

# Write my next lecture: pre-lecture problem classes and in-lecture discussion to assist case-study teaching of synthesis

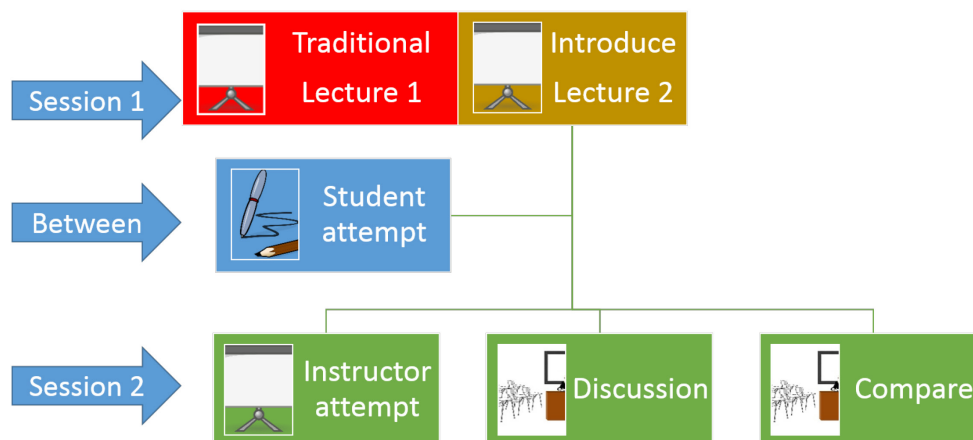
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## ABSTRACT

For an advanced-level module associated with designing drug synthesis, a set of homework tasks were created to help students prepare for their exam. Students were asked to solve the next case study as  
10 homework, effectively writing the next lecture's notes in advance of the session using requisite knowledge and moderate instructor guidance. Students found these activities effective at preparing for the exam, increasing their subject knowledge and confidence towards unseen synthesis problems.

## GRAPHICAL ABSTRACT



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## KEYWORDS

Upper-division undergraduate, Continuing Education, Synthesis, Organic Chemistry, Problem Solving/Decision Making.

The process of delivering content in advance of lectures as a way of better utilizing contact time to enhance student understanding, whilst reducing cognitive load has been hugely popular with learners and instructors since its conception by Lage.<sup>1,2</sup> By using contact time for problem solving and discussion rather than dissemination, flipped learning is highly effective at increasing comprehension, confidence, problem solving and ownership of learning.<sup>3-5</sup> It is also proven that a combined approach of guided, yet independent, study such as homework not only creates a more individualistic learning experience but also helps to understand learning itself.<sup>6,7</sup> For Chemistry, the perceptions of students and lecturers can be changed by the flipped classroom such that students feel in control of their studies, yet still retain access to high levels of valuable contact with facilitators rather than instructors.<sup>8</sup>

Typically, flipped learning makes use of videos and/or readings to deliver formal theory pre-contact session, allowing face-to-face meetings for group problem solving and class discussion. Providing students engage with the content as part of their homework, it has been quantitatively shown to increase performance within examinations.<sup>3,9</sup> The study by Weaver and Sturtevant also hinted at students preferring this format to traditional lectures, offering few suggestions for improvement. Alternative studies have also found that the flipped classroom can benefit both the top and bottom percentiles of the class, allowing it to be used indiscriminately in mixed ability cohorts. It has proven effective at retaining weaker students on programs whilst also increasing the standard of their progression.<sup>10</sup> Furthermore, the approach has been effective at supporting students of higher abilities, with other authors reporting grade increases amongst the stronger students too.<sup>11</sup>

Pleasingly the benefits of flipped learning and homework in general go beyond enhanced academic qualities and exam results. In general instructors have found their students to be highly satisfied with the flipped classroom as a method of content delivery, with many students actually preferring this approach to the traditional lecture style.<sup>3,12</sup> This is most likely due to increased intellectual attachment to their learning and a sense of emotional achievement associated with the ownership and management afforded by trust and responsibility placed upon students.<sup>3,13</sup>

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Whilst the majority of the work to date has focused on the use of pre-lecture video delivery, an opportunity to move away from passive at-home learning does exist. The following work is an approach to create a situation where the flipped classroom becomes an active learning environment both during and away from the contact session. Additionally, an emphasis is placed on independent problem solving, retention of synoptic information and logical exam preparation.

## ACTIVITY DESIGN AND IMPLEMENTATION

The activities were created to supplement an elective UK final-year undergraduate chemistry master's module (comparable to US graduate level) covering the synthesis of four structurally complex anti-cancer compounds. The course is exclusively delivered as four case-study lectures, each of which contains a retrosynthesis of the molecule followed by a suggested forward synthesis. Whilst the targets chosen are specifically anti-cancer drugs, this activity could be used for any course seeking to teach complex, multi-step synthesis. The choice to use case studies was inspired by Dewprashad and Hutchinson's observations that case studies could better connect students to the material and highlight the relevance of core concepts.<sup>14,15</sup> The design of these cases studies draws slightly on Vosburg's *comparative* model for syntheses case studies.<sup>16</sup> These core concepts typically refer to standard undergraduate-level organic chemistry, the prerequisite knowledge that all final-year chemistry undergraduates should have. To this end, it was deemed acceptable that students would be able to attempt these activities as a homework exercise, drawing on their past experiences, textbooks and utilizing appropriate web resources as necessary. To facilitate this, a series of reagent guide sheets are provided on the virtual learning environment to help students recall common synthetic strategies such as oxidation, reduction, halogenation, cross-coupling and aromatic functionalization.

For each of the last three cases studies (one-hour lecture slots) a short homework assignment (available in supporting information) was created and uploaded to the University's virtual learning environment, the links being made available to the students upon completion of the first case-study lecture. There was no activity associated with the first case study and none of the assignments were assessed. At the end of the first lecture the students were informed about the existence of the homework tasks, given some brief instructions on how to go about them. Students were also reminded that each

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75 of the subsequent lectures (one week apart) would serve as model answers for these tasks, and that it was 'allowed' for their approach to be different to that of the instructors. They were also made aware that they would have the opportunity during the lectures to discuss their attempts with the instructor and their peers.

Each of the homework tasks requires the students to perform a retrosynthesis on the next case study's (lecture) target molecule and then design a reasonable forward synthesis. The students are given clear written instruction as to the aims of the task and are then provided with the structure of that case study's target. Given this was a flipped learning activity, it was acceptable that the students receive a reasonable amount of (written and verbal) guidance for the activities, although the amount of instruction decreased during the four week course. For the second case study (first assignment), selected intermediates within the forward synthesis were given and the student therefore only had to fill-in short series of multiple disconnections. In the third case study the target molecule's structure was annotated with likely disconnections/reactions they were familiar with and some starting materials suggested. The fourth case study's assignment was the student's final task and therefore only the likely disconnections were annotated, thus requiring students to design the full synthesis based on starting materials of their choice. This increasing level of difficulty was chosen to help build students' confidence towards synthesis, keep them engaged and help them familiarize themselves with the process. During the case-study lectures themselves, students were encouraged to bring their attempts along to the lectures to facilitate student-instructor discussions. Whilst the lectures were designed to fully answer the tasks, in synthesis there are often multiple approaches that can be taken and students were encouraged to participate, making the lectures feel more like seminars. Through suggestions of alternative routes and strategies, the sessions became more engaging and develop a greater appreciation of synthesis among the cohort.

One of the long-term aims of these activities was of course to help students to prepare for their exams, and these activities were yet to present students with an unguided problem. To this end two fantasy case studies (also available in the supporting information) were created for the students to attempt without any guidance or supportive annotations. For these final two molecules, model answers were provided in lieu of a contact session.

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## EVALUATION AND CONCLUSIONS

105 During the contact sessions it was evident that the student attempts at the homework were very good and that it was only on rare occasions that the synthesis designed for the homework activity was un-workable. Furthermore, the students were happy to discuss their attempts during the seminar/lecture and the quality of their synthesis skills came across strongly during these discussions. Whilst the activities were not directly assessed, nor the only change to the module teaching, 110 both the midterm and final assessment averages (means) increased from 62% to 73% and 64% to 72% respectively compared to the previous cohort who did not have access to the resources. The two cohorts were estimated to be of similar academic ability based on previous exam performance. In addition to providing the second cohort with these activities, the notes were revised slightly and an additional problem/revision session was run.

115 The uptake and effectiveness of the activity was also measured using a simple Likert questionnaire distributed electronically to the students after they had taken the final exam and the module was therefore complete. Out of 43 students registered for the module, 33 responded to the survey. Of these students, 22 indicated that they had utilized the activity and were consequently asked to complete the remaining questions. The 11 who had not attempted the activity were asked to skip the remaining 120 questions that were focused upon the effectiveness of the resource. Before submission of the survey they were however asked for any free comments. Pleasingly, one unengaged student commenting "Although I didn't attempt the homework activities, I feel they would have both increased my interest in the topic and helped with preparation for exams". All of the students who engaged with the material agreed that the *tasks* were useful for exam preparation and overwhelmingly positive responses were given for the 125 remaining questions (Figure 1).

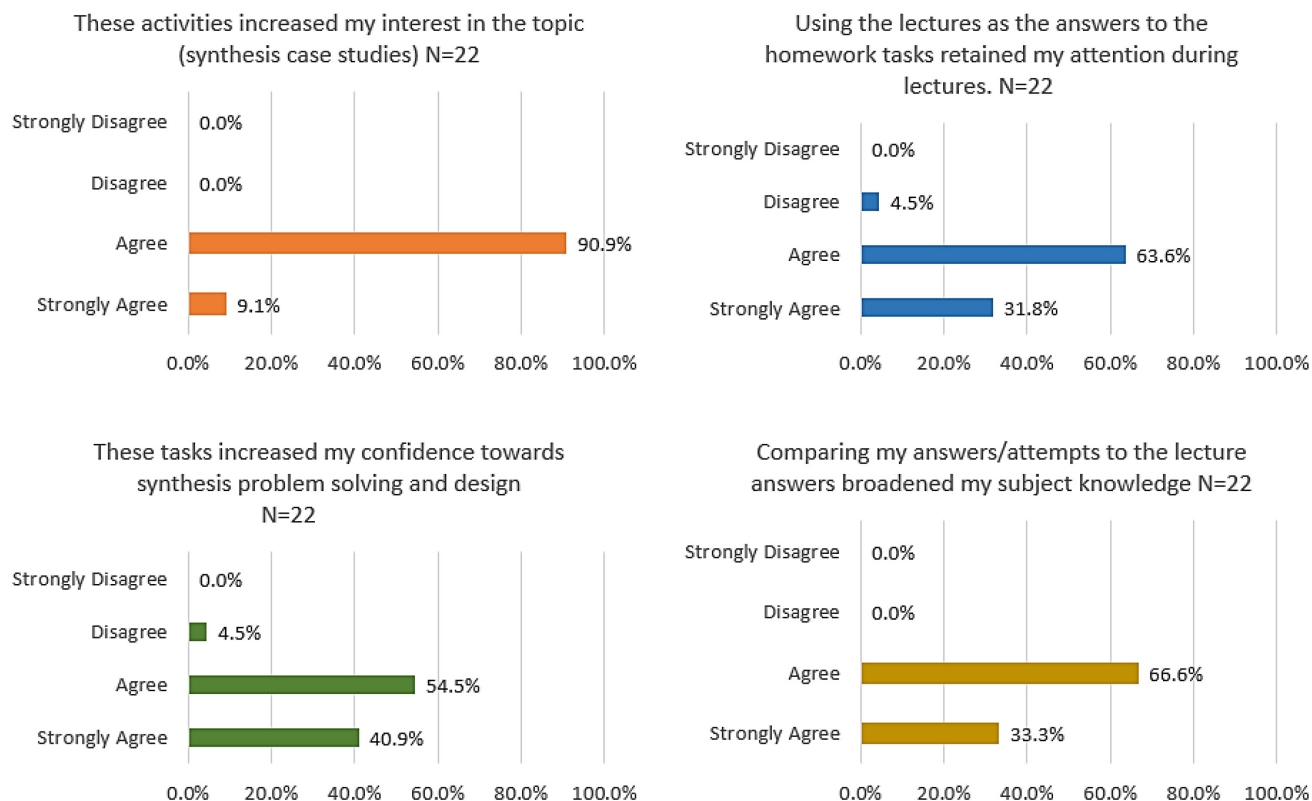


Figure 1 – Likert Data for the positive effects these homework activities had on student interest, problem solving confidence and knowledge.

Free comments associated with the survey confirmed that the students “found the tasks very useful as they cemented the learning objectives of the previous lecture” but also highlighted that these homework activities could be of use in a more general setting. To this end, one student had commented they “thought the homework was really helpful, not only for your content but for the Advanced Synthetic module as well” finding it “more engaging way of preparing for the upcoming lecture than just reading through the slides” What was interesting to note were the homework activities’ apparent versatility with several students actually preferring to save the activities till after the lecture, stating that they were “far more useful when preparing for the exam”.

To conclude, the students who did the homework were very complimentary of the homework activities and the collected feedback data and clearly suggests that they had been effective towards exam preparation and confidence with synthesis problems. The provision of these activities may have also contributed to the increased course examination performance. Those who didn’t conceded it was

“a good idea” but cited “other commitments” for a lack of engagement. Finally, it was also clear that these activities could be rolled out in other modules or as a means of providing students with a more synoptic synthesis revision activity.

## ASSOCIATED CONTENT (SUPPORTING INFORMATION)

All of the homework worksheets (case-study and exam) from the lecture course that this activity supports at The University of Leicester are provided along with an instructor pack. The homework worksheets provide the target molecule of the following case-study along with some guidance questions to assist the student’s solo attempt. The instructor pack provides a timeline/delivery plan for the lecture course and activities along with sample lecture notes that serve to provide brief solutions to the homework activities. Additionally, since the exam homework activity is not supported by a lecture run-through, the suggested answer sheet is provided for instructor and student use. This material is available *via* the internet at <http://pubs.acs.org>.

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