Increasing course continuity with a flipped classroom using research papers: Working with bioinformatics in research

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Introduction

The course 'Course in Bioinformatics and Systems Biology' is a mandatory five-day course for first-semester students in the Master of Human Biology at the Faculty of Health and Medical Sciences, University of Copenhagen (UCPH). Most students in the course lack experience in bioinformatics and programming. Therefore, the primary aim of the course is to introduce students to the possibilities and challenges of bioinformatics. However, this involves covering several different topics with different teachers in the five-day period, allowing only a brief overview of some bioinformatic techniques. Previous course evaluations have indicated a lack of continuity as students encountered various topics and teachers. To address this issue, we proposed a new session, 'Working with Bioinformatics in Research: Flipped Classroom,' for the final session of the course. The main idea is for students to read one of two research papers before class, and then in groups during class work with some of the methods and data types introduced in the course, and actively engage with questions related to the papers during the teaching session. This session aims to help students see how the different methods, tools, and data used throughout the course can be combined and work together in bioinformatics research, thereby increasing the course's continuity and at the same time allow them to work actively with the material in groups to optimize deep learning.

Here, I will introduce the course, discuss the ideas behind the flipped classroom, how it was implemented, analyze the outcomes, and suggest future perspectives.

Planning a flipped classroom teaching session

Justification: The course

The case course is the ‘Course in Bioinformatics and Systems Biology,’ run by the Novo Nordisk Foundation Center for Protein Research, UPCH. The course occurs every fall for first-semester students in the Master of Human Biology and is integrated with two other courses, ‘Molecular Genetics’ and ‘Advanced Cell Biology’, in the first block. The bioinformatics course spans three weeks to integrate with the other two courses.

The master’s degree in human biology includes students with diverse backgrounds, and the majority of them do not have any experience in bioinformatics and programming. Therefore, the main aim of the course is to introduce students to the possibilities of bioinformatics by providing a taste of various bioinformatic techniques. Many diverse topics are covered, and due to the limited time for each topic, students may find it overwhelming to grasp how different techniques and data types complement each other when used in research. Previous course evaluations have indicated a lack of continuity for students, as they encountered various topics and teachers and therefore the ‘working with bioinformatics in research: flipped classroom’ session was introduced as the last session of the course to increase the continuity and understanding of how the different elements can work together.

Methods: the flipped classroom format

To enhance continuity and understanding of how the different topics in the course can work together, we introduced a new session, 'Working with Bioinformatics in Research: Flipped Classroom,' for the final session of the course. The idea is to create an interactive session where students actively engage with topics from the other sessions of the course, learning how to combine and apply them in research. I chose to implement active learning in this session, engaging students in the learning process through activities that require active participation and interaction with the material. Research consistently suggests that active learning, in contrast to more passive methods such as more classical lectures, enhances student

understanding, retention, and critical thinking skills (Prince, 2004). Involving students in discussions, problem-solving, and hands-on activities promotes deeper cognitive processing and a more profound grasp of the subject matter (Bonwell and Eison, 1991). Furthermore, active learning has been shown to foster a positive learning environment, increase student motivation, and instill a sense of ownership over one's education (Freeman et al., 2014). Overall, incorporating active learning strategies into teaching practices can significantly contribute to more effective and engaging learning experiences for students.

Active learning plays a significant role in the so-called 'flipped classroom'. The concept of the flipped classroom is not new and has been adopted for centuries. A more recent formulation, which evolved into what is now known as flipped learning, was introduced by Eric Mazur at Harvard University in the 1990s (Farmer, 2018). Mazur argues that in a traditional setup, knowledge transfer often occurs within the classroom, while knowledge assimilation—active interaction with the teaching material for processing and understanding—typically takes place outside the classroom. In a flipped classroom, knowledge transfer happens before class, and class time is dedicated to knowledge assimilation, such as working on projects, engaging in discussions with peers, and participating in hands-on learning activities. This approach allows for a deeper understanding of the material (Mazur, 1997).

The benefits of a flipped classroom are numerous. Students gain more control over their learning and can proceed at their own pace. Additionally, flipped classrooms offer more opportunities for student-centered learning and peer-to-peer collaboration, both of which have been shown to enhance learning outcomes and student satisfaction (Farmer, 2018; Jensen et al., 2015). Flipped classrooms can also be advantageous for teachers, as pre-prepared materials enable them to focus in-class time on more interactive and engaging activities. However, flipped classrooms demand significant planning and preparation from teachers. Since the flipped classroom in this course is based on entirely new material, it will require planning and preparation in any case. Therefore, I decided to test the flipped approach.

In my teaching session, students are required to read one of two research papers before class (knowledge transfer) and actively engage

with questions related to the papers during class (knowledge assimilation). This approach increases the students' workload both before and during class. However, it is likely to enhance their understanding of the research papers as they actively engage with the material through questions, discussions with peers, and interactions with me in class, thereby deepening their comprehension, as suggested above.

Implementation of the flipped classroom

I decided to include two research papers that employed diverse techniques and data types covered in the course. One paper utilized disease register data (covered on the 4th day of the course) and deep learning methods (covered on the 2nd day of the course) to predict the risk of pancreatic cancer (Placido et al., 2023). The other paper utilized transcriptomics and proteomics data (covered on the 5th day of the course) and biological networks (covered on the 3rd day of the course) to develop a proliferation signature (Locard-Paulet et al., 2022). I intentionally chose two different papers to expose students to various bioinformatic applications and to encompass a broader range of methods and data types taught in the course. Additionally, providing a choice for students has been shown to support autonomy to some degree (Stefanou et al., 2004), fostering a higher sense of responsibility for reading and preparing the research paper before class. I uploaded the questions that students would work with in class to Absalon beforehand to guide their readings. Furthermore, I asked which paper they chose to work with to facilitate the formation of groups for in-class activities.

I began the session with a short introduction to the background of the session, the Intended Learning Outcomes (ILOs) (see Appendix A), a brief recap of the two papers and the elements of the course they address, as well as the plan for the flipped session (see Figure 1).

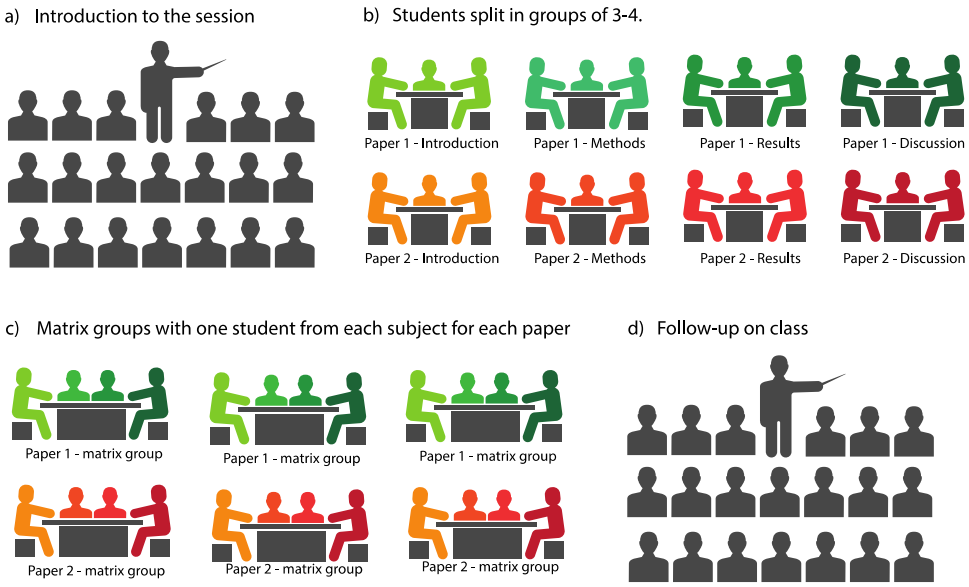


Fig. 1. Overview of the flipped classroom session. a) First, I gave a small introduction to the background of the session. b) students were split in groups beforehand based on which paper they chose to work with and answered questions related to one section of the paper. c) In matrix groups, consisting of students reading the same paper, they would present the answers to each of the sections they were responsible for to each other. d) Lastly, I followed up on the session on class.

Initially, students were divided into groups based on their choice of research paper, ensuring that students within the same group had read the same paper. Each group, consisting of 3-4 students, that were assigned a specific section of questions. The questions were categorized into four parts: a) introduction, b) methods, c) results, and d) discussion, with three questions for each part. While the questions naturally reflected the main outcomes of the papers, they were also designed to revisit key aspects of the earlier topics covered in the course. For instance, question 2b) for Placido et al. focused on the type of machine learning used in the paper and how and why the data was split in a certain way during the training of the machine learning algorithm. Although the paper did not provide explicit answers to all these questions, the intention was for students to draw upon the theory taught on machine learning to formulate their responses.

Each group had the opportunity to work on all questions collectively (see Figure 1b), but they were specifically responsible for presenting the answers to one section of questions to matrix groups later on (see Figure 1c). This approach aimed to promote shared responsibility within each group, as all members had to explain their group's main findings to some of their peers. During the matrix group presentations, students took turns presenting their results from the initial group discussions, providing them with valuable practice in presenting to their peers.

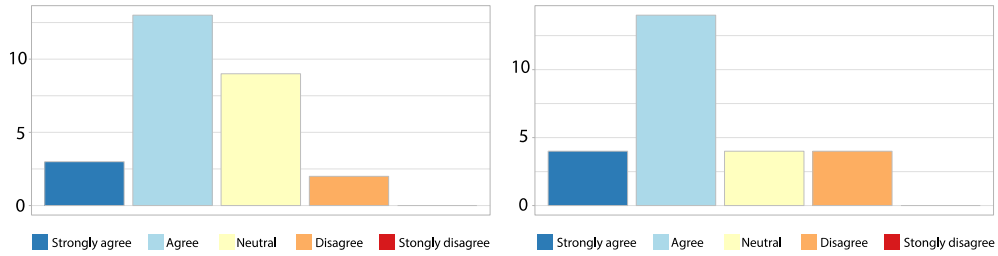
Throughout both the initial and matrix group discussions, I circulated to address any questions and offer feedback to the groups. Following the matrix group presentations, I concluded with a summary, emphasizing the main points, revisiting the ILOs, and connecting the topics to the broader course and the real-world context relevant to the students (see Figure 1d). Towards the end, I asked students to evaluate not only the specific flipped session but also the course in general. The evaluation questions and results are presented in the following section (see Figure 2) and in Appendix B. The effectiveness of the intervention was evaluated based on both the students' feedback and discussions between me and my supervisors, who observed the teaching session.

Outcome and reflections

Overall, the session received positive feedback from students, as indicated in the student evaluations (see Figure 2 and Appendix B). Students expressed enjoyment in the interactive nature of the session and found the group discussions valuable. They appreciated the specific task assigned to each group, and the majority actively engaged in the activity. Many students mentioned that they regularly read scientific papers, acknowledging the difficulty in understanding them. The session and discussions with fellow students were perceived as helpful in grasping the central aspects of the papers (see Figure 2a and b). The primary objectives of the session, namely increasing continuity in course elements and understanding how the methods and data types can synergize in research, were according to evaluations achieved (see Figure 2e and f).

The initial group discussions were particularly effective in supporting the learning outcomes. One student succinctly summarized the positive elements of the session, stating, “I like that it was interactive, and we did it in groups because it allowed for a deeper understanding and hands-on” (see Appendix B). Approximately half of the students felt that the matrix groups effectively supported the learning outcomes (see Figure 2g), aligning with my observations in the classroom. In some matrix groups, key findings from the initial group discussions were new to the peers, providing practice in explaining their findings, which was the intended purpose. The fact that everyone had to present their conclusions from the initial discussion increased participation and ownership. Some students highlighted the benefits of this practice in their evaluations, stating, “Presenting the data to students helps me check if I really know the information” and “The matrix group discussions were really good and made it easier to understand the papers and get a different view on the topics covered” (see appendix B).

On the other hand, the remaining half of the students did not find the matrix groups as supportive of the learning outcomes (see Figure 2g). The effectiveness of matrix groups may depend on each student contributing with something valuable, which was not consistently the case, as most groups answered all questions before turning to the matrix groups. A potential solution is to engage with groups that may not be working well by assessing whether the task was too challenging or too simple and helping. Additionally, providing extra tasks for matrix groups that finish early or seem less engaged, such as writing notes for the follow-up section or formulating questions on the topic, could enhance their experience.



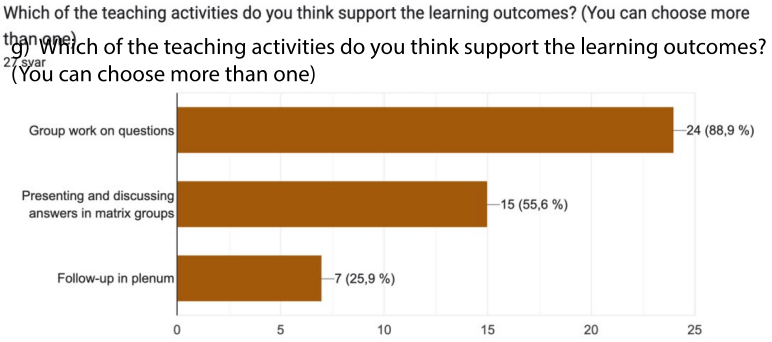


Fig. 2. Results from student evaluation. Majority of the students found the session relevant, and useful for reading scientific papers, and the continuity of the course. For free text answers to the evaluation, see Appendix B.

Six students did not read the paper before class (see Figure 2c), and as the majority did not express this during class, they participated in group work on the same terms as those who were prepared. This may seem unfair to the students who took the time to prepare. Initially, I planned to place unprepared students into the same group so they could read the papers

while others worked on the questions. However, this was not feasible, as none indicated they had not read the paper beforehand. To ensure that all students start on equal footing, a potential solution is to have them read a smaller section of a paper in class and work on related questions. This approach would likely increase the importance of the matrix groups, as not everyone would have read the entire paper or answered all questions. Additionally, including two students responsible for each section, instead of one, in the matrix groups could enhance overall comprehension and reduce fragility.

The formation of groups could also be optimized. Initially, I arranged groups based on the papers that students claimed to have read through a small online Absalon quiz. However, it became evident that some students who hadn't read the paper indicated otherwise. A more efficient approach would involve dividing the groups in class, with those who didn't read a paper sitting at designated tables. Group formation could be achieved, for instance, by using different letters, numbers, or colors on post-it notes. Finally, in the follow-up session, students could summarize the papers and their gains for everyone to benefit from both papers.

Overall, the introduction of the flipped classroom with research papers worked well within the course. Given that it was a completely new section, we did not expect it to run perfectly. As discussed above, there is still room for improvement, and we plan to test out these adjustments in the next academic year.

Future perspectives

For next year, my plan is to put more focus on how the matrix groups can contribute more to students learning. It could be like the setup described above, where students read a part of the paper in class, or I could select another paper with three interconnected elements. In this alternative setup, it's essential for the students to understand both part one and part two to be able to understand part three. The initial groups will focus on parts one and two separately, and then, in the new matrix groups, they'll collaborate to integrate their understanding and tackle part three. This way, initial groups could be formed beforehand, and matrix groups during class to

ensure that at least some students understand their part. Furthermore, I will include some of the smaller changes, like creating the groups in class as mentioned above.

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Appendix A

Intended Learning Outcomes of the 'Course in Bioinformatics and Systems Biology'

Knowledge

- Discuss how the information from biological experiments may be represented in an electronic format
- Describe the basic principles in genetic sequence analysis studies and explain how these can contribute to precision medicine
- Discuss use cases of Machine Learning in a clinical aspect
- Describe how text mining can be used for information retrieval

Skill

- Search for data in publicly available databases such as STRING
- Use data analysis and visualization programs such as Cytoscape
- Produce and critically evaluate biological analyses including variant calling and protein networks
- Integrate heterogeneous data on a biological system for answering biologically or medically relevant questions

Competence

- Master a range of methods for finding, analyzing and integrating heterogeneous biological data in the context of a specific disease
- Critically evaluate the results of such analyses

Intended Learning Outcomes of the session, 'Working with bioinformatics in research: flipped classroom'

Knowledge

- Repeat topics learned during the course

Skill

- Understand the structure of a scientific research paper

Competences

- Analyze research papers and critically evaluate method and results
- Illustrate how topics learned during the course can be applied in research

Appendix B

Results from the open feedback from the student evaluation

What did you like most about this module?

- Group discussion
- Interactive parts
- Matrix groups were helpful
- Group work
- Working group
- The group session!
- I like that we got to discuss the answers with people we don't usually work with and get their opinions
- Presenting the data to students. Helps me check if I really know the information
- Applicable to the course we're doing, we spend a lot of time reading papers so this type of analysis was helpful
- That we could discuss the paper with others
- We worked together and the discussion was dynamic
- The matrix group discussions were really good, and made it easier to understand the papers and getting a different view on the topics covered
- Group work
- The matrix groups
- The group work
- That we had time to discuss the paper. It was really nice with reading questions to focus the reading both before class and in the groups as well
- Working in groups
- The presentation in matrix group
- The ability to learn more by the use of group work and discussion
- Discussing answers in matrix groups
- That I understood the goal of the paper and could discuss it with the group
- I liked that it was interactive and we did it in groups cause it allowed for a deeper understanding and hands on

- I liked that the different days were split
- I liked the group discussions. It helped a lot.

How could this module be improved?

- Give more time about exchanging ideas between different groups
- I don’t know
- Nothing
- Nothing
- Maybe research papers that are a bit easier to understand
- Maybe even have time to explain the other paper to each other
- More background information or a refresher course on what we’ve learned to far would have been helpful today
- Maybe talks and exercises more equally
- It was good
- As told earlier
- The matrix groups were not helpful/necessary
- A bit more structure
- More time for discussion
- More time for discussion
- I liked the structure
- Maybe also discussing the other paper that the other groups read. I felt like today improved my understanding of Deep learning specifically, while I still feel a bit lost in Cytoscape