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Improving Constructive Alignment and Deep Learning: Integrating Multiple Learning Activities

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Problem Definition

How can I change the format of a traditionally lecture-based and problem-solving Astronomy Bachelor course to create an inspiring deep-learning environment that both satisfies the intended learning outcomes (ILOs), provides student engaging teaching/learning activities (TLAs), and contributes to a constructive alignment between TLAs and course evaluations (exams, project reports, etc) and between this course and the Bachelor education in physics with specialization in astronomy?

I made several changes to this course in 2010 with the purpose of improving student active participation and their deeper learning. What are these changes and how did they work in the classroom? Were the intended learning outcomes fulfilled? How did the students react to these activities and were they satisfied with the course format and their learning? This project will address these issues as well as further improvements to be applied for increased constructive alignment and student learning in future executions of this course.

Introduction and Brief Background

The bachelor level astronomy course *Galaxies* is offered in block 1 of year two following a more theoretical course on Cosmology in year 1. The course is mandatory for students specializing in astrophysics. In the new course structure the students learn about the largest structures (cosmology, evolution of universe) first and progressively move to smaller structures (galaxies, our Milky Way, and stars) as they advance in their studies. The idea was to capture the students' interest and fascination for the subject instead of starting with the 'boring' tools of basic astronomy. The course is taught by two instructors: one teaches the curriculum on the Milky Way and its chemical evolution during the first tree weeks ($\sim$30% load) and the other covers the remaining lectures and is responsible for the four hour computer sessions each week ($\sim$70% load). The course has traditionally been divided into standard lectures followed by problem-solving sessions. The computer sessions include a larger project on astronomical data processing and analysis. The approved computer report and a written assignment of four solved problems constitute the student's exam eligibility. These requirements were instituted partially to force student retention. As the course responsible I had the opportunity to shape the course to a certain degree when I took over this course in 2010.

Challenges in Teaching This Course

This course is the only mandatory course on the topic of Galaxies for the Master's degree. The only other course on this broad topic is an elective course on chemical evolution in galaxies at the Master's level. Consequently, *Galaxies* should provide all the compentences that a Bachelor in Physics with specialty in Astronomy need on the topic of galaxies and mass structures in the universe in order to do research projects at the Master's level.

Students taking *Galaxies* have not had courses on atomic physics, quantum mechanics, optics, or stellar physics. In fact, atomic physics is no longer a mandatory course, adding to the complexity. Thus, the students' background alone does not allow for much more than a surface level understanding of the material when picking up a textbook or monograph on 'Galaxies'. How can the students understand galaxies without knowing what stars are, their observed properties, their life cycles and the importance of these cycles for the galaxies? How can they understand interaction between light and matter, so crucial for astronomy, without the proper background? An improved constructive alignment of the course with respect to the Bachelor education will help but will not solve all issues. With the limited background of the students, the curriculum for this class greatly increases since it must include these additional background topics to allow deeper learning of the course topic itself.

There is no suitable textbook on the marked aimed at starting bachelor students that also addresses the course goals. The assigned textbook, “Galaxies in the Universe”, (Sparke & Gallagher III 2007)Sparke & Gallagher 2007) is aimed at upper level (third to fourth year) bachelor students with the necessary background in physics and astronomy detailed above. Finally, the block teaching structure dictates very long class sessions of three to four hours at a time. These are the challenges of this course.

What Should the Students learn?

The course objective and learning goals are published[1] and aim at both declarative and functional knowledge (e.g. Biggs & Tang 2007, Ch. 5)). The course Intended Learning Outcomes (ILOs; e.g. (Biggs & Tang 2007, p. 79)) mostly cover the three bottom levels of the SOLO taxonomy (uninstructural, multistructural, and relational). For example, at the ’uninstructural’ level the students can identify a galaxy type by the imaging and spectropic data. At the ’multistructural’ level they can describe the properties, structure, and internal dynamics of galaxies and larger mass structures, and at the ’relational’ level they can explain the observed properties of the mass structures at small and larger scales, plus relate issues across the curriculum. Specifically, how the properties of the galaxies are affected by the properties and lifetimes of stars is important to understand at a level where the student can account for the consequences of varying the individual property or the composition of the materials making up the galaxy. However, the students do start to reflect and analyze at the top SOLO level (extended abstract level), in particular in the computer projects implemented in 2010.

In addition, the students should obtain operational skills (’functional knowledge’; (Biggs & Tang 2007, Ch. 5)) in use of the IDL software to access, display, and manipulate data, and to make the necessary (relatively simple) computations required for this course. The students need these skills in their later course work and for research projects. Further skills, not mentioned, that I see important include the students’ ability to critically explain the content of gas phase (and temperatures) and stellar populations.

[1] For 2010: http://sis.ku.dk/kurser/viskursus.aspx?knr=120360&sprog=1&inframe=0.

Also, they should be able to reasonably well identify a stellar type from its spectrum[2]. In my opinion, this course should also enable the students to relate to new research by giving them a background to understand the issues on galaxies and their evolution, the astrophysical reasons for them, and to enable them to critically assess basic parts thereof, including the methods for obtaining the necessary observations. The students should be able to follow and understand half, if not most, of scientific talks on the topic and to read and discuss short letter style articles on this and bordering topics. They should have an overview of the main hot research topics within this field and their scientific justification.

Evaluation of Previous Incarnations of this Course

In my preparation for this class I looked into the existing scope and curriculum, talked to previous instructors, and read the student evaluations. In summary I learnt two things. First, somehow the introduction to the IDL software early in the Bachelor study failed. A third year astronomy course instructor reported that even at this late stage many students were unable to work with the IDL software.

Second, *Galaxies* included a large computer project on how to process and analyze astronomical imaging data. Three sessions of three hours were allocated. However, two different past instructors reported that some students needed significant help to pass this part and that it was difficult for many. The course evaluations clearly conveyed the frustration of the students with this activity that seemed disconnected from the rest of the course. Since the learning outcome was rather limited, I concluded that this TLA was unsuccessful. In my own experience it takes at least one to two months of intense training to learn how to process data well[3]. In my humble opinion it is too early to introduce data processing at the start of the 2nd astronomy course when the students have limited overview of what astronomy is or whether it is something they want to seriously pursue. My suspicions were soon confirmed when I started teaching: Most students were novices on programming. Indeed, considerable changes were needed.

[2] An approximative ID is sufficient since some stars have almost similar spectra.

[3] During my studies we had a dedicated course at the Master's level; I also taught this course as a PhD student so I know this is not a simple exercise.

Changes to Course Format in 2010: Student Activities

When I took over as the teaching responsible for *Galaxies* I decided to make some changes of both structural and didactical nature[4], partly motivated by the evaluation just described. I also took the opportunity to change the format of the part of the course for which I was to teach to be more aligned with my own teaching philosophy. I describe these changes and their justification next.

Main Changes Implemented in 2010: Computer Sessions

Extended IDL Introduction

At course start a new and more extended introduction to Unix and IDL was given. The aim was to allow the students to become more confident with computer programming before they were given a larger project. To practise using IDL for computations and writing of small programs the students were asked to make simple calculations that simultaneously gave them a sense of dimensions of our solar system and our galaxy, what the resolution of known telescopes scales to, and they were to graphically display known relations between stellar properties with the aim of giving them a better understanding of these properties. The students were to submit the computer code and a simple listing of the results of their calculations; no formal report was required.

New Computer Project I

The computer project on data processing was substituted with a new project where the students are to add up stellar spectra so to reproduce the spectra of two galaxies of unknown identity, investigate the uniqueness of their model, the distribution of stellar types, stellar ages, and discover the age-metallicity degeneracy. The student are to use their knowledge on stars and galaxies to identify the galaxy types in various phases of the project. The

[4] Changes were made to within the a priori set framework: the general scope of the learning goals, curriculum, and the textbook were already locked in when I took over the class. Major changes need to be approved significantly in advance by the University Board of Studies. I was able to make minor changes to the course description before course start and thereby provide better alignment with the curriculum and the new computer projects.

students need to use what they know about stars and galaxies and get the opportunity to revise their conclusions as new information becomes available. An important part of this project is that the students *must* work in groups, *must* discuss the strategy with their group, and *must* use their astrophysics to *argue* and *justify* their choices, actions, and conclusions. They are to submit a genuine report with supporting figures, captions, and conclusions. Approval of the report constitutes exam eligibility.

New Minor Computer Project II

I generated a new small computer project on identification of emission lines in a quasar spectrum, determination of the quasar redshift, and the mass of the central black hole. This activity is short enough to finish in class in a couple of hours but let the students work with actual quasar spectra and understand its contents.

The Didactical Reasons for the Changes

The main goal was deeper learning of both the IDL software and the nature of stars and galaxies. The students need a shallower learning curve compared to earlier years to become comfortable with software programming and to build confidence and functional knowledge. Problem-based learning (PBL) (or learning by doing) is the didactical method employed here (e.g., (Biggs & Tang 2007, Ch. 3.6)) in the form categorized as 'PBL for epistemological competence' (Savin-Baden 2000) which means that the students obtain competence in problem-solving contexts building mostly on a declarative knowledge-base[5]. The computer project (I) on modeling galaxy spectra moreover trains the students' skills in collaboration, organizing a project, data analysis, and scientific justification. The nature of the project forces the students to gain deeper understanding of the characteristics of stars and galaxies and their spectral data.

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[5] Other PBL categories (or 'models' as defined by Savin-Baden (2000)) are relevant for interdisciplinary, transdisciplinary, and professional fields such as the health-care fields. While scientific topics such as the expansion of the Universe and Dark Energy are indeed interdisciplinary, this particular computer project mostly employs one discipline.

Example of brain-storm session: *I pose the issue to the class: "Spend 2 minutes considering that we may like to know about galaxies - what types of scientific questions do we possibly want to pose? Then we'll do a brain-storm of your suggestions." With my back to the students (giving them anonymity) I write their suggestions uncensored. At the end we discuss each item, consolidate or elaborate as is fit. For example, on the suggestion "How much gas is in the galaxy?" follow-up questions from me would be: "Why would we want to know that? What would this tell us?", "What type of gas are you interested in? Does it matter?", and "Does the gas phase matter? Why? What can we learn from each phase? How?". The students in concert help answer these questions.*

Fig. 12.1. Example of brain-storm session.

Main Changes in 2010: Lectures/Problem-Solving Sessions

First I abandoned the specific problem-solving sessions because the students obtain a deeper broader learning by confronting and using what they know (Mazur 1997, Biggs & Tang 2007) and because the exam does not test their problem-solving skills. Then I changed the traditional lecture format to include a suite of different activities, partly to test their effectiveness at motivating student engagement and partly to vary the activities in class. These activities can grossly be categorized as brain-storming sessions, group-work and presentations, short computational problems followed by discussion, or flash-card activity. The main didactical reasonings behind these activities were to keep the students constantly actively processing the material during our three or four hour sessions; passive students do not learn much. This is the essence of 'constructivism' (founded by Piaget 1950) that states that the students construct knowledge via their own activities. What matters is what the students do, not what the teacher does (Piaget 1950, Steffe & Gale 1995).

Learning Climate

The class room atmosphere is crucial for motivating the students to actively participate in the TLA (e.g., (Biggs & Tang 2007, Ch. 3)). Creating a climate where the student is comfortable asking and answering questions without the sense of embarrasment is a first key step towards deeper learning by most students; the self-motivated, talented students (the "Susan"s; e.g. (Biggs & Tang 2007, Ch. 1)) will learn well in most environments.

Problem Solving (10 mins)	**Problem Solving (5 mins)**
To illustrate the significance of the $M-\sigma$ relation, compare the following after calculating each one for gE M87: *Hint: What is the sphere of influence, R(soi), of its black hole?* **1)** The Schwarzschild radius of the black hole in km and parsec **2)** The radius where σ_e is measured: R_e=96" **3)** The ratio of the gravitational force of the black hole at R(soi) and R_e **4)** Compare R(soi) to the radii of 1) and 2).	Calculate: **1.** The amount of accreted matter in Msun per year needed to retain the luminosity of a quasar ($L \sim 10^{45} - 10^{46}$ erg/s) **2.** Make the same calculation for a Seyfert galaxy ($L \sim 10^{43} - 10^{44}$ erg/s)

Fig. 12.2. Sample 'short calculations'. *Left:* This calculation shows that the black hole gravity is insignificant at the scale where the galaxy mass is measured and that the latter scale is significantly larger than the sphere of influence near the black hole: The M-sigma relation is an amazing fact, not an artifact. *Right:* By dividing two numbers it is clear just how efficient the mass to energy conversion is in black hole accretion: less than 2 solar mass of gas per year is needed to power the most luminous quasars in the Universe!

McGregor (1960) described the perfect climate as one where the students can be fully trusted and the learning outcome is higher ('Theory Y').

At the start of the course I discuss with the students the different class format and what they gain from active participation. In the first couple of weeks I continue to emphasize that it is more important that they answer than the correctness of their answer: everyone in class learn more (deeply) by discussing the wrong answers and the justifications than just hearing the right answers. I use the brainstorming sessions as ice-breaker and warm-up when students in the beginning are still shy (example given in Fig. 12.2). While the students often do not see the point of this exercise, I do find that it breaks the initial barrier. The students experience first hand that it is OK not to have a polished or correct answer and the group is more responsive after that.

Short Calculations

This activity was adopted to give the students the experience of self-discovery and to emphasize important points that would otherwise typically go unnoticed. I give two examples in figure 12.2. The students get 5-10 minutes to compute the numbers and we discuss the results, their meaning and

What is the origin of the particular structures of different E-gals?

A) The merger history of the galaxy
B) The collective rotation of the stars
C) Presumably the conditions under which they were formed
D) The evolutionary sequence of the galaxy
E) The motion of the dark matter

Fig. 12.3. Sample peer instruction question aimed at motivating discussion in class. Each of the topics (A – E) had been addressed earlier in the course. The students had to use scientific reasoning to answer this question. A good discussion came of it as individual students had different ideas of what is more important in this case. The discussion clarified that many of these issues could play a role.

implications afterwards. In the left example the students get to see first-hand that by no means can the central black hole in galaxies gravitationally affect our measurements of the galaxy mass farther out: the observed relationship between the masses of the black hole and of the galaxy is real. They also discover just how insignificant the gravitational pull of the black hole is away from the center: the supermassive black hole will never be able to swallow the entire galaxy – something that many students do ponder on.

This activity typically spawned some wide-eyed reactions from the students – telling me that the intended goal of learning through self-discovery was generally fulfilled. I got comments like: “Did I make a mistake?”, “Wow!?”, and “That just cannot be – it’s not much gas needed!” But, in the beginning the students were a bit hesitant to start this type of activity. The students were likely unsure about what to do – some because they had not read before class. It was clear that I had not defined the didactical contract with the students well enough. One improvement to make is to prepare the students at the start of each class for the types of activities to come. On the positive side, some students possibly realized the advantage of having read before class. The ideal activity would inspire the students to take responsibility for their own learning.

Group-work and Presentations

The rate of information in a traditional lecture can be quite high. Group-work offers both a break in the information packed lecture and offer deeper learning as students are kept active and directly work with the material (e.g. (Biggs & Tang 2007, Ch. 2)).

As an experiment I had the students read primary literature in class with the aim of presenting and discussing it with their peers. I selected three four-page articles on a topic that covered an active and important research area with significant updates since the book was published. With this activity the students are acquainted with hot research topics and their scientific justification, explore the research methods, and hone their analytical and critical assessment skills. Each group of three or four was given a different paper with the key text high-lighted and a set of questions to consider (Fig 12.4). After 70 minutes of discussion internally in the group and with me, each group presented the high-lights to the class for discussion of the results, the reasons of these studies and how they are connected.

Questions for group-work on primary literature:
1. *What are the main results of the paper?*
2. *Why did the authors undertake the study? E.g., did they want to test a specific hypothesis?*
3. *Which parameters are involved and how were they measured? Just provide an overview - significant detail is not needed.*
4. *Do the authors compare their results with others? Which? Why?*
5. *Do you see a connection with one or more properties of galaxies or observational results that you already know?*
6. *What do the main results mean? What could they potentially mean?*
7. *Burkert & Tremaine paper only: Is it difficult to understand the connection they see? Why (not)?*

Fig. 12.4. Questions for group work on primary literature.

The students took well to this activity and dived into it with enthusiasm. After a first reading some students found it (right-fully) non-trivial to read but after a short discussion with me where I re-stated the goals of the activity and asked a few leading questions they were back on track. All groups seemed satisfied with this activity. From discussions with individual groups

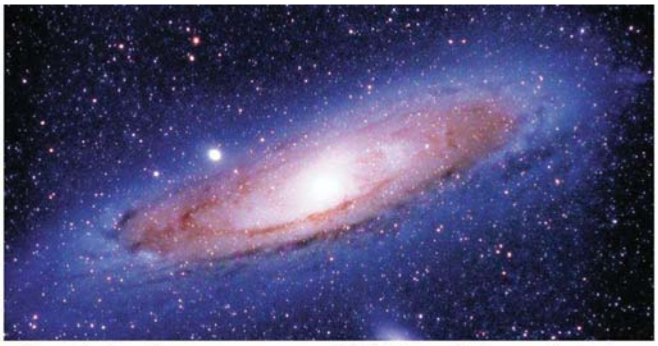
I saw many of the students be more engaged than usual, reaching a deeper understanding of the topic and being able to connect the issues brought up. However, the discussion time available was a little shorter than optimal for a satisfactory institutionalization of the discussion at the end.

Flash-card activity

This activity is heavily inspired by Prof. Eric Mazur of Harvard University (Mazur 1997) who used this peer instruction activity mainly to test the conceptual understanding of the students. In *Galaxies* I have primarily used it to activate the students and discussions in class, to hone their reasoning skills, and to help place the material in larger context. I pose a multiple choice question on a power-point slide (example shown in figure 12.3. The students consider the question for 1-2 minutes. Then they vote on my cue with a colored flash card (showing the letters A, B, C, D on different background colors). The colors of their cards gives me a quick overview of whether the students grasp the idea or not. If the majority answer incorrectly, I need to explain the issue or concept again in a different manner. If there is a division of correct and in-correct answers I tell them: “Find someone who disagrees with you and convince him or her that you are right!” After some discussion we re-vote. I vary the procedure a little depending on the question. Sometimes the students may discuss with their neighbor before voting. At the end I institutionalize and our discussion then includes why some answers are not as correct (or complete) as other answers. Instead of explaining or stating the right or wrong answers I enter a dialog with the students. The goal is for the students to explain to their peers why some answers are better than others.

In figure 12.5 I show an example of a question without preset answers: “Just inspecting this galaxy image and knowing its typical size and hence the light-travel time across the galaxy, what can we infer about the galaxy and the stars in it?” Students are confronted with their knowledge and practise reasoning. Through what is by some referred to as “Socratic questioning” (i.e. a dialog that guide the students to reason the right answer; see e.g. Prather et al. 2008[6]) in concert we converge at the conclusion: “The light-travel time is 100,000 years. Since the distribution of stars, both red and blue, is even, this shows that either both blue and red stars live longer than

[6] See http://astronomy101.jpl.nasa.gov/teachingstrategies/teachingdetails/?StrategyID=9



[h!]

Fig. 12.5. Sample peer instruction question without preset answers. Again, the students need to use their reasoning skills to answer this question. They realize the power of astronomical methods: we do not need complicated data to learn about the cosmos.

100,000 years and/or stars are continuously forming. Otherwise we would see a change in stellar colors from front to back. The back would be redder since blue stars live briefer lives."

After the first couple of questions the discussions were quite lively; this indicates that the questions were at the appropriate level and open enough to motivate student engagement. Thus, this activity is appropriate to expand upon.

Instructor Evaluation of Activities

In general, the students seemed to receive these activities well even if they were a new experience for most students. The majority of the students participated ($\sim$15 of the $18 - 19$ in class). All students typically participated in the flash-card activity, while a couple of students were more reserved/hesitant during the discussions. However, the overall activity level in the class was generally high. This suggests that the students like the activities or are not strongly opposed to them. Some improvements can be made to optimize the implementation and the learning outcome.

Are the ILOs fulfilled?

The evaluation of the students' written reports on the Computer Project (I) to model and analyze galaxy spectra showed that the majority of the stu-

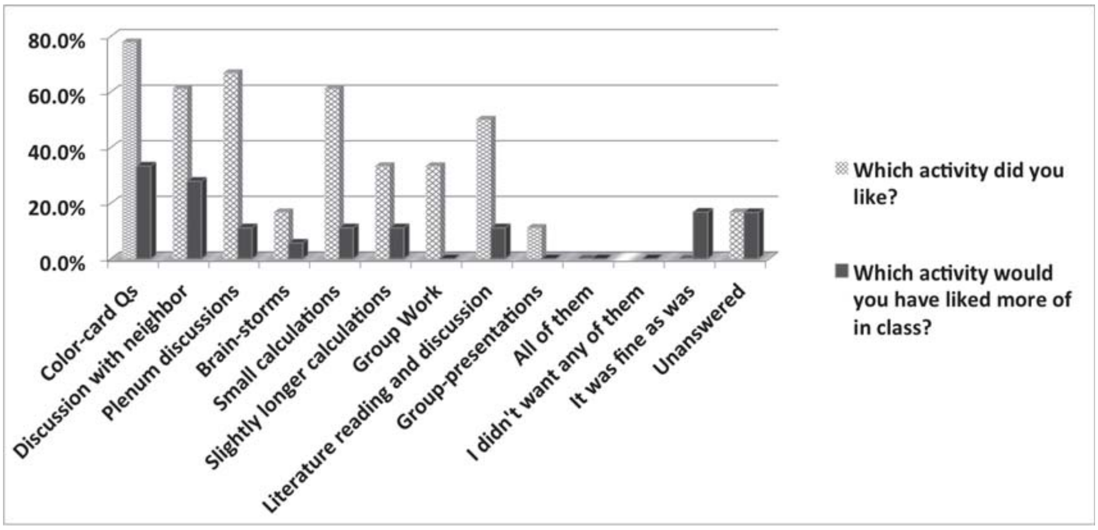


Fig. 12.6. Student activity in class.

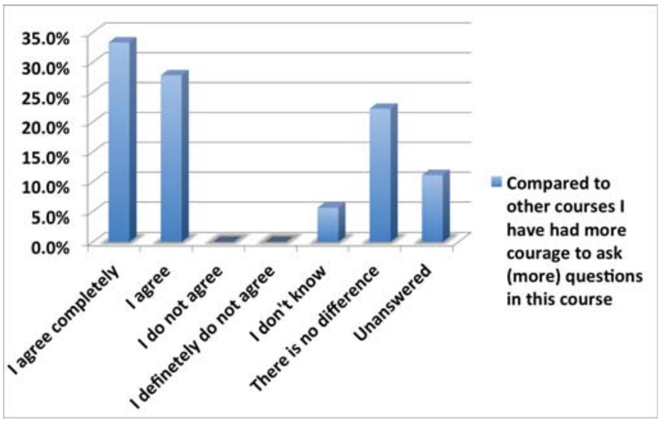


Fig. 12.7. Courage among students to ask questions.

dents had gained the expected deep declarative and functional knowledge associated with the spectral properties of stars and galaxies, not to speak of their ability to access, display, and manipulate data with the IDL software. All students delivered a high-quality report: 17/18 (8/9 reports) scored above 90% and 1/18 (1/9 reports) scored 79%. The reports also demonstrated the students ability to use scientific justification. The activity in the computer room demonstrated the students ability to organize, collaborate, and discuss the task and the science. My own impressions from the lectures and the final exam are that the ILOs are generally fulfilled. In particular, for the students that actively participated in the open discussions the intended learning outcome (including reaching the highest SOLO level) was obtained. However, improvements still need to be made to ensure the quiet, shy or hesitant students also obtain a high learning outcome. This is more difficult to evaluate given their quiet nature. The final exam evaluates this somewhat, but is not a direct measure, partly due to its different context.

Student Evaluation of Course Activities and Format

Before (and after) the final exam I gave the students an on-line, anonymous course evaluation in addition to the one administered by the University[7]. Due to the breadth of the survey and the many open questions I will here only focus on a few key points. Eighteen students responded out of 18 participating in computer sesssions, typically 13-17 participated in lectures (all passed).

Evaluation Question: What did you like the best about the lectures?
- *"The discussions have made a difference for me, I really feel I have learnt a lot from them. The way the material is covered in the slides is less tiring."*
- *"It works just fantastic with the use of power point (slides)"*
- *"That you are presented the material in a different way, makes it easier to place in perspective. The discussion with the teacher and other students makes you more certain that you have understood the material correctly."*

(Students' comments translated by author)

Fig. 12.8. Evaluation question I.

The students liked most of the lecture activities (Fig. 12.6), and felt the climate in class motivating for asking (more) questions (Fig. 12.7). However, the comments also showed that the smaller class size was a motivating factor for some students. The comments showed that typically the students felt they learned a lot from lectures (Fig. 12.8 and 12.9), although some students pointed out their dislike of group presentations. Some felt they learned nothing from the other students' presentations.

The students did not find the level of computer sessions too high (Fig. 12.11 and 12.10) – although they were challenged they also reported to have learned a great deal compared to other computer courses (Fig. 12.14).

[7] Due to the length of these three evaluations, they are not shown in their entirety here.

Evaluation Question: What specifically did the lectures do for you?
• *"I feel I have gotten the maximum possible out of the 3-4 hours we are there. That is, I have obtained a good understanding for galaxies, gas and my physical intuition is improved."*
• *"I retain the material much better, when we have worked with it and had it presented. I gained a lot from the presentation, illustrations and explanations from the lecturer, but also by discussing the material with the other students."*
• *"Overview. Insight into the methods and thought-process of astrophysicists. Gotten the loose ends under control. Obtained stronger interest in astronomy in general. Hopefully I'm smarter."*
• *"Better understanding" (half the students made this comment)*
(Students' comments translated by author)

Fig. 12.9. Evaluation question II.

I am very pleased to see that the students themselves found their hard work rewarding and their competences useful in multiple regards (representative comments are reproduced in figure 12.10). Notably, their computer reports also showed that they nicely rose to the challenge, so I conclude that the level was appropriate.

Question: "List the most positive about the Computer sessions"
• *"The level was not too high, which means you get to dig into the IDL functions you work with and understand them properly. This is contrary to Astro 1 where all possible foreign programming terminology and functions are thrown in your face for the first time and somehow you are expected to grasp them the first time or to know them beforehand."*
• *"That the pace was slow. We were not thrown into something we have no clue about [...] In this course we took one step at a time, which made us remember things better and obtain a better understanding for how to approach things"*
• *"The enormous competences that we have obtained"*
• *"It actually helped to understand the material"*
• *"To get a feel for the work of a 'real astronomer'. We also gained better control of the material we had read [...]"*
• *"The positive was the structure of the problems and that they had to be submitted forced one to get them done."*
(Students' evaluation comments translated by author)

Fig. 12.10. Evaluation of computer sessions.

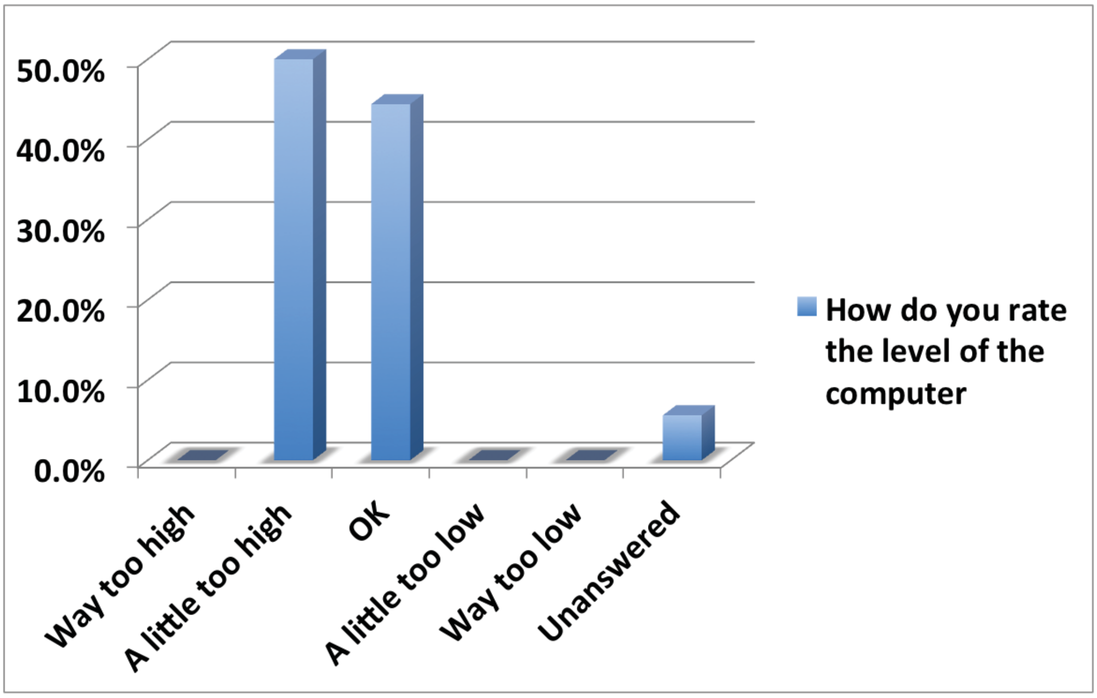


Fig. 12.11. Evaluation of level of computer sessions

The negative comments (Fig. 12.13) include the little relevance for the exam, that it required work outside of class (note: some students took it literally that they needed to work on it at home – as oppose to working in the computer room). In general, the students did find the IDL introduction too long. I agree.

Some students did not like the thought of needing to work outside of class (see e.g., Fig. 12.13 and 12.15). Many prioritize their lives outside their study (Fig. 12.15). On the question "How many hours did you actually spend on the computer projects outside of our sessions in the computer room?" one student commented: "4 hours spread over the course. Pulled serious teeth, and I think it was too much compared to how large the computer session are of the course. During a short period it resulted in that I did not have time to prepare for the lectures." The typical load of the students was three to five hours per week, fluctuating from week to week. The students also saw little relevance in the computer projects after completing project I (Figs. **??**, 12.10). This explains the decreasing attendance during the last computer sessions.

The comments show that the IDL introduction needs to be adjusted and there is a disconnect in the didactic contract with the students and in

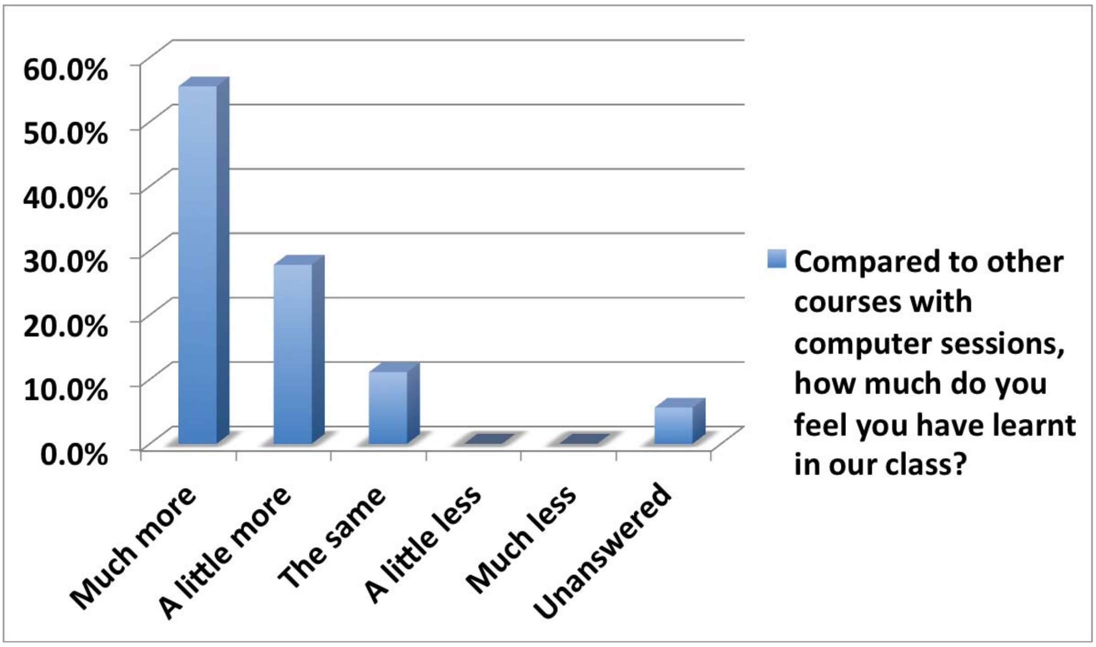


Fig. 12.12. Students relative evaluation of outcome of computer sessions

the constructive alignment between activities and the exam. Otherwise, the work-load for the mandatory computer project was reasonable. When the IDL introduction is shortened, the average load will be better. However, overall the students found that the course was inspiring (questions 39 and 40; not shown here), increased their interest in the subject, and that they learned a lot. (I quote one student: "I have NEVER during my studies attended lectures this much".) They felt the outcome was worth the work.

Looking Ahead: Concrete Changes to be Implemented

The two main areas that needs improving are the textbook and the IDL Introduction project. An alternative to the traditional student presentations is also desired. I propose solutions to these issues in this section. While there is also room for improvements for the TLAs that worked well, I choose here to focus on discussing the textbook and student presentations only; the IDL introduction simply needs to be shortened and the few exercises therein made more effective in regard to learning outcome. In future course offerings I will continue to expand on the discussions inspired by the colored-card votings, the short calculations, and reading and discussing primary literature on hot research topics.

Question: "List the most negative about the Computer sessions?"

- *"They took way too much time!!"*
- *"Too much programming, especially in pc task 1, it was much the same"*
- *"[...] (especially the first task) was WAY too much busy-work. You spend a lot of time on something very easy [..] you spend a lot of time learning very little. This was both with regard to subject contents and programming-wise. Project 1 [IDL introduction, author comment] I feel was very off with regards to the learning contents. [..]"*
- *"It is TOO much to expect that we were to do large parts of the programming at home, especially when you don't have IDL on your own computer"*
- *"That they are such a large part of the course without direct releance for the other parts of the course and especially the exam. Moreover, it is not possible to down-prioritize them, if you feel you don't have time for it all."*
- *"The questions were sometimes to complex/too broad/too difficult to understand which meant that I often spend longer time to get the overview and understand the problem than the actual solution."*

(Students' evaluation comments translated by author)

Fig. 12.13. Evaluation of computer sessions.

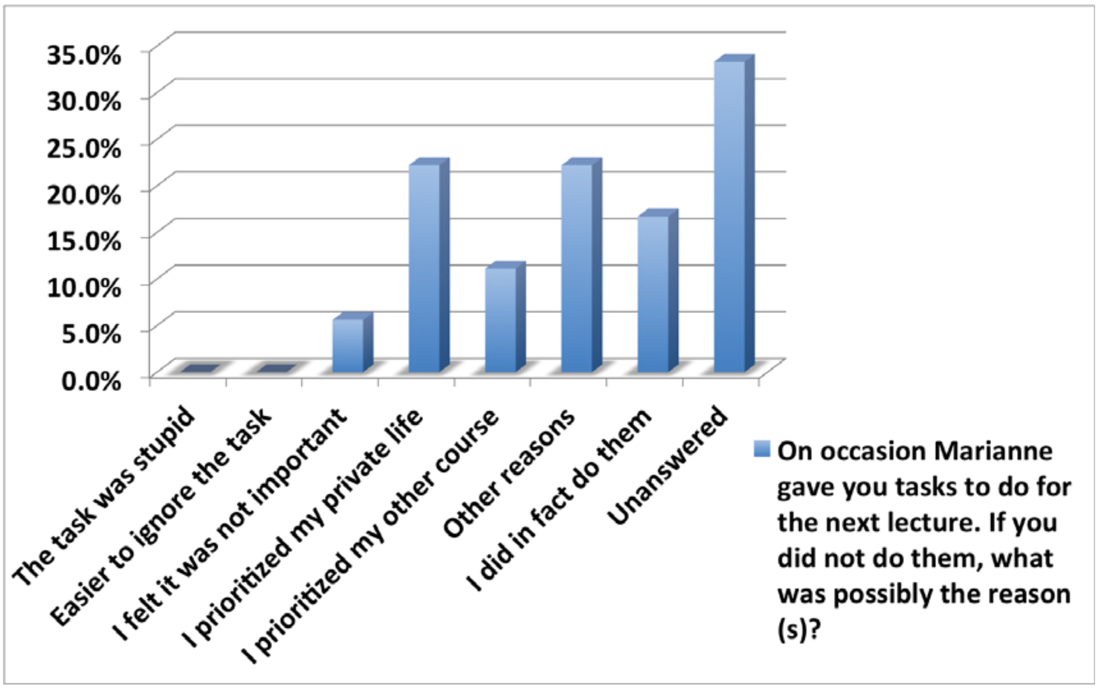


Fig. 12.14. Why task was not done.

The Didactical Contract

For the activities to work well, the students have to buy into the new course format from the start. The student evaluations reveal that it is common for the students to feel it is not or should not be necessary to do much work outside of class despite the emphasis from the instructors to the contrary. While I typically asked the students to consider one or two questions on the next day's reading and to formulate two questions for me (so to help them focus), most students didn't do this. This suggests that the didactical contract was not established well enough from the start. The students have to agree to it and see the benefits of all the activities. I plan to enter a dialog with the students about their own experiences of how they learn best, advices from prior students (from student evaluations), and statistics of last year's students activity level and their final grade. While the final grade does not guarantee deep learning, the grade is, afterall, a strong motivator for most students. There is also a need to remind the students about the didactical contract and review it occasionally.

The Textbook

The students find the textbook hard to read because it fluctuates between giving an overview of galaxy properties to providing rivers of facts and details. The latter is mostly repetition for students with a background in stellar astronomy, but is overwhelming for the beginning students that take *Galaxies*. While I will be on the look-out for a different textbook I know the options are very limited. The current solution is to help the students to read the book by way of activities that help to extract the essense and outline what is important in concert with the other TLAs. The didactical reason for these small exercises is that they are the type of questions a naturally self-motivated student (a 'Susan'; e.g. (Biggs & Tang 2007, Ch. 1)) would ask of herself. Her notes for class would include these considerations. These discussions are also good upon which to build the lectures of the day.

Selected home-work/group-work tasks

Sample home-work tasks to be applied in 2011 are listed below. The full list is shown in Appendix A. The results of the home-work tasks will be discussed and summarized at start of class, at times combined with discussions within student groups of three, as indicated.

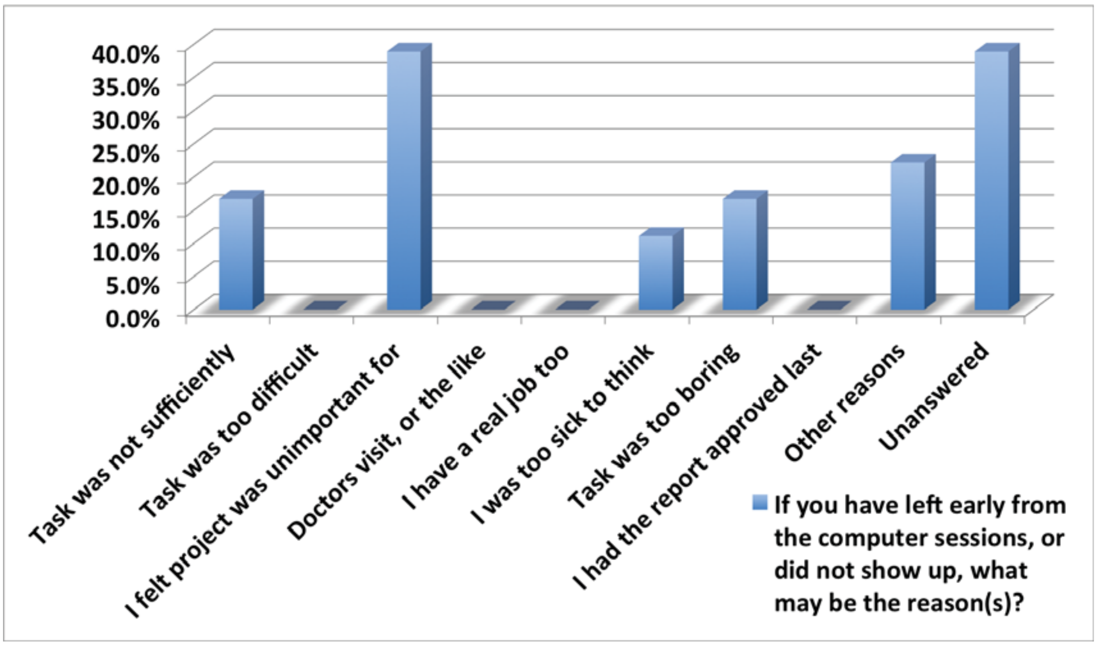


Fig. 12.15. Reasons for leaving early from computer sessions.

Spiral Galaxies II: *Home-work A:* "Which components of spiral galaxies contribute to the rotation curves? Why do each of them have the specific radial profile we see?" In-class group work will place special emphasis on the last question plus these: "Why must we conclude the presence of dark matter? Explain the physical reason for its radial profile."

Home-work B: "What is the Tully-Fisher relation and how is it useful?"

Elliptical Galaxies II: *Home-work:* "List the differences between spiral and elliptical galaxies. Who can find the most?" In-class group-work: "Discuss: what are the physical reasons for these differences." The summary discussion will include addressing the potential effects of evolution.

Early Universe and Young Galaxies: *Home-work:* "List the various methods to find proto-galaxies and young starforming galaxies. How does each method work?" In-class group work: "What physics is involved here?"

In class the students spend some time in groups of three to compare notes and discuss any new questions. To motivate participation among all groups, each group will contribute with a subset of the answer at random. The results will be the basis for follow-up discussions and institutionalization of the issue.

Group-work and Student Presentations

Student presentations is one way of motivating the students to actively participate in group-work. However, as the student evaluations suggests many students may not learn anything from the presentations of the other students. On solution is to have all groups work on the same issue (group-work tasks in this course have centered around different topics for each group) and present parts of the result. The students then help validate the results and supplement what other groups have presented. The presentations then become a plenary discussion. In addition, an alternative way to summarize, institutionalize, and provide formative feedback to each student is to require a short 1 page essay to be submitted before next class. Next, I give examples of topics – although in these cases topics are typically different for each student but the students need to assimilate the information for their report.

For example, I will start group-discussions based on the following questions: "Which are the different methods for measuring the mass of galaxy clusters and how do they work?" After a 5 minute brain-storm/discussion, the groups report back and in concert we generate an overview of the problem and the possible solutions (in this case three methods exist). Then each group picks one mass-measuring method to investigate further. After 1 hour's work each group provides a summary. If multiple groups work on a single sub-topic, each group provides part of the solution. The other groups act as opponents/validators and will supplement information.

Another group-discussion question is: "How does the distance-ladder work and how is it calibrated?" In this case I will adopt an alternative, fun implementation, namely a role-play. Each group of three are astronomers, expert in a particular distance determination method. The overall aim is for each group to try to solve the puzzle of how to calibrate the distance ladder to use it for the most distant objects. The groups are to exchange information since each group is only experts in one method. Internally in the group the students are to assimilate the information and determine how one can calibrate the distance ladder. When a group believes it has cracked the riddle, it presents its hypothesis to the class whereafter the other groups validate and judge the proposal based on scientific reasoning. If rejected, any other group gets the opportunity to propose a solution. The game aspect of the role-play is engaging and motivating to most students. I have seen first hand how such an activity can turn otherwise passive, introverted engineering students into a lively party. This in itself validates the success of the activity: the students are actively processing the material, they use their scientific reasoning, and will, no doubt, remember this activity.

Regardless of the implementation, the students are to submit a one-page summary of the solution. This report is a means to provide formative evaluation (feedback) on their understanding of this topic. Also, this report can also be the basis for one of the questions on the final oral exam.

Improving the Constructive Alignment

Course Activities and the Exam

The final oral exam is currently based on questions, known to the students, that cover the entire curriculum of the textbook. The computer report is not directly assessed during the exam; it is graded and approved three weeks before the exam. Some students saw little relevance of the computer projects to the rest of the course and the exam. As an additional motivator, I will include all the computer projects except the IDL introduction in the exam. The large project would the an exam question of its own, while the smaller projects (done in class) will be part of the curriculum for the questions on their topics. The write-up of the projects can be optional, yet if submitted the students will obtain formative evaluations. Like-wise, the 1-page summaries based on group-work can also be made part of the exam curriculum. While from a didactical viewpoint one would aim towards all oral exam questions to be based on students projects/work, my experience tells me that this format needs to be introduced a little at a time. Next time I teach *Galaxies* I will make all computer projects part of the exam curriculum and also pick one group-work project that forms the basis of one of the exam questions. Although many students dislike the group presentations they cannot be discarded since the students need to practise expressing themselves for the oral exam.

Galaxies in Context of the Bachelor Education in Astronomy

The current background of the students is poor on stellar astrophysics and the physics of radiation and its interaction with matter. The constructive alignment of this course in the Bachelor education thus needs to be improved. Simply moving *Galaxies* to the 3rd year does not resolve all issues. Atomic physics is no longer a mandatory course so the students will only learn what I teach them on the topic. And while having a background in stellar physics would clearly help, changing the order of the astronomy courses is not possible[8] So what are the options? To achieve the ILOs the curriculum has increased so to address the missing background of the students. A non-appealing option is a significant cut in currriculum, leaving *Galaxies* to be only a bare-bone introductory course. To exploit the natural appeal that astronomy often has to many, this course should not loose the ILO related to the students obtaining an overview and understanding of the cutting edge research areas and of what astronomy research is. These activities contribute to the official competences of the Bachelor education as defined by University of Copenhagen. These aspects can be retained by the following idea that grew out of a discussion with a colleague.

Better alignment between the four astronomy courses may be obtained if a simple reshuffling of the curriculum is made: the topic of star-formation can be moved from course 3 (planetary physics and interstellar medium) to course 4 (stellar astrophysics and evolution). At present both courses touch on this topic, but it can be better coordinated. Course 3 already addresses the interstellar medium of the Milky Way. Extending that curriculum to other Milky Way issues like chemical enrichment models, measurements of gas and stellar dynamics, etc., currently taught in course 2 (*Galaxies*), is appropriate. This would free up time in *Galaxies* to provide the relevant background, allow TLAs that hone the reasoning and analysis skills, and to address the ILO related to current hot research topics. My colleague and I are proposing this minor change to the astronomy teaching faculty.

Conclusions

Teaching the *Galaxies* course with the aim of optimizing the student learning outcomes involves a multitude of challenges. This project describes the changes I made to the original format of traditional lectures: I mixed power-point presentations with a suite of student activities and changed the computer projects to allow the students to learn IDL programming at an appropriate pace and to use it to obtain deeper understanding of the material taught in this course.

The students liked most of the activities and found them helpful to their learning. They learned more during the computer sessions than they had in

[8] The stellar astrophysics course requires a background in advanced physics and is therefore a third year course. Offering all astronomy courses late in the third year is not possible.

previous courses and they were generally happy with the course which they felt was inspiring and increased their physical intuition.

The overall conclusion is that most of the activities implemented in 2010 are generally successful and with further improvements to, especially the IDL introduction and use of the textbook, this course format and structure has the potential of optimizing the learning outcome for the students. This can be further improved by a better constructive alignment of the course within the Astronomy Bachelor education.

Acknowledgements

This project (and Adjunktpædagogikum) has helped me understand to a greater extent the many dimensions involved in teaching well – from the little things the instructor does in class to how the class fits into the overall education and the intended competences. Thank you.

A Home-work Tasks for Focused Textbook Reading

The home-work and group work tasks to be applied in 2011 are listed below. The solutions will be discussed and summarized at start of class, at times combined with discussions within student groups of three, as indicated.

Spiral Galaxies I: *Home-work A*: "List the characteristiscs and properties of spiral galaxies. Include how you identify this galaxy type on images."
Home-work B: "Spiral galaxies have spiral arms. What are they? What is happening there? Are they rigid? Explain your answers."

Spiral Galaxies II: *Home-work A:* "Which components of spiral galaxies contribute to the rotation curves? Why do each of them have the specific radial profile we see?" In-class group work will place special emphasis on the last question plus these: "Why must we conclude the presence of dark matter? Explain the physical reason for its radial profile."
Home-work B: "What is the Tully-Fisher relation and how is it useful?"

Elliptical Galaxies I: *Home-work A:* "List the characteristiscs and properties of elliptical galaxies. Include how you identify this galaxy type on images." *Home-work B:* "List the properties that astronomers can measure on elliptical galaxies. Include the measurement method."

(Elliptical) Galaxies II: *Home-work:* “List the differences between spiral and elliptical galaxies. Who can find the most?” In-class group-work: “Discuss: what are the physical reasons for these differences.” Summary discussion will include the potential effects of evolution.

Galaxy Groups and Clusters: *Home-work:* “Jot down the main characteristics that define groups and those that define clusters. Compare them: how are groups and clusters similar, how are they different?” In-class discussion: “Why do we see these differences? What are the physical reasons for them?”

Active Galactic Nuclei I: *Home-work:* “Make a bulleted list of the measurements that support the Unified Model, namely that different AGN types are separated only by source orientation.”

Active Galactic Nuclei II: In-class group work: ‘ Draw a model of the central engine of quasars. Label each physical component with the type of emission it generates. Which part of the spectral energy distribution does that component contribute to?”

Large Scale Structure: *Home-work:* “Draw in a pie diagram the types of structures we see on large scales and label them. Make a list of uncertainties and artifacts that are inherint in the redshift surveys.” In-class group-work: “What are the consequences of the uncertainties and artifacts of redshift surveys?”

Early Universe and Young Galaxies: *Home-work:* “Make a bulleted list of the various methods to find proto-galaxies and young starforming galaxies. How does each method work?” In-class group work: “How does each method work and why?”

In class the students will spend some time in groups of three to compare notes and discuss any new questions. To motivate participation among all groups, each group will contribute with a subset of the answer. The results will be the basis for follow-up discussions and an institutionalization of the issue.

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/