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Active students in problem-solving classes

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Introduction

MatIntro is an introductory course in calculus at the University of Copenhagen. It is a mandatory course for a range of studies, including mathematics, physics, chemistry and biochemistry. The course has been running for about seven years in its present form. Compared with previous introductory courses in mathematics for biochemistry students, the course has been successful in obtaining a much higher pass rate. However, there is still a large gap between the exam results and the pass rates of the biochemistry students and the chemistry, mathematics and physics students.

I have previously analyzed the structural alignment of the course as well as the overall alignment of the biochemistry study plan (KNUD written assignment on structural alignment). The analysis showed that parts of the internal alignment were good – i.e., the intended learning outcomes (ILO), the teaching-learning activities (TLA) and the assessment of MatIntro was well aligned. However, it also showed that some aspects of MatIntro lead to *passive students* and a *surface approach to learning*. These aspects include the assessment, which is partly based on a multiple-choice exam, the workload – including weekly hand-ins and a very tight schedule in order to cover a large curriculum, as well as a lack of peer-to-peer learning activities. Group work used to be an important aspect of the course, but Danish legislation now prohibits group exams, and this has changed the student motivation for group work quite significantly.

The analysis also demonstrated that mathematics does not play an important role in the biochemistry Bachelor programme study plan, and that there is a misalignment between the overall study plan ILO and the way mathematics is presented to the students in MatIntro.

The present project

During September and October 2010 (block 1 at the University of Copenhagen) I was the class teacher for thirty-two biochemistry students on the MatIntro course, and I used this teaching as an opportunity to test out some ideas to *improve student activity* and *active learning* for this very common type of “problem-solving” mathematics classes. The setup is classical – a number of exercises are handed to the students some days before class. During the class hours, the students and teacher will discuss or calculate the exercises. Depending on the ability and motivation of the students, the students have prepared in some way for the class. Typically, five to ten students arrive having prepared quite well, while other students have not prepared at all.

Focus, delineation

As a teacher for a problem-solving class, I am, of course, not in a position where I can change either the intended learning outcomes or the assessment of the course. And since these aspects have already been analyzed in my previous assignment, it makes sense to focus on the teaching-learning activities in the problem-solving classroom. Of course, these activities have to be aligned with the ILOs and assessment. In order to discuss the alignment of new TLAs to the ILO and assessment, I repeat parts of the discussion about alignment and have reproduced the course ILO in figure 9.1.

Alignment of ILO and assessment

These ILOs fulfil some of the criteria of the intended learning outcomes that are recommended in outcomes-based teaching (Biggs & Tang; 2007). The sentences used to describe the different outcomes state very clearly what the students should practice doing during the course.

The final summative assessment, which consists of two multiple-choice tests, is well-aligned with the ILOs: The multiple-choice tests are in my

Present ILOs for the MatIntro course:

Aim:
At the ends of the course the students should be capable of:
1. Following proofs
2. Solving problems with or without the computer algebra system Maple.
3. Mastering the subject matter content described below.

Course description:
Use of Maple
1) Complex numbers.
2) Number sequences.
3) Continuous functions in 1 variable.
4) Differentiability and integration of functions in 1 variable.
5) Continuity of functions of several variables, topology of R^n.
6) Differentiability of real functions of several variables.
7) Extrema for real functions of several variables, Lagrange's method.
8) Taylor's formula.
9) Surface and volume integrals.
10) Solution of simple differential equations, numerical integration.

Expected competencies:
By the end of the course the student must be capable in general to follow mathematical language and reasoning within the subject of the course, and specifically be able to
- perform arithmetic with complex numbers,
- decide convergence and determine limits of real sequences,
- determine limit values of functions,
- perform computations involving continuity considerations,
- perform differentiation and integration of functions of 1 variable,
- solve basic differential equations of order 1 and 2,
- determine Taylor polynomials and estimate remainders for functions of 1 variable,
- decide simple topological properties of planar sets,
- perform differentiation and apply the chain rule to functions of several variables,
- describe a function geometrically by means of graphs and level curves,
- determine the tangent/tangent plane of a graph or level set in plane or space,
- examine extrema of functions, with or withour constraints,
- pose and compute double and triple integrals,
- give correct arguments in applications of theory and methods,

and in addition use Maple, when relevant in association to the above.

Fig. 9.1. ILOs for the MatIntro course.

opinion sufficiently effective in assessing whether the students are able to perform the ILOs given above.

In the SOLO taxonomy (Biggs & Tang; 2007, p. 76ff), these highly quantitative ILOs encourages uni-structural and multi-structural knowledge. It could be argued that this level of operational knowledge is sufficient on a first-year introductory "toolbox" course.

Motivation

However, there are other problems with the ILOs, and these problems are related to the motivation of the students. As remarked by Biggs and Tang (2007, p. 23), factors that encourage a surface approach to learning include:

- An intention only to achieve a minimal pass. Such may arise from a "meal ticket" view of university or from a requirement to take a subject irrelevant to the student's programme.
- Assessing for independent facts, inevitably the case when using short-answer and multiple-choice tests.

It is not difficult to argue that algebra is an important tool to learn for the biochemistry students. However, the present ILO does not argue at all. There is *no* intention in the ILO to highlight the relevance of algebra as an important tool for the biochemist. The highly operational goals of the ILO, along with the assessment in the form of multiple-choice tests, will without doubt cause many a student to turn to surface learning – with the intention to achieve a minimal pass, as the content apparently has little to do with the remaining biochemistry programme.

Alignment of ILO and TLAs

The teaching-learning activities of MatIntro are quite diverse. There are lectures (210 minutes a week), classroom teaching (180 minutes a week), computer exercises (80 minutes a week) and independent work with teaching assistance (90 minutes a week). There are, in my opinion, a lot of resources and time available for TLAs. The question is whether these resources are used in an optimal way to stimulate learning.

The computer exercises encourage active students, and most of the exercises require a good understanding of the software, as well as some understanding of the mathematics. These exercises are also based on group-work. I consider them the best part of the TLAs of the course.

The lectures are carefully prepared, but are seldom activating the students. The classroom teaching is based on end-of-chapter exercises. My usual practice as a class-teacher has been to encourage the students to present the exercises at the blackboard, however often there are only a few students that dare to present. In consequence, I (the teacher) go through the exercises, and the students sit back, more or less passively listening and taking notes.

Another reason for the lack of volunteering students is probably that this type of presentation is not aligned with the assessment. There is no oral examination that would motivate the students to practise presenting at the blackboard.

I think the way that the problem-solving classroom teaching is dealt with is one of the major problems of the present TLAs, and something should be done to engage the students in active, deep learning. Inspired by IUP and KNUD, I wanted it to be different this year - and I have therefore focused on changing aspects of the teaching that would engage the students to become active learners, and that would break the routine in the problem-solving classes.

Restating the didactic contract: moving away from blackboard-centered teaching

At a meeting prior to my first encounter with the students at MatIntro I was advised by my pedagogical and chemistry supervisors to explicitly inform the students how the exercise classes would be conducted, in other words to restate the "didactic contract"; the didactic contract is a term coined to explain the often unspoken contract between teacher and student, that if the student engages in the activities proposed by the teacher, this will lead to learning. When the expected blackboard-centred teaching is reformed towards student-centred activities, the unspoken tradition of classroom teaching is broken, and it becomes important to inform and motivate the students for the new type of activities. Due to administrative circumstances, I only knew the names and e-mail addresses of the students in my class very close to the first encounter with the students, so I had no way of informing the students in advance. However, during the first session, I told the students about my plans for the teaching, and they seemed to be satisfied with that. I also told them that my reform of the teaching was part of my project in KNUD. I will later discuss how this satisfaction for some of the students turned in to a mild frustration during the course.

As a class teacher for the MatIntro students, I am, of course, not in a position where I can change the course structure, nor the topics to be covered. There is also a mandatory set of exercises given by the course organizers. I therefore have a (very) limited amount of freedom to change the classroom teaching, and I have chosen to focus on, and experiment with, aspects of the teaching that are relatively straightforward to implement and evaluate. These “new” TLAs are not specifically designed for mathematics, and could probably be used in all kinds of problem-solving classroom teaching. The limited flexibility imposed by being a small part of a large course is also a very common situation for most exercise-class teachers.

Each of the experiments was used a few times during the nine weeks that the course was running. Below, I will present the background and motivation for the experiments; how they were actually conducted and I will try to discuss and evaluate them. Notice that most of my evaluation is based on either direct observation and discussion with the students, or by asking rather open questions that the students have answered on yellow post-it notes. Due to time limitations, I have purposely not made a more formal in-depth questionnaire, but I hope to demonstrate below that my approach has been a quite successful way to interact with the students.

Active learning and variation

The activities that I have tested are all meant to encourage deep learning and to break the monotony of the traditional problem-solving class. As noted by Biggs & Tang (2007), breaks and changes in the activities every fifteen minutes or so are desirable. Few can keep their concentration for longer.

Quick evaluation using post-it notes

The success of the TLAs can be evaluated in different ways. A natural way is to try to sense the atmosphere in the classroom – are the students engaged? Sometimes, it can be fruitful to evaluate the success in a more formal way. On the other hand, time (mine, as well as the students) did not allow me to make a large, formal survey for the students to fill out – this would easily take another 30 minutes of precious maths exercise time. Instead, I chose to write a question on the blackboard, and the students had a few minutes to fill out a yellow post-it note with their answer. I could then analyze the answers later, and report back to the class.

In contrast to other quick ways of evaluating the teaching (like asking students individually in a break) this method sends the signal that the teacher is taking the students’ opinion seriously. It also allows everyone to be heard. Of course, it is important to follow up on the evaluation, and I did this, first of all, by telling the students about the results of the survey, and also by trying to change the teaching according to the critique raised by the students, as I will report below. During the course, problems arose because a group of students felt that we were moving too slowly, or did not discuss all the exercises. As a second part of this report, I have focused on how I have tried to reflect and respond to this problem.

First part: New teaching-learning activities in the exercise classroom

The following TLAs were tried during the course, mixed with more traditional blackboard-centred teaching.

ConcepTests and multiple-choice exam questions

Background

Eric Mazur (1997) and others have demonstrated how simple conceptual tests can engage the students in the lecture hall. The tests are often anonymous, because this allows the students to respond more freely – they are not afraid of giving the wrong answer. The tests are multiple choice, they are clearly worded, and cannot be solved using equations. The purpose is twofold: It allows the teacher to evaluate the students' understanding, but most important, the tests are used to activate the students, because they have to think, and because they are encouraged to discuss the answers with their fellow students, thereby stimulating peer-to-peer learning.

This type of TLA is in good alignment with the MatIntro course assessment, because it is based on multiple-choice questions. In fact, I found that some of the multiple-choice exam questions from previous years could be used for this type of activity (i.e., those that did not demand long computations). Furthermore, I used questions taken from a collection available from a project called 'GoodQuestions' (Department of Mathematics, Cornell University, USA; 2005).

Execution

I found that rather quick 'probing' questions were the best choice as a supplement to the deep and rather difficult exercises which were part of the mandatory weekly programme given by the course administrators in the course. An example is given in the figure 9.2.

> **Probing question:**
> Is the following statement true or false:
> At some point during my life, my height (in decimeter) was exactly the same as my weight (in kilograms).

Fig. 9.2. Probing question.

This question cannot be answered using equations. It draws on basic calculus concepts, namely the properties of continuous functions, such as the completeness of real numbers and the intermediate value problem.

The answer is "true", if we consider my height and weight as continuous functions of my age; as a newborn, my height (or length) was about 0.5 m, while my weight was 3 kg, while now my height is about 1.9 m and my weight 80 kg. Somewhere along my lifeline, the weight and height curves must have crossed, *if the curves are continuous.* So the discussion with the students of course continued: Do we grow continuously? In the mindset of a biochemist this is not a trivial question – perhaps we grow one molecule at a time?

Evaluation

I found this type of activity stimulating and rewarding. The students became more active, and they began to discuss with their peers as well as with the teacher. Another important bonus is that the students got a feeling for the level of their peers. This is rewarding, because normally many students can get the feeling that everyone else understands - and therefore they will hesitate to expose their own lack of understanding.

This activity requires some way of displaying the question and the possible answers. In the case of the question given above, it was easily written on the blackboard. But in many other cases, an overhead projector or similar is advisable because it can take a long time to write on the blackboard.

Often, this type of activity uses an electronic answering system (like in the television quiz *Who Wants to be a Millionaire*). I did not have such a system. Students raised their hands when they agreed – often I chose to use questions with only two possible answers. Of course, this is not optimal, because some students might not want to expose their (lack of) knowledge, and will respond according to the majority. However, the most important part of this exercise is to initiate active learning and peer discussion – the students' immediate answers are of secondary importance, but can be used in order to probe whether further discussion is necessary to increase understanding.

Because some of the questions were taken directly from the previous year's multiple-choice exam there was an extra motivational factor for the students; there was an extremely close alignment between the TLA and the assessment.

Cooperative learning: Circle the Sage

Background

Because Danish legislation prohibits group-based assessment, an important motivational tool for implementing group-based learning processes has been removed. Prior to the change in legislation, MatIntro had mandatory group-based hand-in exercises. I have tried to come up with ways to re-implement cooperative learning activities in MatIntro.

One very popular teaching strategy at the primary school level is the so-called *cooperative learning* method. Some writers use the term cooperative learning in a very broad sense, which would include the learning activity "group work". In a Danish context this often means that a group of students have been given a common assignment, but they have been given no instructions about how the group should work together. At the other end of the spectrum, the term *cooperative learning* is used to signify a very structured type of TLA, where each individual member of a group has different and very explicit roles. This method has especially been promoted in Danish primary schools by Spencer Kagan, who has written a book and some teaching material with different TLAs (Kagan; 1994).

I decided to try out one of these procedures, and my choice fell upon the exercise called "Circle the sage". This procedure was chosen because it is rather easy to explain to the students and does not require a lot of reorganization of the students (and furniture!) in the classroom.

As the name implies, students who have mastered some specific area are "sages", and the other students can then ask these sages questions.

Basically, the sages are co-teachers in the given exercise. This procedure has several benefits compared with a traditional teacher-centred activity. First and foremost, the number of teachers is multiplied with the number of sages. The sages are socially as well as mentally on the same level as the other students, and they may be able to explain the topic in a down-to-earth manner: They know where the pitfalls are. The sages, who will gain little from a mere repetition of a topic they have already understood, will have the opportunity to sharpen their understanding by being forced to explain it to fellow students. Weaker students can often feel exposed by asking the teacher "trivial" questions, but would probably have less trouble asking a fellow student.

Problems

The students may not actually be explaining the material correctly. Also, the topic chosen should be considered carefully. A topic that is too diffuse topic might lead to uncertain sages and frustrated students.

Evaluation

I have only tried this method once, as I found it difficult to find topics that were sufficiently "closed" for the sages to feel confident.

The process is rather time-consuming, because there will be some people who have to move around in the crowded classroom. It also creates a lot of noise because all the groups are discussing at the same time. I think the students were quite satisfied, however I would like more physical space next time I have to do this exercise. Positive side-effects of this exercise are that the teacher removes him- or herself from the centre of attention and into an observer role. Furthermore, the activity can form an important break from blackboard-centred activities. The topic covered during the "circle the sage" activity was unfortunately not part of this year's multiple-choice exam, so I do not have a more formal way of evaluating the success of this activity. I think this procedure could be evolved further, but I would like to have a way to recruit sages so that it is not always the same group of students that are the experts.

Groups presenting at the blackboard: "Group efficacy"

Background

From previous MatIntro classes, I knew that it can be very difficult to persuade students to present exercises at the blackboard. They want to be sure that they have done the exercise correctly before they expose their knowledge in front of their fellow students. Often, I have observed that only three or four students want to go to the blackboard out of a class of thirty students. I wanted to change this for the benefit of all the students. There is no doubt that presenting results to others sharpens the understanding of the topic. Activating the students, and creating the atmosphere that it is all right to "expose your brain" at the blackboard can be important through the whole course – and further on.

Why will the students not go to the blackboard? Partly because they are not confident in themselves. In order to improve their mathematical learning confidence – or "efficacy/capability beliefs" to use the vocabulary of Bob Evans – I chose to invite the students in groups. My idea is that when a whole group of students is responsible for a presentation, this should increase the efficacy of the individual members of the group. Another reason for students hesitating to go to the blackboard is that there is no oral exam, and thus no impetus from assessment. However, this last aspect was out of my control, other than the general "social assessment" from the fellow students and teacher: We expect all participants to make a contribution to the learning activities.

Execution

In the pre-class preparation time, groups of students were told to prepare different problem-solving exercises, and they were told to present their exercise as a group. Of course, only one or at most two students would actually speak up and write on the blackboard, but the rest of the group was present next to the blackboard – ready to back them up if there were questions that the presenters could not answer.

Evaluation

This idea proved to be quite as expected – the students were happy and enthusiastic, and told me that they were more confident when a whole group was presenting.

However, there is a drawback. Normally, if I have the impression that the students have understood the topic, I would skip the rest of the exercises and carry on to a new topic with other exercises. That flexibility is lost here, because the presentation is delegated to the students, and because there is an implicit promise that all students should present their prepared exercise.

I realize that we used a lot of time for this exercise. Perhaps this method should only be used a few times in each course, as it is really very time demanding. Alternatively I will have to think of another way to shorten the exercise if it appears to be superfluous because the students have understood the topic.

Buzz meetings – Two minutes of peer-to-peer discussion

Background

An easy way to get some variation in the teaching is to let the students discuss a problem in pairs. Discussing a problem peer-to-peer allows the students to verbalize and accentuate their understanding, and provokes the students to move away from a surface-learning approach.

Implementation

This activity was used from time to time during the course on an ad-hoc basis, as problems arose in the exercises, especially when I had the impression that the explanation I provided was inadequate for the students.

Evaluation

As the students became comfortable with the approach, it became faster and easier to switch back and forth from the blackboard-centred teaching. Of the different activities discussed here, this activity was the easiest to implement. One drawback is that it is difficult for the teacher to evaluate the students' gain. A follow-up exercise could be a way to provide formative assessment, however, this is not always easy to find on-the-fly.

I really liked the small breaks that this type of activity gave, as it gave me time to think about the next TLA.

Context

Background

My first post-it note question for the students was given on the first day of the course. The question was: *What would you like to bring with you from the MatIntro course?* All students answered, and the vast majority indicated that they wanted to learn how mathematics can be used in biochemical applications. A minority (around 10%) indicated that they simply wanted to pass the course. The responses are quite as I would expect; most students are very enthusiastic and have high expectations as they begin their studies. Of course, I would like the students to keep this enthusiasm, and one way to do this is to introduce some myself.

In the MatIntro course a few of the hand-in exercises have a chemical or biochemical context. However, to make the exercises manageable for the students, the biochemical content has been simplified and diminished to a degree where the exercise can hardly be said to help the students understand how mathematics can be used in biochemistry.

The biochemistry study plan is of no help for defining topics where mathematics could be relevant for biochemists, as mathematics is hardly mentioned.

To give at least some contextualization, a few times I chose to use ten minutes to present some recent biochemical research that involved a lot of mathematics. One was a presentation of the 2009 Nobel prize winners in chemistry, who elucidated the structure of the ribosome – the molecular machinery for decoding DNA. This type of activity, of course, does not activate the students immediately – but I hope it increased their general motivation for doing mathematics.

Evaluation

Each class has a spokesman who speaks for the class at a meeting with the course organizers. Through this meeting I learned that the students liked this particular contextualization aspect of the classes very much. However, given the very tight schedule of the course, I will have to consider whether the contextualization can be implemented as part of actual exercises. Again, time issues prevented me from using more of this type of activity.

Second part: Midway evaluation, related to the problems of the teaching level or a *backwash* problem?

The student evaluation of MatIntro (after about four weeks course) presented via the spokesmen as mentioned above, indicated that my teaching level was too low, and that I was spending too much time helping math students with weak maths capabilities. Perhaps my "experiments" were also taking more time than some students would find beneficial.

However, my impression is that it is often the best students who raise their voice in these matters, and I had the suspicion that parts of the class were satisfied with the level of the teaching. The students less confident with math are also often less confident when it comes to speaking out with their opinion.

Inspired by the quick survey I had used in the first lectures, I again posed a single question: *How do you find the level of the teaching? Should it be higher, lower or just the same?*

Out of the thirty students in my class, I received twenty-two answers on post-it notes. They showed that eleven students considered the level to be right, one thought it was too high, while ten students would like me to raise the level – many of these answers indicated that I should basically just speed up, which would ensure that we could get through more exercises. Admittedly, there were exercises that I would have liked to do, and we had not had the time. I felt that I would have to find a way to speed up, while still answering the questions posed by the "weaker" students. My choice, which was explicitly stated to the class, was to skip some of the easier exercises, so that we only looked at a few easy exercises, and thereby had more time for the difficult ones. This seemed to satisfy most of the class.

Backwash

I must admit that I used fewer experimental TLAs in the last weeks of the course. After the first multiple-choice test (in week 4 of the course), five to ten students were in a situation where they might not pass the course, unless they achieved a good score in the second test. This is the normal situation. Actually, my class had the highest mean score of the four biochemistry MatIntro classes (about 10% higher than the rest); whether this is significant is an open question, however, it seems to indicate that the new activating TLAs had a good influence on students' performance, even in the multiple-choice test.

Given their bad marks, most students were eager to discuss as many previous exam questions as possible. What I experienced was, I believe, a *backwash* effect; while teachers see the ILO as the central pillar in an aligned teaching system, the students will always see the assessment as what defines the actual curriculum (Biggs & Tang; 2007, p. 169). Since the most important part of the assessment is the multiple-choice test, this was the focus of the students. The didactic contract that I set up during the first day of the course was falling apart as we reached beyond the first multiple-choice test. In the students' eyes, the focus moved entirely towards the second test, especially for the weaker students. It is not trivial to propose new TLAs that can be well aligned with a multiple-choice assessment, and that still encourage a deep-learning approach!

This was probably my greatest challenge during the course – that the students have very different maths capabilities, and that their minds were focused on the multiple-choice test. The large differences in math capabilities seem to be more significant for the biochemistry students than for other groups of students:

In the histograms in figure 9.3, I compare the total number of points that the students achieved in the multiple-choice exam. The number of points ranges from 0 to 20. Evidently, the biochemistry students generally get fewer points than the maths and physics students, and the spread of points is larger. Notice that while the biochem histogram is approximately bell shaped, the maths/physics histogram is skewed towards the high grades.

One interpretation of the biochem histogram could be that there is a group of biochem students that struggle, and they will be satisfied with passing the course, while another group of biochem students will try to get a high grade. In contrast, for the maths/physics students, the majority of students will study to get a high grade.

Another interpretation is that the histograms demonstrate that the present course is better suited to the maths/physics students than to the biochemists. As argued by Biggs and Tang (2007, p. 171f), a bell-shaped curve of grades is not desirable: If the teaching and learning is good, we should have every reason *not* to expect a bell-shaped curve at university level, both because the students are not randomly selected, and because we should be able to make most of the students turn to deep learning instead of surface learning.

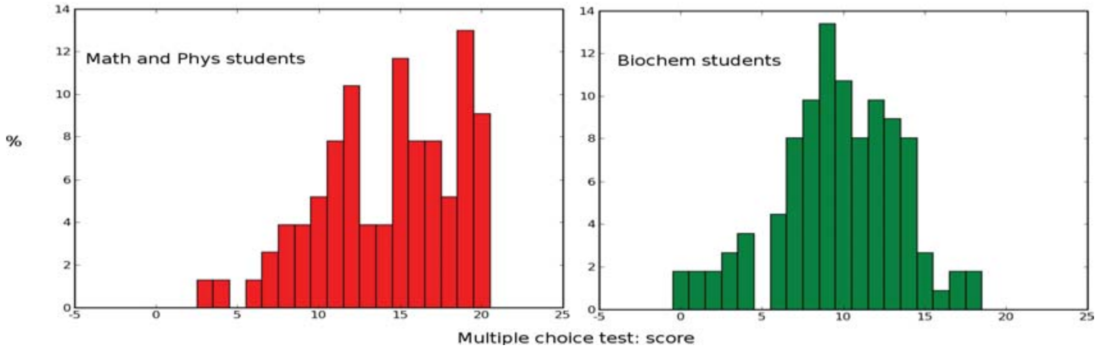

Fig. 9.3. Multiple-choice test: scores

Looking ahead: Re-organizing the problem-solving classes

The evident success of MatIntro in bringing much higher pass rates makes it difficult to argue for a total restructure of the course. If I had the power, I would basically advocate splitting the course into fraction one for the maths/phys students and another for the chem/biochem students. However, a smaller re-organization of the problem-solving classes might solve some of the problems related to very large differences in maths capabilities of the biochemistry students.

The situation reminds me of an approach that was presented during the KNUD course, and used in an undergraduate-level physics course at the University of Copenhagen. In that case the teaching in three parallel exercise classes varied according to the level of preparation that the students had. The students could then choose on a day-to-day basis which class to attend, depending on how well they understood the topic, and how much they had prepared for the exercises:

1. One classroom for the students that had not prepared at all, or could not solve any of the problems.
2. One for the students who had tried to go through the exercises, but could not do it all (or did not have the time).
3. One for the students who had done all the exercises, and would like to discuss the fine details of the exercises, or perhaps look at advanced exercises.

Obviously, such an approach requires that the number of students is sufficiently high to have three parallel classes. With more than 600 students this is not a problem for MatIntro, not even if we consider the biochemistry students only, which totals about 120 students in four classes.

Such differentiation would solve the problems with students getting frustrated because the level is not appropriate for them. When I introduced this idea to my fellow teachers at the MatIntro course, they raised two questions:

1. *Administration:* It will be a nightmare in terms of administration - what if all the students choose to go to the same classroom? What about the hand-in exercises?
2. *Inspiration:* Do the weaker students not need to be inspired by the strong students? If they do not experience how the strong students handle the exercises, how can they improve themselves?

My answer is that implementation of new ideas always require more energy and effort than doing the usual thing – however, in this case I think there are good reasons for trying a new scheme. If the level of the students is different that expected, e.g. that all students arrive well prepared, then the teachers have to adapt e.g. with more classrooms at higher level, and none at low level.

Regarding the inspiration from better students, my experience is that students tend to find study partners that are more or less on level with themselves. Consequently this source of inspiration is probably not much present anyway, unless the classroom TLAs are of the *cooperative learning* type. Furthermore, the students can always move to one of the other classrooms if they want to be inspired at another level – the differentiation is entirely based on the students' own idea about where they think they will learn the most. I will propose this idea as a pilot project for next year's MatIntro course.

Post-course evaluation and conclusion

On the last day of the course, I tried to get some further responses from the students, and I asked them the following question, which was to be answered anonymously on a post-it note:

> *Please give your best suggestion for an improvement in the problem-solving classes.*

Apart from expressing their general satisfaction with the teaching (which I did not ask for), I got the following suggestions for improvements:

1. More student activation/interaction.

2. More emphasis on the necessity to prepare at home before the classes.
3. More exam questions (at least one each class day).
4. More strict use of the blackboard (I apparently have a tendency to mess it up)
5. More cake!

I was surprised by suggestion 1 as my impression was that most students thought there was plenty of activation. At least this suggestion will encourage me to try even more ideas next year. Suggestion 2 is something I have not considered very much – in my standard version of the (unspoken) didactic contract, preparing at home is mandatory. But I will emphasize the need to prepare before class next year, or even design small assignments that will ensure they have prepared. Suggestion 3 was expected: Again, the "backwash" effect. Suggestion 4 was also expected, and the use of the blackboard is something I am constantly struggling with. Suggestion 5 is of course not serious, since I think we had about as much cake as anyone can eat. See below for further comments on the quality and quantity of cake.

My class of students ended with a mean final score very similar to the other biochemistry classes, and quite a bit lower than the scores for the chemistry, physics and maths students.

There are other ways to measure success than the final grading, and I can say that I have personally enjoyed the helpful, hard-working and enthusiastic atmosphere that I believe was partly created as a product of the student-centred TLAs. That the students also enjoyed and contributed tremendously to this atmosphere is also reflected in the number of homemade cakes from students that we enjoyed during the course. I volunteered to bring cake the last day of the course. I hope my teaching abilities are better than my cake was.

All contributions to this volume can be found at:

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

The bibliography can be found at:

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