Do you have any other feedback (for example what were the most positive aspects and what would you have changed?)
- Please comment on the flipped delivery approach used in this module.

The module feedback form was made available during the penultimate week of the teaching block in which this module was taught and remained open until after the assessment took place. Of the 102 students registered on the module during the 2017–2018 academic year, 53 responded to the module feedback form, representing a response rate of 52%.

Lastly, whilst no statistical analysis has been conducted, levels of attainment—pass rate and average mark—for the past four years (representing one year of the traditional lecture-based paradigm, and three years of the flipped approach) are presented.

**Results and Discussion**

For the first section of the feedback form, a positive response is either ‘Agree’ or ‘Strongly Agree’, with anything else regarded as negative. (This aligns with the way the National Student Survey rates responses). For this study, there is a very strong positive outcome. 11 of the 13 categories achieve a positive rating of over 80%. The data for all statements is shown in Figure 2.

The two categories that failed to meet the 80% threshold where statements 7 (Feedback on the module has helped me improve my academic performance) and 8 (The Library has enabled me to access the resources on my reading list). For statement 7, 71.7% of respondents gave a positive rating. As there is no assignment during the module (apart from the online e-assessments) students would not normally receive feedback tailored to improve performance. For statement 8, 30.2% of respondent gave a positive rating, but the majority of respondents (60.4%) gave a rating of ‘Neither Agree nor Disagree’. As all the content is contained within the course notes, a copy of which the students receive at the start of the module, the students’ need to access the resources identified on the reading list is not a necessary component of the course.

It is worth highlighting that four of the categories (statements 1, 11, 12 and 13) achieved a positive rating of 100%. With regards to the flipped implementation, statements 11 and 12 are relevant: “I understand how the module fits within, and supports, my wider studies” and “The module is well organised and has run smoothly”. It can also be argued that statement 13 (I am satisfied with the module) should carry greater weighting, and achieving a 100% positive response rate for this question is particularly pleasing. Students are clearly satisfied with the module.

For the second section of the feedback form, a full presentation of all the qualitative comments made is not appropriate for this paper. It is possible, however to identify some common themes, with selected quotes to justify these themes.

The first theme is the clear preference to the flipped classroom approach to teaching. It is noteworthy that there was not one negative comment concerning the delivery approach. Quotes supporting this theme include:

- “It’s much better and engaging than old method”
- “This delivery approach is by far the best style of teaching so far in my degree.”
- “The flipped delivery approach was a great idea.”
• “100% preferred the flipped classroom approach compared to conventional style.”
• “This was absolutely amazing and I feel like I have really benefitted from this approach.”

Somewhat linked to this theme is the second theme, which was a desire to have more modules taught using the flipped classroom approach. Supporting quotes include:
• “I think that the rest of the lecturers in this university should use this module as how they should deliver.”
• “[I] firmly believe that other engineering modules could benefit from similar approaches.”
• “The reverse [i.e. flipped] teaching method needs to be ran on more modules.”
• “I would like to see this style of delivery in more modules.”
• “Very well delivered and other modules should include it. It made a difficult module much easier, very happy”
• “I wish that more lecturers would adopt this approach!”
• “more modules should be done this way.”

The third identified theme is how the approach made revision for the assessments more straightforward as they had already ‘put in the hard work’ during the module. Quotes include:
• “It also made my revision much more effective as I was able to dive straight into past papers and example questions leaving me very confident going into the exam.”
• “The tutorials were both helpful for revision and general learning.”
• “It gives you more of an incentive to do all of the work for that week there and then rather than leave it till the end of the semester, just before exams.”

Lastly, the fourth theme highlights the extreme levels of satisfaction with the module as a whole. The following quotes show high levels of appreciation:
• “By far the most well taught module I’ve taken.”
• “The best module I’ve experienced in my time at UWE.”
• “It has been the best taught module I have had since I have been at UWE.”
• “Keep doing your thing! Top lecturer.”
• “Keep up the excellent work.”

There were a limited number of comments containing constructive criticism. There seems to be a desire to have more worked examples covered in the teaching sessions, and some desire a switch to have a one-hour whole cohort session and two-hours in smaller groups. These comments have been considered in the design of future runs of the module.

The levels of attainment for the past four runs of the module are shown in Table 1. In the 2014–2015 academic year, the module was taught with the traditional approach. The pass rate and average mark for this particular cohort were particularly poor and as such, a mark uplift was applied (with external examiner approval) to bring up the pass rate and average mark. It was these results that motivated the shift in approach. It is clear that in the 2015–2016, 2016–2017 and 2017–2018 academic years, the levels of attainment have shown a significant uplift. Whilst tests of statistical significance have not been conducted, the results suggest that the change of delivery approach to the flipped classroom method has brought about this step change in levels of attainment.

Table 1: Levels of attainment for the most recent four runs of this module

<table>
<thead>
<tr>
<th>Academic year</th>
<th>Pass Rate</th>
<th>Average Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014–2015</td>
<td>57.38%</td>
<td>45.98%</td>
</tr>
<tr>
<td>2015–2016</td>
<td>85.57%</td>
<td>57.88%</td>
</tr>
<tr>
<td>2016–2017</td>
<td>91.80%</td>
<td>69.70%</td>
</tr>
<tr>
<td>2017–2018</td>
<td>92.16%</td>
<td>69.60%</td>
</tr>
</tbody>
</table>

Conclusions

In an effort to address the deficiencies of a traditional lecture-based delivery approach and to increase levels of active-learning, the flipped classroom approach was implemented for a third-year engineering module entitled ‘Vibrational Dynamics’. Details of the implementation approach are provided, highlighting the pre-study educational resources provided, the use of the virtual learning environment to support the approach, the use of e-assessment to support engagement and the structure of the teaching sessions. To evaluate this implementation, the formal module evaluation activity that takes places at end of the module was used. This formal module evaluation is divided into two sections: the first section provides quantitative data using a Likert-scale against 13 different statements. The second section provides qualitative data, with students able to comment using free text on certain questions provided as part of the evaluation. Attainment levels were also used to compare this approach to the previous approach using the traditional lecture-based delivery.

The results of the evaluation are very positive. In the first section of evaluation, 80% of students either ‘Strongly agree’ or ‘Agree’ with 11 of the 13 statements, with four statements achieving 100% positive results. The two categories that did not achieve 80% positive results were not relevant to this module and the approach used to deliver the content. The second section of the evaluation highlighted four themes: a strong preference for the flipped approach, the desire to have other modules use the same or similar approach, the benefits of this approach when it comes to exam revision, and the clear levels of satisfaction with the module. Whilst statistical significance has not been determined, the step-change in levels of attainment following the implementation of the flipped classroom approach suggest that the it can provide benefits in terms of results. In summary, when implemented as described, the flipped classroom approach has been successful for engineering education.

References


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