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# What to do about MatIntroKem?

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## Introduction

The introductory mathematics course offered to freshman students in chemistry and biochemistry has posed an insurmountable obstacle for too many students for more than a decade. The percentage of students failing the course has been on the order of 30% for more than ten years. This, of course, is a problem for each individual student, who wastes time that was better spent learning chemistry, and also for department finances. The number of students failing will never become zero, but ideally it could be cut in half.

The objectives of this paper are to provide an analysis of the course, and to suggest some ideas for change or improvements. It will serve as a white paper for my work with Professor Tinne Kjeldsen to develop the course.

## Course curriculum and structure

The course *Introduction to the Mathematics for the Chemical Sciences (MatIntroKem) NMAB13022U* is mandatory for first year students in chemistry, biochemistry, and nanoscience. Chemistry students and nanoscience students will subsequently take additional mathematics courses.

The course curriculum comprises a range of topics from differential and integral calculus. An estimated 20-25% of the curriculum is a review of high school A-levels.

### Intended learning outcomes (ILOs)

The course description (kurser.ku.dk) breaks up the ILOs of the course into knowledge, competences, and skills. The paragraphs on knowledge and competences are hard to read. The writing is convoluted and does not seem specific. Only the skills paragraph gets to the point. 11 skills are listed. 9 of these are specific mathematical capabilities, such as *make Taylor approximations for functions of one variable*. Also, the students must be able to *argument correctly for application of theory and methods in solution of exercises*. Proficiency with Maple (a mathematical software) is listed as one among 11 skills to acquire.

### Learning activities involving teachers

During a regular week, a student meets four teachers. **A:** The lectures are given by a mathematics professor (4 x 0.75h= 3h). **B:** The classroom teacher is a chemistry or physics graduate student or faculty member (2 x 1.5h). Here connections to chemistry can also be made. This person also grades the homework assignments and multiple choice tests. **C:** A mathematics student is available for questions during an exercise session (1.5 h). **D:** A mathematics student helps with Maple questions (1.25 h).

The weekly bulletin announces what will be the topic of the lectures, and which exercises will be covered as part of activities B and C.

### Assessment

Homework assignments and two multiple choice tests count towards the final grade. The 4 best (out of possibly 6) homework assignments count 50% of the grade. In previous years, each of these has comprised three in-depth exercises, one of which was corrected by the classroom teacher. This year an assignment contains one in-depth exercise and 12 short specific exercises.

Two multiple choice tests each count 25% of the final grade. Each multiple-choice test comprises 12 exercises, which must be done in 75 minutes. These are short specific exercises.

Two conditions must be fulfilled to pass the course. First, the average grade must be 5 (out of 10). Secondly, in the multiple-choice tests, one must score a total of 6 points out of 20 (10+10) possible points. Virtually everyone who fails, fails because of this last condition.

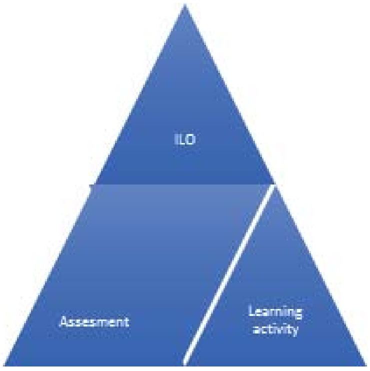


Fig. 1.1: Bigg's constructive alignment model. (Rienecker, Jørgensen, Dolin, and Ingerslev, 2015, Section 2.2)

## Constructive alignment

The constructive alignment model put forward by Bigg's (Rienecker, Jørgensen, Dolin, and Ingerslev, 2015) advocate that optimal student learning requires an alignment of the ILOs, the learning activities, and the assessment.

The ILOs (which we identify with the 11 skills) is largely a listing of the curriculum. The 9 topical skills are covered progressively by learning activities A, B, and C. A general discussion of the application of mathematics in the sciences, *the modeling aspect*, which to some extend is introduced in the lectures, the in-depth homework assignments and some (terrible)textbook exercises are not stated as an ILO.

The intention that the students must be able to *argument correctly for application of theory and methods* ... is not given separate attention.

The use of Maple is taught separately, and used in the in-depth homework problems. In the 2016-2017 edition of the course, Maple is predominantly used for plotting functions in various ways. The use of Maple's algebraic features has been toned down.

The bottom of the triangle connects learning activities with the assessment. The assessment corner is dominated by the multiple-choice tests. They only count 50% of the grade, but this is where people fail the course. Only short specific exercises appear on the tests. Notably, the multiple-choice tests involve no use of Maple and do not test the quality of the mathematical arguments of the students.

The points for the homework assignments are given out more leniently. This is where the in-depth, and modeling aspects appear. The argumentation and Maple aspects are worth some points, but are not in focus.

The left side of the triangle represents excellent alignment between the ILOs and the assessment. The list of specific skills is well tested by the multiple-choice questions. Maple skills are not tested, but the basics is required to score high on the homework assignments. The modeling aspect is not mentioned and leniently tested.

## Discussion

As should be evident from the above analysis the course has some issues with the constructive alignment. Beginning at the top of the triangle, a clear strategy for development of the course should manifest itself in clearly written ILOs. The listing of the curriculum is good, but outcomes a bit higher on the taxonomy scales are needed.

The phrase on *correct argument for application of theory* seems to be a relic from the time when all science students took the same mathematics course. The intent is to infuse the students with *mathematical maturity*, which is a strong prerequisite to absorb more abstract mathematics. This is hardly necessary for chemistry students. They need a much stronger focus on specific computational skills. Thus, this ILO should be eliminated.

The role of Maple or other software is due for reconsideration. Is it worth 9x8x1.25h (= 90h) of mathematics student time to teach the students to plot a graph? What is the level of ambition? Clearly, there is simpler software for producing nice figures. An algebraic software like Maple can do a lot more, but it requires investment of time and effort. It seems a bit odd that the teaching of Maple is handled by a fourth teacher without interaction with the other three.

We have come to a fork in the road, and we must take it. Either Maple is integrated stronger in the course, or it is abandoned. Commitment is time consuming, and the course is relatively packed already. An increased focus on Maple would force us away from the successful multiple-choice tests in their current form.

Part of the curriculum comes as worksheets written in Maple. The students have very mixed feelings about these. I don't see them as the future of mathematics teaching.

The modeling aspect, how to apply mathematics in the sciences, deserves a stronger spot. This should be clearly defined in the ILOs. The current textbook was chosen for this purpose. It has a huge number of examples of science applications. Not all of these are convincing. Especially, a number of the exercises are problematic. Modeling shouldn't interfere with the training of solving the short specific exercises.

Moving to the left tip of the triangle, can we improve the learning activities? My personal experience with the course is as a classroom teacher. The classroom teachers take different approaches to the teaching. No class has performed significantly better than others, and the handling of the classroom seems more of a personal choice.

At the moment, the classroom teaching, B, and the exercise sessions, C, are not correlated in any way. Would it be beneficial with a stronger communication here? Could the class room teacher focus on topics, which have proved difficult during the exercise sessions, C?

Daniel Kahneman (Daniel, 2011) describe the two systems of our brains. System 1 is the quick, automatic system that we rely on make split second decisions. System 2 is the slower system, responsible for conscious analysis and reasoning. Conventional lectures and classroom teaching is easily handled by system 1. No need to disturb system 2. Deep learning, on the other hand, which the students can apply two years from now, require activation of system 2. Teaching system 1 new tricks, which can be applied in a flash, is a task for system 2. In *make it stick* (Brown, Roediger, and McDaniel, 2014) a number of learning techniques that have been demonstrated to work are presented.

One technique for learning a topic is the practice of *recalling* it. It is more efficient to extract the method for solving some integral from memory, and do it, that to be force fed ten integrals in the classroom. The students like copying the answer from the blackboard, but that induced no learning. Can the quiz function of Absalon be used to set up multiple choice questions that can trigger *recalling* in the student brain? This would also constitute some feedback, which is scarce in this course.

Another useful notion is that the recalling a specific technique should not be done many times in a row. It must be mixed up, or *interleaved* with other tasks. A sizable portion of the curriculum review high school mathematics. Basic differentiation reappears when calculating partial derivatives of functions of multiple variables. Simple integrals pop up when solving differential equations by separation of the variables. Can we invoke these recurrences of basic calculus in a more systematic way? As interleaved practice of basic techniques. If this is an option, we can cut part of the early curriculum and expand on the later parts. If the students have bought the premise that they need to solve a given differential equation, they have a stronger impetus to solve the integrals.

The final tip of the triangle is the assessment. The multiple-choice test function well in their current form. Now changes are required. Stronger components of modeling or Maple use will challenge this.

I have stayed away from specific discussions of the curriculum. This may develop over time, but not independently of other courses.

## The Christmas miracle of 2016

December 21st 2016 the students had their first multiple choice test. The exercise set was comparable to previous years. Yet, the students scored 2-3 points (out of 10) higher on average than usual. This improvement is much too large and the number of students too large for this to be a coincidence.

Many students already have the required 6 points (out of 20) and no longer worry about failing the course. The mood in the classroom is different and the percentage of students failing the course will drop significantly.

How did this happen? Two changes have been made to the course this year. A new professor is lecturing and the six homework assignments have been changed. Professor Tinne Kjeldsen has extensive experience from RUC, teaching mathematics to students from other programs. A change of the focus and style of the lectures, may have contributed to a stronger alignment of learning activities and assessment.

The change made to the homework assignments, with a stronger focus on the short specific exercises, has also improved the alignment between of learning activities and assessment tremendously. That the changes made this year, have already impacted the failure rate significantly is very promising for the future development of the course.

## Conclusions

The course has some specific constructive alignment issues. The garage sale of course components have not found their final form. The poorly defined

ILOs are symptomatic of the issues. A way forward is a clear reformulation of the ILOs. Decisions must be made on the modeling aspect and on the fate of Maple.

The Christmas miracle suggests that a tipping point has been reached, where most students will absorb most of the curriculum, and only a small minority will fail. This opens the possibility of adding new contents to the course.

## References

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