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Towards a balanced curriculum and fair assessment of students from different disciplines in an interdisciplinary science course.

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Objectives

The project aims to improve the course Biological Dynamics, which will be offered for the second time in block 4, 2011, based on the students' evaluations from 2010 and my experiences from giving the course in 2010.

I will focus on the main challenges we encountered in the course. One objective is to plan the curriculum and the teaching activities so that students, despite different educational backgrounds, feel both confident and challenged, and experience a positive learning climate. Another is to develop teaching activities which are aligned with the overall aim of the course, namely promoting interdisciplinarity and equipping students with a common language with which to discuss topics that cover multiple disciplines. Finally, I will discuss the challenge of assessing the course participants fairly, so that students from all backgrounds have an equal opportunity to do well in the course provided they put in the effort.

Background

The field of molecular biology is advancing from the qualitative description of isolated molecular mechanisms to a quantitative understanding also of their interactions and regulations at the "systems-level". Thus, the common notion of biology being the ideal discipline for the "scientifically inclined but mathematically challenged" students needs revision, and this development has produced a challenge for the educational system. The advantage of quantitative approaches in biology has always been apparent, but the application of mathematical skills to create simulations or manage large data sets means that the need for basic mathematical literacy in biology has never been greater (Wingreen & Botstein; 2006; Gross; 2004). Biological Dynamics was created to address the challenge at the Master's level, where many students have already solidly identified themselves as biologists, chemists, physicists, and so on. The aims of the course are to educate students from different disciplines in the interdisciplinary skill set between biology, physics, and mathematics, which is necessary for a modern integrated understanding of biological systems, and also to teach the students how to communicate with peers educated in disciplines other than their own.

Biological Dynamics is co-organized by myself and Namiko Mitarai, an associate professor in the physics department. The course is inspired by an interdisciplinary course in quantitative biology that I attended at Princeton University, USA, in 2006 (Wingreen & Botstein; 2006).

The course is open to students from most of the disciplines at the Faculty of Science. In the past year we had a total of 51 students from eight different educational backgrounds (biology, biochemistry, bioinformatics, molecular biomedicine, biophysics, physics, maths, and computer science). We do not make specific course prerequisites but ask that students who sign up have an interest in the quantitative analysis of biological phenomena.

Balancing the curriculum

We chose to centre the course around a curriculum of eight scientific articles, one per week. The nature and quality of the articles are of paramount importance for the success of the course for several reasons. First, they must serve as vehicles for teaching both biology and quantitative analysis. Second, they constitute proof for the students that important scientific insights can be gained from an interdisciplinary approach, and must be sufficiently sophisticated to withstand detailed study and to inspire the students. These were our criteria for selecting the articles.

Namiko and I developed introductory lectures in physics and biology, respectively. Initially, our intentions with the lectures were twofold: First, to provide the disciplinary background knowledge required for understanding the articles and second, to put the article into context by deepening and widening the students' insight into the topic beyond the specific hypotheses treated in the article. During a normal week, students would attend the introductory lectures on Monday, read the article at home, and participate in a class discussion about the article on Wednesday. Importantly, the curriculum consisted of the lecture notes as well as the articles.

I found it challenging to define a level of difficulty in my lectures such that every student would benefit from attending. To obtain feedback from the students on the perceived level of difficulty in the material of the lectures, I often asked for a show of hands during the lecture from anyone who had "learned something new" after the first 5-10 minutes of introduction to the topic. I found this to be a reasonable measure of the students' prior knowledge of the topic. We also made a midway evaluation after the first four weeks of the course. To be able to take the students' background into account, we asked them to indicate their educational background on the evaluation.

What is your educational background?	Students' answer	Total students enrolled
Biology-oriented	19	27
Physics-oriented	4	11
Equally Biology and Physics-oriented	10	11
Other (math/computer science)	2	2
Prefer not to answer	0	
Total	35	51

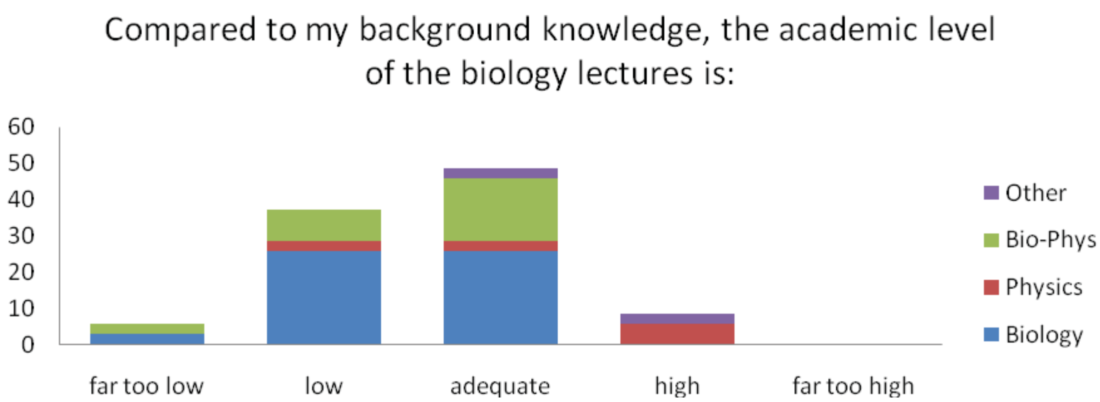


Fig. 15.1. Midway evaluation. The percentage of students giving the indicated answer is shown on the Y-axis. Colours indicate the educational background of the students. A total of 35 students answered this question.

In total, 45% of the students indicated that the academic level of my lectures was either "far too low" or "low". Noticeably, all but one of these students had a background in either biology or biophysics, and the 9% of students who indicated that the academic level of my lectures was "high" all had a background in physics or "other", which in this class meant computer science or mathematics. This evaluation was not satisfactory, as it appeared that in my efforts to make the biology lectures accessible for everyone in the course, I lost more than half of them, since 54% reported that the academic level of the biology lectures were unsatisfactory in one direction or the other. The physics lectures suffered from the same problem, with 31% of the students reporting that the level was "high" or far too high", and 31% reporting it was "low" or "far too low" (Fig. 15.2).

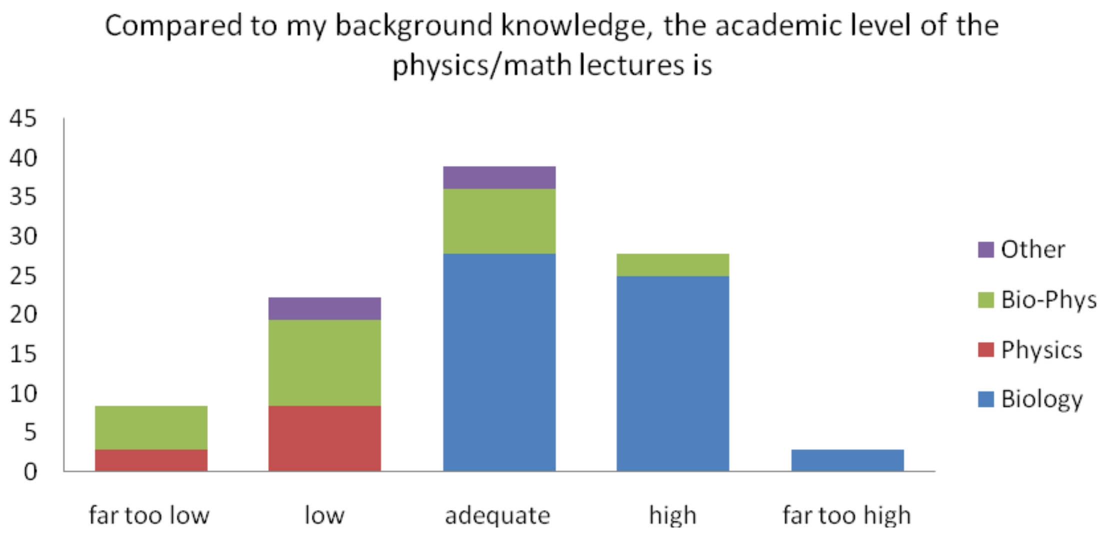
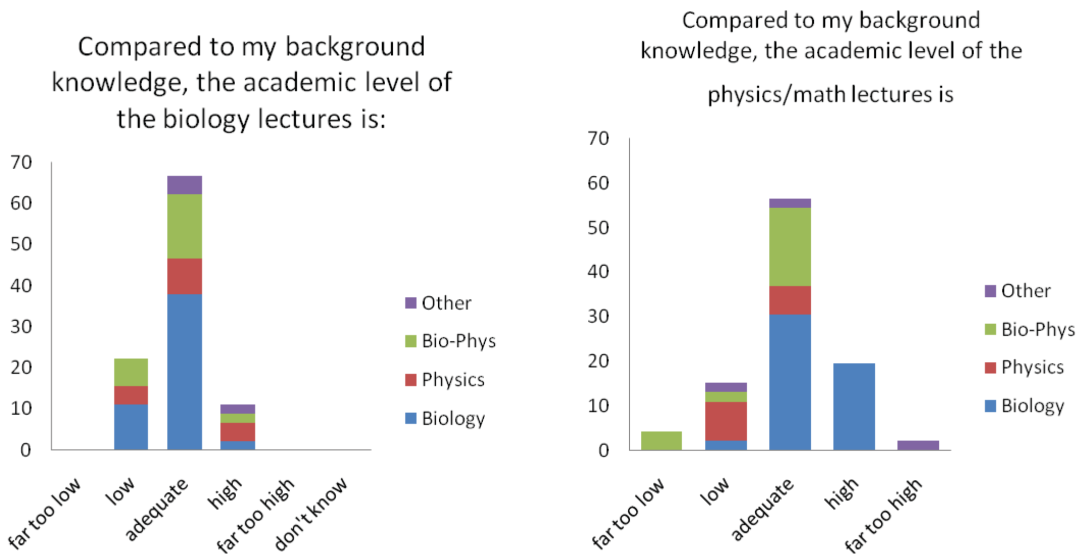


Fig. 15.2. Midway evaluation of the physics/maths lectures.

Does the varied educational background of the student body in this class make it an unattainable goal to give lectures from which everyone can learn from? Do we need to split the class and teach the biologists physics and the physicists biology? We rejected the latter option because separating the students to teach them different things is not likely to increase communication and collaboration between them.

In my opinion, the key to good lectures in this course will depend on more team-teaching between Namiko and I, so that the interdisciplinary curriculum is presented in an interdisciplinary way. Namiko and I need to develop the lectures together, incorporating the mathematics and the biology into coherent entities, rather than requiring the students to construct a multidisciplinary understanding of the topic by assembling knowledge from strictly additive disciplinary lectures themselves. From the beginning of the course, Namiko and I had tested our lectures on one another before presenting them to the students, and always attended each other's lectures. But we increasingly made an effort to teach each other the subject matter for each topic, while the lectures were still under development, thereby making them less disciplinary, and taking each other's intended learning objectives into consideration. This approach seemed to remedy the situation somewhat, since at the end of the course, 64% of the students found the academic level of the biology lectures appropriate, and 56% of the students found the physics/maths level appropriate (Fig. 15.3).



(a) Biology (b) Physics/maths

Fig. 15.3. Final evaluation of the biology (a) and physics/maths (b) lectures, respectively.

It is clear that we still have ample room for improvement of the lectures. Ideally, I believe that the lectures for this course should present the material in a way that neither the biology nor the physics students have seen before. At the very least, all students should feel that they got a fresh look and a new perspective even on familiar material. This can best be achieved by investing more time into integrating the maths and the biology by Namiko and me prior to presenting it to the students. However, as also pointed out by Gross (2004), preparing team-teaching with faculty from other disciplines takes much more time than teaching a solo lecture. The experience we have gained from giving the course once, especially attending all of each other's lectures, and assessing the students performance together at the exam, certainly provides a good starting point for collaborating to improve the lectures in 2011.

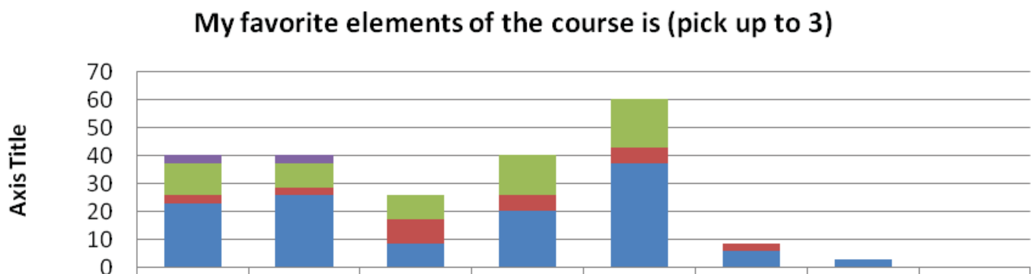
Teaching activities to promote interdisciplinary communication

The course contained three teaching activities aimed at promoting collaboration between the students, which were teacher-controlled to different degrees. First, the weekly classroom discussion of the articles which Namiko and I led together. Second, weekly group exercise sessions, where a group of four students, ideally from different backgrounds, had two hours to solve three or four problems based on the content of that week's curriculum. Third, an oral presentation of an assigned article prepared by each student group, which had to be approved in order for the students to qualify for taking the exam.

We feel that the group exercises were generally very successful. To get the right distribution of educational backgrounds, Namiko and I divided the students into groups. We found that the students were generally enthusiastic to teach each other the knowledge needed to solve the problems. In the students' rating of which teaching activity they favoured, the group exercises took first place (Fig. 15.4).

It is my conviction that almost all the students reached the intended learning outcome of being able to discuss scientific ideas with peers from other disciplines, and gaining new perspectives on material from their own discipline. This assertion was confirmed by the students' evaluations, where 78% agreed that the group exercises increased their understanding of the course material (Fig. 15.5a) and 70% agreed that mixing students with different backgrounds in the groups enhanced their understanding of the course material (Fig. 15.5b).

It was our impression that the more student-centred activities worked better to promote the students' communication skills. My reflection paper discusses my work with my pedagogical supervisors to make the classroom article discussions less teacher-focused and more student-centred, so I will not discuss that here.



	The Monday biology lecture	The Monday physics lecture	Reading the assigned paper	The Wed. paper discussion	The Wed. group exercises	The multiple choice test	Another part (please specify)	No favorite elements
Other	3	3	0	0	0	0	0	0
Bio-Phys	11	9	9	14	17	0	0	0
Physics	3	3	9	6	6	3	0	0
Biology	23	26	9	20	37	6	3	0

Fig. 15.4. The percentage of total students who picked the indicated activity as one of up to three favorite course elements.

Of the students who were neutral or disagreed to the first statement, several had commented that they lacked a verification of their answers from the teachers at the end of the group exercises, as they often had doubts as to whether their group had solved the exercises correctly. We did attempt to discuss the groups' results with them before the end of each class, but it is an important point to which we will pay greater attention to next year. The other disagreements were from a group where we lost the diversity early on, as the physics-oriented students in that group dropped out of the course. The students in that group commented that they had not really gained the full interdisciplinary experience they had hoped for, because the group consisted of solely biology-oriented students. Naturally, this situation should be avoided in the future, but we were glad to know that the students considered it a disadvantage to not be mixed with students of different backgrounds.

Assessing a diverse group of students

There are some special challenges associated with designing a fair exam for assessing a group of students with very different prior knowledge. First,

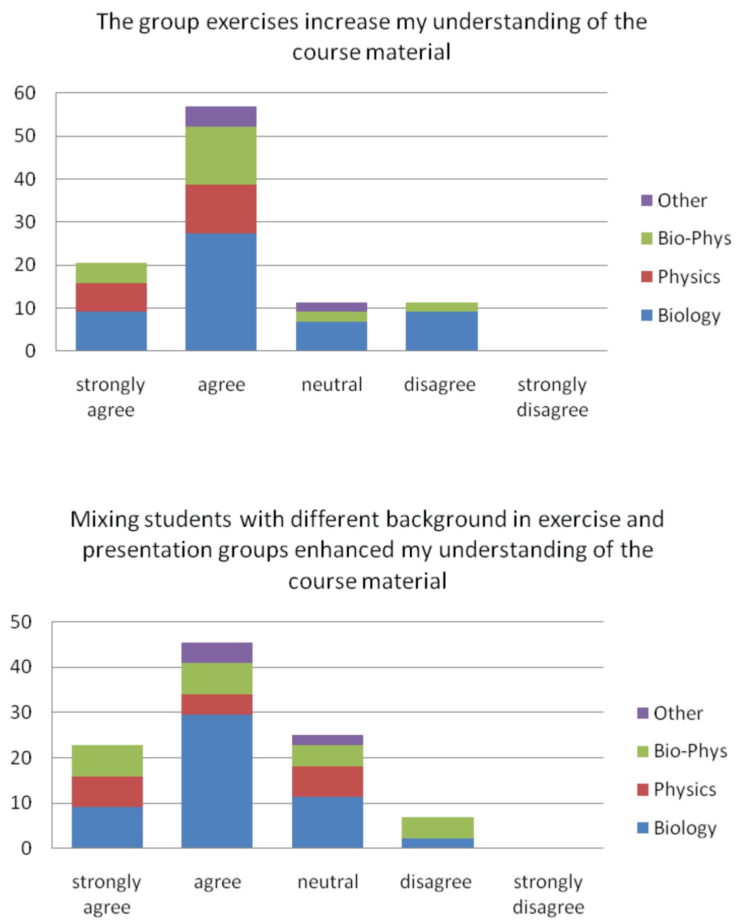


Fig. 15.5. The percentage of students who picked the indicated answer in the final course evaluation.

it is crucial that the assessment be criterion-referenced rather than norm-referenced, both because of the better educational logic associated with criterion-referenced assessment (it involves judgment of the performance rather than judgment of the people (Biggs & Tang; 2007)) and because norm-referenced assessment becomes less meaningful the broader the distribution of specific skills is among the student body. Second, there is an increased risk that less confident students will doubt their ability to perform well in the exam in a course like this, because it is clear during class that some students have a lot of specific knowledge about topics that might be completely new to others, and this doubt can create a negative learning climate. Third, since interdisciplinary communication is among the most important intended learning objectives for this course, the exam should ideally test this skill. Fourth, the exam should be designed so that no educational background provides a specific advantage or obstacle to success.

We designed an oral exam, which we think fulfils these criteria to a large degree. In the exam, the student draws one of the eight topics from the course, and has ten minutes to present this topic, after which the censor and examiner asks questions from the other seven topics for fifteen minutes. The students were given the specific exam questions for a given topic in advance, on the Monday of the week that dealt with this topic. Our reasons for revealing the exam questions this early were twofold. First, it clarified what the students are expected to know at the exam, and we think this served to decrease the doubt that less confident students might have about whether they are able to perform well in the exam. Second, it gave the students a chance to discuss the questions with their peers during the group exercises, as well as outside of class, and come up with answers that satisfied students of different educational backgrounds, which in effect meant coming up with answers that cover the perspectives of multiple disciplines.

Namiko and I put a lot of effort into constructing the exam questions every week, to assure that approximately equal amounts of our two disciplines' knowledge was required to satisfactorily answer them. We were both present for all the exams. During the exam, we took turns asking the student questions, and afterwards we independently assessed the student before discussing and agreeing on the grade. In nearly all cases, we agreed completely on the grade that the student should receive, and in the cases where we did not agree, we were never more than one step apart on the seven-step grading scale, and were able to reach consensus within a couple of minutes. Assessing students with different backgrounds can be a challenge when the faculty, like us, is not truly interdisciplinary, but represent two different disciplines. However, I think we succeeded in assessing the students fairly. The distribution of final grades is shown in figure 15.6.

The grade distribution shows no obvious bias towards student of a particular educational background. This distribution, together with our very positive personal experience of the students' collective performance at the exams, and their generally positive oral feedback, leads us to believe that the exam form is appropriate for this course. Thus, we intend to carry on with this form of exam, although 51 oral exams in one week represented a great commitment from the teachers.

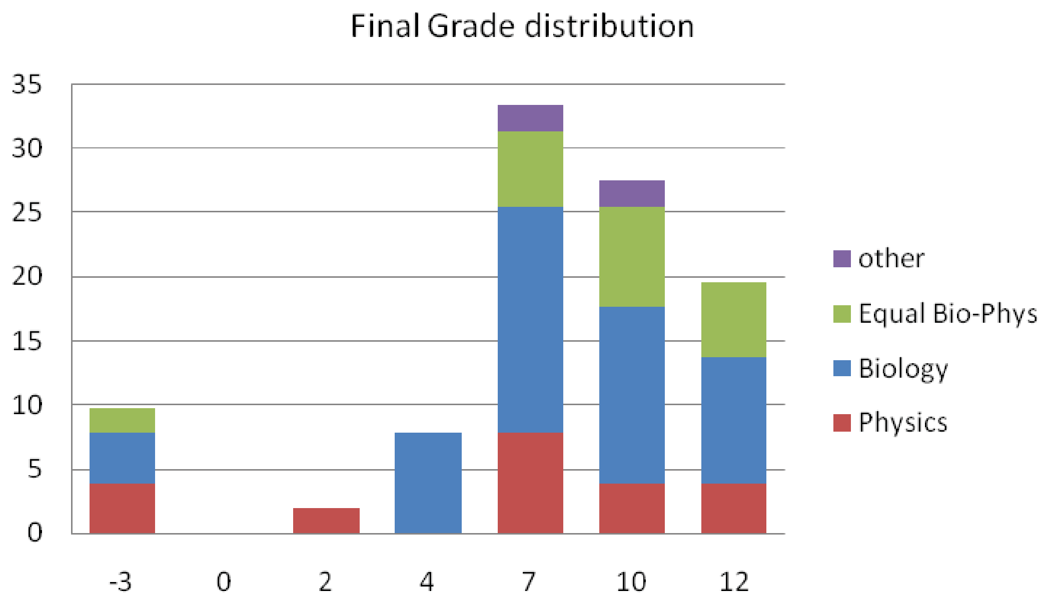


Fig. 15.6. The percentage of students receiving the indicated grade is indicated on the Y-axis.

All contributions to this volume can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/2010-3-1/

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