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Mixed Lecture-exercise Teaching to increase Student Activation

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Objective

To investigate the potential for higher student activation through a less clear division between lecture and exercise elements in the teaching. Specifically to answer the questions:

- Are the students activated to a higher degree in the mixed-type teaching than in the classical divided lecture-exercise teaching?
- Do the students appreciate this mixed-type teaching and do they feel that they learn more efficiently?
- How much more demanding of the teacher is this type of teaching (if at all) than the classical type?

The project is based on the course *Geofysisk Fluid Dynamik* which was taught single-handedly by the author in Block 2 2011-12.

Introduction

Previous evaluations of the course *Geofysisk Fluid Dynamik* have motivated a restructuring of the lecture-exercise division. I had concluded that I generally wanted more exercise time but have also been occupied with finding ways to get students more activated during the lecture elements of the class. One way of doing this is to include buzz groups and concept questions with clickers in the lectures but perhaps even more drastic measures can be taken. If the division between lectures and exercises is less clear, so that all hours are just called "teaching" and are basically a mixture of lectures and exercises, the students will not have the long periods of one-way communication during which their level of activation can be lowered. Quoting Gibbs (1981): *Where there is scope for the negotiation of student goals, and for the negotiation of meaning, there will be a greater likelihood of students at least trying to learn what you want them to. Lectures offer little such scope.*

During the KNUD program, I was at one point tasked with answering the question "When should the teaching be parted into lectures and exercise classes?". I found that, according to Gibbs (1981), the answer is probably never! At least not with lectures in the traditional form. However, even Mazur (e.g., 1997) seems to have a lecture and exercise structure. The lectures follow the Peer Instruction (PI) model (Mazur 1997) but they are, nevertheless, lectures. In addition to these comes time where focus is on the students' work with problem solving. In fact, he concludes that their problem solving skills improve with the increasing conceptual understanding associated with the PI lectures.

One of the main, but perhaps rather surprising, conclusions from the pre-project work that was done during the KNUD program was that the students love structure – almost above all. They want schedules to be adhered to and they want to know when we are doing what. An implication of this is that teaching an entire course as a series of similar hours that each combine lectures (even in a modern form) and exercises (even in a modern form) may be too messy and unstructured for the students' taste. Especially for courses with an attendance larger than what can be managed by one teacher in terms of walking around helping groups in problem solving may the combined lecture-exercise model become unwieldy.

A structure of divided lectures, in a modern form (e.g., PI (Mazur 1997) or active thinking activity (Schneider 2007)) and exercises, in a modern form (Rump n.d., Alexander & McDougall 2001, Splittorff 2006), could thus appear to have the following advantages:

1. it lives up to the students' demands for structure
2. it breaks the monotony so that a long eight-hour block structure stretch is sub-divided into different components.
3. it lets the teacher and students have time where focus is on the concepts and underlying understanding and time where the details are put

to work. The concept-oriented lectures are thus not polluted with or confused by the typically detail-oriented exercises.

This needs to be tested and the proposed project will take an approach similar to that of Sandelin (2008), with the exception that here lectures will be mixed with pen-and-paper exercises rather than computer labs. The number of students in this year's run of the course was around 25, so the concern of too unwieldy a class-size was not relevant. The above advantages of the divided-type teaching may, in fact, be applicable to a mixed-type teaching as well. The students' demand for structure could be catered for if there is a clear, pre-defined structure of each hour and of the daily or weekly content. The concepts vs. details may also be kept divided by dedicating some of the mixed-type hours to one and some to the other. This will also have the effect of breaking the rhythm.

The report is organized as follows. The next section discusses certain aspects of the course intended learning outcomes to put the chosen teaching-learning activities into the proper context. This is followed by a description of the method used in the project, the results of the questionnaires and a discussion of these along with some of my own reflections. The last section concludes the report.

Intended Learning Outcomes

Before proceeding with a description of the mixed-type teaching, a couple of comments on the course intended learning outcomes (ILOs) are in place to put the tested teaching-learning activities (TLAs) into the proper context.

In my opinion, the students should – after having completed the course – know the background for and the derivation of the different terms in the governing equations for geophysical fluid motion. They should, in my opinion, not memorize all the details but they should know where the terms come from, describe which physical processes are behind them and discuss the assumptions that were made in their derivation. When an equation exists in several forms depending on different assumptions, the student should be able to describe these differences and choose the right form for a particular application.

The course ILOs, as they are given in SIS (Appendix B, in Danish), reflect this ideal to some extent. There are, however, some points where they could have been more optimal or to the point. A couple of examples are:

"*Write up and describe the momentum equations for the atmosphere and ocean given on a rotating Earth*". In line with the above, I do agree that the students should be able to describe were the terms come from. I do not believe, however, that the students should be able to recall all the details and this is certainly not something we assess at the exam, which is open-book written. Having assessment tasks (ATs) aimed at testing this would simply invite to copying from the textbook. In a broader interpretation of this ILO, where the intent is to have abilities in deriving new results, we do currently test it as exam questions routinely have elements of independent derivations.

"*Understand the concepts circulation, vorticity and potential vorticity and solve simple exercises involving these quantities.*" I agree that these concepts should be *understood* although this word is somewhat vague. With regard to the part about solving simple exercises I am a bit in doubt: At first glance, it seems wrong to have as an ILO to be able to solve simple exercises, but as the course is presently, it is quite well-aligned with the TLAs and ATs. It is to large extent what we do in class and at the exam and they are akin to the typical situation of "a point mass on an infinite and friction-free table" often used in classical mechanics. The argument for this is that these simple exercises are good for illustrating concepts and assessing the student's understanding thereof. The simple exercises should thus perhaps not be an ILO in itself but enter as a tool both in the TLAs and ATs.

In light of these considerations, constructive alignment of the TLAs with the ILOs and ATs requires that the students themselves work with both the derivations of the central results as well as with simple (and sometimes not-so-simple) applications thereof.

Method

The alternative to the classical division between lectures and exercises, that I tested in this project is a mixed type teaching (MTT) where short (15-20 min) runs of theory introduction are interleaved with only slightly longer (20-30 min) exercises pertaining to this and previous theory. In some instances the student-active exercise stretches consist of the students performing some of the derivations that I would otherwise have done on the blackboard during the lecture. The above time allotments are to be thought of as being quite flexible. Sometimes longer exercise stretches are necessary.

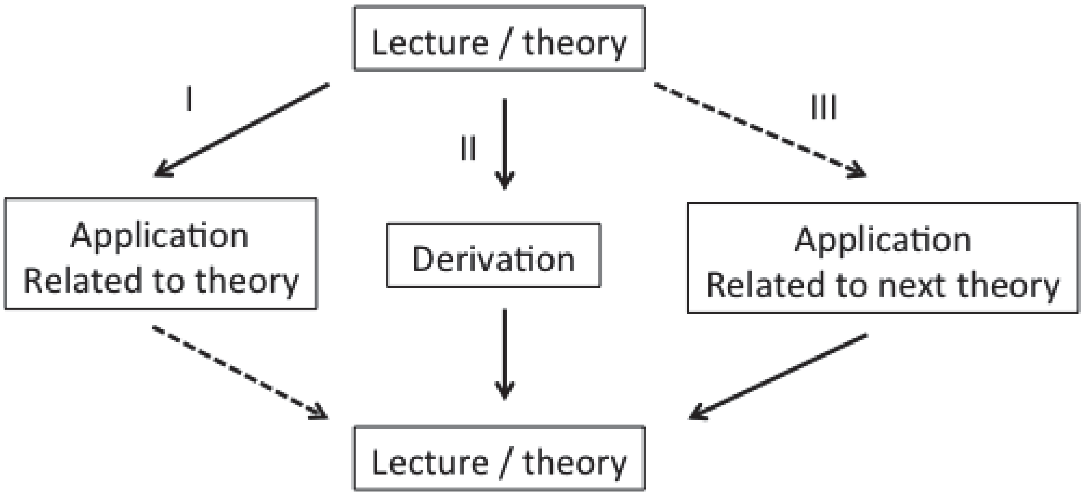

Fig. 11.1. Schematic of an MTT cycle showing how a lecture or theory stretch is followed by either I) an application related directly to the material just covered, II) an intermediate student derivation session or III) an application or exercise used to motivate or lead up to the next theory stretch. The solid arrows signify transitions between student inactive and student active sessions that are directly linked while the dashed arrows signify transitions that are less directly linked.

Figure 11.1 illustrates how an MTT cycle can take several forms. Simply put, student inactive theory or lecture stretches are followed by student active sessions of exercises/applications or derivations. The latter are illustrated by the middle route (II) and link the theory stretches together directly because they all work toward the same final result. The exercises or applications may be somewhat digressive in the context of teaching theory but they do serve to either illustrate or motivate it. The two outer paths show this: either the application pertains to the theory just covered (I) or it is used to motivate or lead up to what is coming next (III). All three of these MTT cycles are tested in the teaching.

To secure a proper flow of the MTT cycles, the student active derivation steps and exercise stretches should have relevance to the topic of the hour. While this is fulfilled per default in the derivation steps (route II), it may be a bit more challenging in the other two forms and requires careful planning. Moreover, repetition of previously taught material is more difficult to fit into the MTT exercise stretches as it may remove focus or confuse the conceptual picture the teacher is trying to convey. It should thus be included where possible as tools used in the problems pertaining to the current topic. An alternative is to have a softer structure, where an hour or two during the week is devoted to pure exercises where repetitions would fit in more obviously. While not practiced in this project, this could be done in the long eight-hour day, where the afternoon could have longer exercise stretches to make it a little less intense.

The second week of the course Geophysical Fluid Dynamics 2011-12 took the MTT form. This constitutes the experimentation part of the project. Important in the assessment of the effectiveness of the format is a week of (hopefully) well-executed teaching in the classical divided lecture and exercises format. The entire experiment thus fell in the following two steps:

Step 1: Teach one week in the classical format – with the adjustments to the lecture vs. exercise load that I would have made anyway. This week ends with a questionnaire on the perceived efficiency and student activation of the format.

Step 2: Teach one week in the MTT format. Ends with another questionnaire that compares the two formats, probes for the proposed strengths and weaknesses of the MTT and asks for comments.

In the evaluation it is also necessary that I assess the (added) workload for the teacher.

Results and discussion

Results of the pre-questionnaire

After the first week of teaching, I gave the following questionnaire to the class via the online Absalon system. Four questions were asked and to each the student could declare him/herself to “agree fully”, “agree”, “neither”, “disagree” or “disagree fully”. 15 students answered the questionnaire and the results are given below. The numbers have been rounded off so the total is not always 100%.

1. I feel activated in class when the teaching is divided into lectures and exercises.

Agree fully	Agree	Neither	Disagree	Dis. fully
47%	40%	13%	0%	0%

2. I stay attentive throughout lectures.

40%	47%	7%	7%	0%

3. I stay attentive throughout exercises.

40%	53%	7%	0%	0%

4. I would prefer a structure where lectures and exercises are combined over one where they are clearly divided.

47%	20%	27%	7%	0%

The conclusion from these four questions which were meant to serve as a basis for comparison with the results after the MTT experiment in week 2 is that the students seem quite unambiguously to feel activated in the classical format and to stay attentive throughout both lectures and exercises. Nevertheless, there is also a clear preference for the MTT format – even before they have tried it (or, at least, my version of it). The reason for this is unclear; one might have expected question 4 to be negative if the others were positive or vice versa. It has to be said though, that this class is especially motivated. They really are very alert and attentive and when given a task or a question they start right away and do exactly as asked. With this kind of group, the classical format may appear to be working for them but they may still feel that something else could work even better.

Results of the post-questionnaire

After the MTT experiment of week 2, the following questionnaire was given and 12 students completed it. Note that 8% corresponds to one student. Question 9 asks for comments and the five comments given are repeated in full in Appendix A.

1. I was more attentive when we did exercises than in normal exercise hours.

Agree fully	Agree	Neither	Disagree	Dis. fully
33%	50%	8%	0%	8%

2. I was more attentive during lecture stretches than in normal lecture hours.

17%	42%	33%	0%	8%

These first two questions compare the level of attentiveness experienced by the students in the MTT relative to the classical format. For both lecture and exercise stretches, more than half “agree fully” or “agree” to being more attentive in the MTT. This positive result is most pronounced for the exercise stretches and this surprises me somewhat: one of the main reasons why I expected the MTT to be efficient is that it limits the lecture stretches to about 15-20 minutes which is the maximum that attention can be held during lectures (Biggs & Tang 2007, p. 110). Exercise hours are student-active also in the classical format and I would thus have expected the major increase in attentiveness to have been in the lecture stretches. It seems that the direct relevance to theory of the student-active sessions increases the level of attentiveness and this is an unexpected bonus for me.

3. I experience the teaching to be more unstructured in the MTT than otherwise.

8%	17%	50%	8%	17%

One of the major concerns with the MTT is that the structure so adored by the students is sacrificed in a format where the student is continuously tossed between active and inactive. The response to this question indicates, however, that even if this is the case, it is not experienced as being more pronounced than in the classical format. We did adhere to the 45 minute classes, breaks were respected and it was clearly communicated where we were in the MTT cycle, i.e., student active or inactive. This appears to have given adequate structure to the teaching.

4. It is an advantage of the MTT that new material is brought to application in exercises right away.

67%	25%	0%	0%	8%

All but one of the respondents “agree fully” or “agree” to it being advantageous that new material is brought to application right away. This is as expected and the major surprise is actually that one disagrees fully. One of the respondents who gave comments did not find the MTT to promote deep learning and he/she has some very well-articulated reasons for this. One may speculate that the one respondent who disagrees fully here is this same student and I will refer to my thoughts on his/her comments.

5. The MTT gives too long stretches without breaks or variations.

0%	0%	42%	42%	17%

The long series of MTT cycles, for instance, eight hours of it on Thursday, was another of my major concerns with the MTT. With all classes being the same mixed format, the long day may become an unending succession of monotony. None of the respondents agreed (or agreed fully) to the MTT giving too long stretches without breaks or variations so either my concern was irrelevant or the question was understood differently than I had intended. In either case, lack of variation seems not to be something to be concerned about based on these responses.

6. I feel more activated in the MTT than otherwise.

17%	58%	17%	0%	8%

Three out of four students “agree fully” or “agree” to feeling more activated in the MTT than otherwise. Along with a similar result in question 8 this is what I take as the major indicator of the MTT experiment being successful. Having employed a format that activates that many students more (or, at least, lets them feel more activated) was exactly what I was hoping for.

7. Broad concepts are more often buried in details in the MTT than otherwise.

8%	8%	50%	33%	0%

This question relates to the third concern with the MTT discussed in the introduction, namely the risk that concepts are lost because the theory is so quickly applied. Applications tend to involve a lot of mathematical calculations and algebraic manipulations not directly related to the theory and could therefore pollute the clear-cut conceptual message. More than 80% either disagrees that this is the case or says “Neither”. This indicates that this concern is not a massive problem for the format. It is, nevertheless, something I think one should stay aware of.

8. I experience the MTT to be a more efficient way of learning than the classical way.

17%	58%	17%	0%	8%

This is the major success parameter: More than three out of four find the MTT a more efficient way of learning. Whether they actually did learn more efficiently or they just experienced that they did so is not measured here, but given the comments discussed next it really does seem that this format may mobilize a higher level of attention and clarity.

9. Please give extra comments and thoughts on the MTT vs. the classical format.

See Appendix A for the individual comments (five answers).

One thing that three out of the five comments agree on (students 1, 4 and 5) is that doing some of the intermediate derivations (route II in Figure 1) works well. They say that it gives a deeper understanding of the applied equations and it forces you to think over the math and not just nod and think that you understand. Student 5 feels safely guided through the material and has a sense of getting more of it.

Another student (number 2) notes that the MTT keeps him/her focused such that one does not doze off as is not uncommon after lunch in a classical lecture.

Student 3 does not find the MTT to promote deep learning and argues very well for his/her case. In a nutshell, the major problem with the MTT is that the student-active sessions are too short to allow the student to properly delve into the problem and the physics. The time allotted should be spent going the direct way pointed out by the teacher without detours or else there is too great a risk of not finishing. For this student, and for many others, I would suspect, there is a lot of learning in starting a problem, getting stuck, starting over in a different way and getting through with a few hints here and there. The MTT does not as easily cater for this type of process because of the rather quick turnover necessary for the next cycle to start. He/she also points out that preparing the exercises beforehand is almost stupid in the MTT.

My own reflections

The route II (Fig 11.1) type of exercise element, where derivation of sub-steps in the lectures were made by the students, worked particularly well. I feel that having worked with the details of the derivations, the students were more alert and more clear on all the definitions in the subsequent discussion of how this fits into the bigger picture. The institutionalization step thus becomes more relevant for the individual student because he/she has a larger degree of ownership over the results that are institutionalized.

The timeliness of the student-centered work is of the essence here and is perhaps less pronounced for exercises that subsequently show applications of the theory (route I). Of course, the student also here sees the practical consequences of the theory but this might work equally well in a subsequent dedicated exercise session (classical format).

In fact, I found that the many route I applications that I did employ were not nearly as interesting as the two other routes, despite the fact that an overwhelming majority of the respondents found the direct application to be an advantage of the MTT. An example of a particularly efficient use of route III, where an application is used to motivate the next theory, is the consideration of the Coriolis force on two metal balls rolling toward each other:

The exercise was an application of a result we had derived earlier of the magnitude of the Coriolis force on an object moving in a rotating coordinate frame (as the Earth) and the task was to determine the velocity the balls must have in order to just avoid hitting each other. This went fine and seemed like a straightforward (and very idealized) application of previously derived results. After we had discussed this exercise, I asked the class in a Concept Question manner whether the balls would hit each other or miss each other if they were started with larger initial velocity. The trick here is that with a larger velocity there is a larger Coriolis force so one might think that they miss each other, but since they travel faster the force has shorter time to act and the result is actually that they are deflected less and hit each other. The class' initial response was about 50-50 between the two options but in the ensuing buzz, many looked closer at the calculations in the exercise and realized the travel-time trick. The result was an almost unanimous count on the correct result in the second round of questioning. The institutionalization of this result circles about the fact that the Coriolis force is more important for slow, large-scale motions than for fast, small-scale motions. This led naturally to the introduction of the so-called Rossby number, a non-dimensional number fundamental to meteorology which measures the importance of the Coriolis force in terms of the characteristic velocity- and length-scales of the motion.

With only one week of the MTT and placed early in the course, I did not feel a large need to have exercises that took up material from earlier in the course. All exercise/derivation steps thus pertained to the theory just covered or about to be covered. Later on in the course, there is a need to tie things together with and to recapitulate earlier theory. This is easily done by having the students do old exam problems since these are often of a more general and overarching character. Including such problems in the MTT may have the downside of taking focus away from the particular theory being taught this week. A solution may be to have longer general exercise sessions (say 2 hours) combined with the MTT. This may also help to alleviate the problems pointed out by student 3, because it gives exactly the time for individual pondering that he/she called for.

In fact, one should perhaps consider taking the consequence of the popular route II and focus mainly on this type of student-active session in the MTT stretches and then have the applications mainly in devoted exercise hours. Unless, of course, there are particularly timely and relevant route I or III applications such as in the above example.

Two issues concerning the practical execution of the MTT were discussed with my department and pedagogical supervisors: i) When have sufficiently many come sufficiently far in the problems for us to proceed? and ii) How do I proceed? Do I do the entire problem/derivation on the board or do I just sketch it? Do I get students to do it?

With regard to issue i), my experience is that we cannot wait for all to finish everything, otherwise a large part of the class will have to sit and wait for the slowest. The teacher needs to find a point where enough have come through or close to before proceeding. I have monitored the progress of the students and found that when the general noise in the class begins to change character from being focused on the problem to being focused on other things, it is time to move on. This is, of course, a sliding scale, but I feel that I have been reasonably successful at finding the point. To improve my intuition on when the point has been reached, the supervisors suggested that I start making a mental note to myself of why I tend to stop at the times I do. This will help to make it more deliberate than just a gut feeling. It does come from a gut feeling in the first place, however, so the point is to try to make the criteria that tend to produce that gut feeling more clear.

With regard to issue ii), the risk of having a student do the exercise is that it takes longer (and we have already spent time on the derivation having them sit and work with it) and they might do it in a less clear or well-organized way such that a possible institutionalization may be partially lost. This leads to the more fundamental question of why I want them to go to the blackboard, and this is perhaps not of paramount importance since they do get a chance to work with it. Either having come all the way through or getting stuck halfway is enough, in my opinion, that seeing the teacher do the problem or derivation will be much more relevant to them. Having said that, if time permits, I would still prefer to have a student come up and do it. Their presentation may not be so well-polished as what the teacher would do, but it would be presented in more student-like-terms. This will then give the teacher a chance to gauge what level of understanding this particular student has and to show the entire class, how the same basic solution could/should be presented in the "proper academic terms". An oral presentation is not formally part of the course ILOs but they do include something about "writing up and discussing/describing the basic equations". That aside, I may have a hidden ILO that has to do with educating them in the use of academic language, argumentation and reasoning. Fulfillment of this, I think, comes about through setting an example during lectures, exercises and one-on-one discussions, but also through helpfully and cheerfully helping to hone the arguments of a student at the blackboard. This helps the entire class, since the rest might (hopefully) be thinking "Hey, I would have said it the same way as the student, but Peter's way does sound clearer".

The MTT did take longer to prepare because relevant problems had to be found for every 20 minutes of lecturing. It also took time to find the proper level for the student derivations and to estimate the time needed for each of these. The comparison is probably not completely fair: For the classical divided teaching, I could re-use my lecture notes and exercises from previous years and when they were planned, time went into choosing the right exercises and the level of difficulty for them. Starting from scratch in both formats, my guess is that one is not significantly more demanding than the other. In fact, a format where MTT sessions focus mainly on route II augmented by longer exercise sessions, will definitely not take much more preparation.

Conclusions

Two weeks of teaching were compared. In the first, a classical approach was taken where there was a clear division between lecture classes and exercise classes. In the second, a mixed approach was taken where short (about 20 minutes) lecture stretches were interleaved with similarly short exercise stretches. The latter could either be application of the theory just introduced (route I), derivation of intermediate results of the lectures (route II) or applications meant to motivate the theory to be covered next (route III).

The mixed type teaching (MTT) was very popular with the student respondents. In particular, they found the direct application of theory to be an advantage of the MTT and they felt more attentive in both lecture and exercise stretches (especially the latter). Three potential problems with the MTT, with less structure, long stretches without variations and concepts being buried in details, did not seem to be cause for concern. In general, the students felt more activated and found the MTT a more efficient way of learning.

Something that I myself found particularly successful – and which was also pointed out in the comments of several respondents – was the route II derivations of intermediate results in the lectures. In short, if the lecture goes from A to B to C to D, the students are simply tasked with deriving the B-to-C-step. This seems to give much more value to the institutionalization step in C-to-D. In fact, in light of the discussion of the course ILOs, inclusion of such derivation steps offers an easier and more straightforward alignment of the TLAs to the ILOs. Carrying the alignment over to the ATs is another matter and beyond the scope of this project.

Focusing mainly on this type of student activity in the MTT and having separate dedicated exercise hours may also answer a couple of concerns encountered along the way. It gives the students ample time (during the exercise hours) to struggle sufficiently long with the problems without the time pressure of having to finish before the teacher continues with new theory (a concern raised in a student comment). Moreover, it provides time for more general exercises (perhaps old exam questions) that take up the broader picture and older theory without taking focus away from the theory of the current MTT session.

The nutshell-conclusion is thus that the MTT was very popular with the students and both they and I experienced it as a more efficient way of organizing the TLAs. It was also found, however, that augmenting the MTT classes with dedicated exercise hours may give the optimal combination.

A Comments from post-questionnaire (in Danish)

Student 1

Det er godt, at vi bliver sat til at lave nogle af udledningerne, så man selv lærer at tænke på matematikken og ikke bare forstår og nikker. Hands on, super godt.

Student 2

Jeg synes i høj grad at jeg vedbliver at være fokuseret i det blandede format. Man sidder ikke og døser hen som man måske kan have tilbøjelighed til at gøre under to timers forelæsning i træk (eksempelvis efter frokost).

Øvrigt kan det bemærkes at der på det blandede format måske skal være "ekstra"-opgaver til de, der bliver "hurtigt" færdige, så de ikke bare sidder og laver ingenting.

Student 3

Jeg føler ikke at det virker for mig at skulle omstille hovedet mellem at modtage info og regne opgaver hele tiden. Det er selvfølgelig en smagssag. Men jeg følte mig en anelse irriteret over at forelæsningen hele tiden afbrydes, man mister hurtigt kontekst.

En af de større ulemper er at det på det nærmeste er dumt at forberede regneopgaverne hjemmefra.

Regner man hjemmefra vil man i de tidsrum hvor opgaven regnes (forudsat man har kunne lave den) blot sidde og vente på at de andre bliver færdige, fordi det ikke kan nås at finde en ekstraopgave man kunne have lyst til at lave, som det ellers kunne have gjort hvis undervisningen var skarpt opdelt.

Jeg har i løbet af ugen også opdaget at de opgaver jeg ikke har kunne regne har jeg ikke fået lært ordentligt i undervisningen. Hvis jeg er gået i stå i en opgave, lærer jeg mere ved at få små hints til at komme videre for så (stort set) selv at klare opgaven. Det syntes jeg fungerer bedre end at få hele opgaven gennemgået på tavlen på kort tid. Men denne metode fungerer ikke i den korte tid vi regner opgaver i. Hvis man går i stå har man ikke meget tid til at sidde og overveje det problem man arbejder med. Det bliver på den måde (desværre) hurtigt et spørgsmål om at få regnet opgaven for at være klar til den videre undervisning, frem for at forstå fysikken i problemet.

På den måde får man nemlig ikke "tingene i hånden" på samme måde og kommer dermed ikke ligeså grundigt rundt om tingene.

For at opsummere kort, syntes jeg det største problem er at der simpelthen ikke er tid nok i de små "regneperioder" til at sætte sig ordentligt ind i problemet og forstå fysikken og det desværre, i stedet, kun bliver et spørgsmål om at nå at regne opgaven.

Student 4

Det er rart selv at få udledt de ting som man ellers bare tager for givet når de står i bogen

Student 5

Jeg synes, det giver god dybdegående forståelse af de anvendte ligninger, når vi selv sættes til at udlede dem.

Desuden føler jeg at det er trygt at blive guidet gennem stoffet på den måde og jeg har følelsen af, at få mere med. Når vi er så lille et hold føler jeg ikke, der er den store forskel, men jeg kunne forestille mig, at det ville være kanon til at aktivere studerende på større hold, hvor det ellers er let at "gemme sig".

B Course ILOs (in Danish)

1. Opskrive og beskrive bevægelsesligningerne for atmosfæren og oceanet givet på en roterende Jord.
2. Operere fortroligt med differentialoperatorerne gradient, divergens og rotation på todimesionelle vektorfelter og skalarfelter.
3. Beskrive de grundlæggende antagelser bag de primitive ligninger, shallow water ligningssystemet og det Boussinesq'e ligningssystem.
4. Opstille ligningerne bag og forklare geostrofisk balance, cyklostrofisk balance, inerti-bevægelse og gradientvindbalance.
5. Opstille ligninerne i forskellige vertikale koordinatrepræsentationer.
6. Beregne geostrofisk vind / strøm og gradientvind ud fra trykfeltet samt vurdere under hvilke antagelser, disse er gode approksimationer til vinden / strømmen.
7. Forklare "Ekman spiralen" og analysere betydningen af Ekman pumpning i forbindelse med cyklonale og anticyklonale strømninger i atmosfæren og oceanet samt anvende begreberne i simple opgaver.
8. Forstå begreberne cirkulation, vorticity og potentiel vorticity samt regne simple opgaver hvori størrelserne indgår.

All contributions to this volume can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/2011-4/

The bibliography can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/kapitler/2011_vol4_nr1-2_bibliography.pdf/