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Revising a Bachelor Program in Astronomy

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Introduction

In early 2014 a committee was formed to evaluate and recommend a revision of the bachelor and master programs for students pursuing studies in astronomy at the Niels Bohr Institute, University of Copenhagen. The work of this committee led - through a somewhat convoluted process - to a new structure for the astronomy-specialization of the physics education at the Niels Bohr Institute. This new structure will be implemented beginning in the fall of 2015. The most important change is the establishment of an introductory/overview class as the first astronomy course in the bachelor program.

In the following I describe the work of this committee and the process that led to the adaptation of its central recommendation. My aim is to present my own qualified reflections as an active committee member, describing loyally the motivations and deliberations of the committee, while also presenting my own perspective from my current privileged position of hindsight. I've been careful to distinguish my personal reflections and opinions from the positions of the committee as a whole. Not because there was much internal disagreement within the committee (indeed there was not), but because other committee members cannot be held responsible for my current reflections and might possibly disagree with some (or all) of them.

My focus here is on the revision of the bachelor program. The committee also reviewed the master program but because the bachelor revision was the first that would be implemented and the master program revision would depend on the new structure of the bachelor program the efforts of the committee were primarily focused on the bachelor program and I've decided to exclusively focus on this aspect of our work.

Specific Background

The Niels Bohr Institute is the physics department at the University of Copenhagen. It is a large department which covers a wide range of physics-related fields. Entering undergraduate students at the Niels Bohr Institute are presented with a choice of 5 specializations at the bachelor level. These are: "pure" physics, astronomy, biophysics, geophysics or meteorology. In addition to the final project, the specializations each consist of 4 mandatory courses, totalling 30 ECTS points, equivalent to half a year of classes. The remaining courses are either mandatory classes shared by students of all specializations or free electives. Thus, our assignment as committee members was to suggest revisions for 4 courses, equivalent to half a year of full-time coursework. In the existing structure the 4 slots were filled with the classes: "Cosmology" (Year 1, Quarter 4), "Galaxies" (Y2Q1), "Planets and Star Formation" (Y2Q3) and "Stellar Structure and Evolution" (Y3Q2).

The committee was essentially self-selected, formed from the people that volunteered at an openly announced introductory meeting. There was 7 members in all with a good coverage of all the sub-fields of astronomy represented at the department. In particular, the two administrative subdivisions of astronomical research at the Niels Bohr Institute the "Dark Cosmology Centre" and the group "Astrophysics and Planetary Science" were evenly represented with 3 committee members and 4 committee members, respectively. All committee members were relatively junior teaching staff or postdocs. One person left during the period to accept a job in the private sector. As a postdoc I was one of the most junior committee members both in terms of academic status, time at the institution and previous teaching experience.

Perspectives from the literature

There is a substantial existing literature on design and implementation of curricula. Several relatively recent books give thorough overviews from a practical (Diamond et al. 2008) or more theoretical perspective (Wolf & Hughes Eds., Lattuca & Stark 2009) while numerous journal papers exploit various aspects in greater detail. Here, I will merely draw attention to a few points that are of particular relevance to our work in the astronomy-review committee.

The word curriculum sometimes refers to detailed planning for a single course performed by a single person or small team; other times it may refer to the higher-level structure of an entire program as planned on the departmental level. Curriculum is more than just content and may be divided into at least 4 parts: content, organisation, teaching and learning methods, and assessment (Knight 2010). One definition views the curriculum as an academic plan (Lattuca & Stark 2009) but others distinguish between the "planned", the "created" and the "understood" curriculum (Knight 2010), which is essentially another way of saying that what we planned in the committee is not likely to correspond perfectly with what teachers will eventually execute which again will not be received by the students exactly as intended. A banal insight, perhaps, but important.

Another way of looking at the components of a curriculum distinguishes between the three *domains* of Knowledge, Action and Self (Barnett et al. 2010). Science-curricula tend to be heavily weighed towards the knowledge domain although there is a general trend towards including more learning activities that focus on what students do and what skills they learn rather than on the knowledge transmitted: elements that can be said to belong in the action domain. This, in part, is in response to modern student-centered pedagogical thought (e.g. (Biggs & Tang 2011)), in part in response to demands from employers for graduates trained in relevant generic skills (Hills et al. 2010). Also, however, this is in response to a very old tension in the teaching of science: the desire to teach students not just the *results* of science but also the scientific method itself. To transform them from acquirers of knowledge into producers of knowledge (Manathunga et al. 2011). In short: to turn students into scientists.

In practice, most curricula have grown by some complex, historical process involving the weighing of many interests against each other. They "evolve by accretion, with new requirements and constraints often layered incompatibly on top of existing structures" (Director et al. 1995). Teaching staff have dual – sometimes conflicting – loyalties to their institution on one hand and to their academic discipline on the other (Barnett et al. 2010). In addition multiple other constituents are invested in the curriculum ranging from students themselves (and their families) to employers and governments. As a result "curricula have tremendous inertia and often resist all but the most incremental of changes" (Director et al. 1995) and when changes happen they may be haphazard, governed as they are by "the constructed, negotiated, contested, provisional and often-complex nature of what happens in departments" (Knight 2010).

In *Designing and Assessing Courses and Curricula* Robert Diamond (Diamond et al. 2008) lays out a detailed method for guiding a process towards curriculum change. Stated very briefly the first 4 steps of this suggested process are:

1. Gather support and assemble the team
2. Gather essential data
3. Think in the ideal
4. Adjust from the ideal to the possible

Under point 1, Diamond underlines the vital importance of broad support before embarking on a project of curricular change. This includes support from management, including adequate time to perform the work, as well as support from the teaching faculty. When it comes to assembling the team to execute such change (such as our committee) Diamond has some interesting suggestions. He advocates strongly for including a facilitator to guide the process and act as devils advocate by challenging assumptions and asking hard questions. A facilitator is usually a person with substantial teaching experience but from a different academic field. Somebody from a department for teaching and learning or pedagogical development can also make a succesful facilitator. In addition Diamond stresses the desirability of including as far as possible the people that will actually teach the courses. Unlike some other workers (Bovill et al. 2011, Bovill 2014) he doesn't advocate giving students real power over this process but he does support including student perspectives as far as possible.

"Essential data" under point 2 in Diamond's process is things like surveys of incoming students and of graduating students as well as statistics of passing rates etc. It also includes formal requirements, existing guidelines from accrediting bodies etc. as well as experience from other institutions and perspectives from the pedagogical literature. Once this is in place the idea of the division in points 3-4 is to begin with a careful, structured brainstorming process and think through carefully, and in some detail, what the ideal solution would look like. Only afterwards should one adjust to what is possible. The point is to not limit the good ideas too early as one will often find that constraints or limitations are not as absolute as initially perceived.

A final perspective, comes from a detailed case study of a dramatic overhaul of the curriculum for the degree in Electrical and Computer Engineering (ECE) at Carnegie Mellon University (Director et al. 1995). This case study from 1995 was very influential and is still highly relevant (Grimson 2010, Ambrose 2013). Believing that "real impact in engineering education will be made only by looking at the curriculum as a whole, in the context of present technological and societal needs, and not just by constant repolishing of aging courses." (Director et al. 1995) the ECE faculty took a "wipe the slate clean" approach, started from the ideal, and thoroughly overhauled their curriculum. The changes were rooted in a number of perceived problems, among them an increased student diversity both in terms of the skills and background of entering students and in terms of the career aspirations of graduating students, a proliferating amount of material to cover and an inflexible existing curriculum making even small changes difficult to implement. The solution was a curriculum with a few, broad, introductory courses followed by a high number of electives for the students to choose freely, subject only to some broad constraints ensuring a certain level of depth and coverage.

Of particular interest in our context is perhaps their argumentation for the establishment of a new freshman introductory course: "The course motivates and introduces basic concepts ... in an integrated manner, provides hands on laboratory experience early, and strives to imbue students with some ability to look at the 'big picture"'. One of the major changes we suggested was the establishment of the course "Introduction to astrophysics" and our motivation for recommending this was almost identical.

Work of the committee: Planning process.

The committee met regularly through the winter and spring of 2014. At the meetings we assigned tasks, discussed work already accomplished and how to proceed, and generally worked to build consensus. After establishing the "boundary conditions" of our problem (i.e. four courses of each 7.5 ECTS points) we quickly decided to approach it by "wiping the slate clean" and imagining the best possible plan. Each committee member was assigned the task to independently conceptualize a set of four courses. When we met and compared notes it turned out that there was a large overlap between our different concepts. In particular, every one of us had planned for some flavor of introductory course as the first course. Some envisioned a more traditional construction or had some emphasis on historical elements, some had particular emphasis on hands-on activities or exposure to current hot research topics, while others again emphasized central concepts with course titles such as “Light and Gravity”. The point remained that all of us wanted the first slot filled with a broad, cross-cutting, introductory course rather than a more narrow disciplinary course.

We had a long list of arguments for beginning with an introductory course:

- To familiarize all students with some basic astronomical concepts that later courses can draw on. Specifically we felt that some basic familiarity with the life cycle of stars would be beneficial for later courses on e.g. galaxies, but a thorough treatment of stars would benefit from being late in the bachelor program when the students knew more fundamental physics.
- To give all students an appreciation for the big picture and a context for more specific later material and to emphasize the unity of central physical concepts and phenomena in astrophysics. As one example disks are found on many scales in astronomy from galaxies to planetary systems to Saturn’s rings.
- To provide a single-class foundation in astrophysics for students pursuing another specialization and to ensure that all students with a bachelor in astrophysics have been exposed at some level to all major areas of astrophysics from cosmology to planets.
- To give students specializing in astrophysics an early contact with the research that happens in the department and to give them basic research-relevant skills (e.g. programming). This will allow them to make an informed choice of early independent research projects and to succeed in such projects.
- To act as advertisement for the astrophysics-specialization and entice more students to seek out this specialization.

While individually the validity of these points may be contested (and indeed were contested by other faculty members), to us in the committee they added up to a compelling case for establishing an introductory course. In my view the case is still convincing.

We conceived the introductory class to be co-taught by several faculty from different branches of astrophysics and to be a mixture of lectures and hands-on exercises. In addition we envisioned each week to include a short guest lecture on a subject of current research interest and relevant to the material covered that week. Since this introductory course was central to our conception of the bachelor program we spent a lot of time drafting quite detailed plans. We drafted plans for the three following courses as well but these were less detailed. In all cases the plans would of course be subject to changes once a lecturer for the given course was identified. Once all these plans were in place we sent them to the wider faculty in astrophysics with a request for feedback and an invitation to a public hearing on the suggested changes.

Work of the committee: Outcome

We received only a limited amount of written feedback before the hearing. The limited detailed feedback we did receive was largely negative. The hearing itself was a well attended and rather contentious affair. Several senior faculty members were quite critical both of our plans and of the way we had organized our work. The criticism concentrated on two main points:

1) People felt that our plans for the introductory course were far too ambitious and that the course was in danger of devolving into a very superficial course filled with "material the students could read themselves in the encyclopedia".
2) We were also criticized for not having done sufficient preparatory work on analysis of the available data on student passing rates, student satisfaction etc. And for not having a clear statement of what we wanted to achieve with the revision: What were our specific success criteria?

This led to some sharp exchanges between committee members and other faculty and in the end the hearing ended up being perhaps less constructive and productive than it might ideally have been.

Over the following months I did some analysis on behalf of the committee aimed at addressing point 2) of the criticism above. We had statistics of student enrolment and passing rates for the four astronomy courses beginning in 2008. These statistics show a substantial variation in number of students signing up for the first course ranging from 28-52. Meanwhile the number of students showing up for the fourth course is remarkably stable, varying only between 15-18. This does on one hand appear to show room for improvement in retention of students through the astronomy-program, in particular, there's a large drop between courses 1 and 2. On the other hand the remarkable stability of enrollment for the fourth course could be interpreted to mean that the actual number of students sufficiently motivated to stick with the astronomy program is hard to change and that the great variability in sign-ups for course 1 rather represents a variable number of students taking this course despite having no intention to specialize in astronomy and/or students that drop out of physics entirely after the first year. The numbers are hard to interpret with confidence.

We did not have surveys of the attitudes of astronomy students going back in time but on short notice we passsed out a questionnaire to students of the astro 1 course in late spring of 2014. This questionnaire had a low response rate (~40%) and so one should be careful about drawing conclusions but it did appear to show 1) that the students were overall quite satisfied with the astro 1 ("Cosmology") course and 2) that students interested in fundamental physics were particularly appreciative of the current astro 1 course while students planning to specialize in astronomy tended to like the idea of a broader introductory course. A later survey of students on the astro 2 course ("Galaxies") appeared to re-enforce these tentative conclusions.

At this point we were in a sense overtaken by events outside our control as the University's implementation of new government reforms ("fremdriftsreformen") moved forwards. We were informed that a new structure for the entire physics education would be implemented with a number of elements that were already decided at the faculty and department administration level with no room for input from us. The new structure still had 4 slots for astronomy courses but they were moved, most significantly there were now no astronomy courses in the first year and the first astronomy course was moved to early in the second year. The timeline for providing course descriptions for the four new astronomy courses was highly compressed (~2 weeks) requiring immediate action from the astronomy faculty.

This lead to a second faculty meeting focused on the implementation of the new course structure. This meeting was quite practical and focused on scrambling to get things in place in time to get a workable program under the new structure. We were able to argue convincingly that our proposed set of courses would fit well under the new structure, the impending substantial changes meant that keeping the status quo of the current course structure was no longer an option, and as the only detailed proposal that was developed enough to have a chance of being ready within the severely constrained timeline we essentially ended up having our proposals accepted by default as the only horse in the race.

Discussion

In light of the literature perspectives outlined above and with hindsight of knowing the outcome, my own current view of the process towards change in the astrophysics curriculum and the work of our committee is mixed.

On one hand I strongly believe that our detailed proposal for a new bachelor program in astrophysics is fundamentally sound and has great potential to lead to a strong and successful program. I find the overall case for an introductory astrophysics course as I've outlined it above to be highly convincing. In the committee we agonized quite a bit over the danger of the introductory course becoming too superficial in nature and the detailed draft plan for the course that we produced is aimed precisely at ensuring the correct balance between depth and breadth. In particular we planned for extended hands-on excercises that would delve more deeply into specific subjects. In light of that I believe that the course can be executed in a way that avoids a superficial, "encyclopedia" treatment of the material. The proof of this will ultimately be in the actual execution.

On the other hand I view the *process* through which we arrived at this result as quite flawed. Partly the flaws lay in choices made by the committee early on, but mostly they were in the construction of the committee and in the some of the fundamental constraints under which we worked. Referring to the steps of method outlined by Diamond (Diamond et al. 2008) of 1) *gather support*, 2) *gather essential data*, 3) *think in the ideal*, 4) *adjust to the possible*, we did well on points 3) and 4) but failed on both 1) and 2).

First of all: Efforts on building of explicit support from faculty and management were lacking. I believe that we should have had an early meeting with astronomy faculty and representatives of management (e.g. vice director for education) present. This meeting should then have assembled the committee, explicitly formulated the scope of its task, and clarified an agreed-upon decision-making process. It never, throughout, became entirely clear to me exactly who had power to decide on whether or not to accept our proposals. Final responsibility rested with department management but they were clearly willing to accept the consensus of the astronomy faculty. How exactly this consensus would emerge, and who would speak for it, was severely unclear.

Secondly: Given enough time, we would have benefited from spending some effort on collecting more information before beginning our work. Even my limited literature search here revealed several interesting ideas. Especially the thought of including a facilitator-type role on the committee is, I think, intriguing. We could have sought guidance from the department of science education or from faculty at other departments with experience of similar processes. We could also have explored the inclusion of student perspectives. There is some thruth to the criticism we received at the hearing: that we should have spent effort on analysing data on student satisfaction, sign-up rates etc. However: we worked under severe time pressure and while to some extent this data was available, doing a really solid analysis would have required substantially more time in order to collect survey data under the existing course structure. Ideally this would have require years of data-collection and some funding for secretarial or student-assistant help in digesting this data. Clearly it would be beneficial to now establish an explicit procedure for collecting and digesting such data under the new course structure in order to have it available at a later date.

Finally, as planners of a limited subset of courses in a larger program we were squeezed uncomfortably between administrative levels "above" and "below" us. The departmental level above required our work to fit into an already specified structure that defined time-slots and what other classes the students would follow while from below we were constrained by the need to leave freedom for as-yet-unspecified teachers to define specifics of the courses we were planning. These constraints together severely restricted our options. The constraint from above affected us very explicitly when the wider curriculum structure changed substantially late in the process. The constraint from below was maybe less explicit but probably more serious.

In hindsight I believe strongly that the question of who would take on the teaching of these 4 bachelor-level courses should have been defined very early in the process and these people should then – if at all possible – have become members of the committee. This would have given the committee far more freedom to go into detail with course planning. As it was we were compelled to focus primarily on content and we left for example the question of assessment entirely unexplored. In addition it would have pre-empted much of the criticism that emerged at our hearing. Much of the resistance we encountered came (understandably, maybe) from faculty members that taught existing bachelor-level courses. If the decision about who would teach the new courses was already taken and accepted such discussions would have been had within the committee, in a smaller, more constructive forum with more time to work out differences.

Conclusion

I was a member of the committee established to evaluate and recommend a revised bachelor program in astrophysics at the Niels Bohr Institute, University of Copenhagen. Here, I've presented my personal reflections of this process. A central recommendation of the committee was the establishment of a cross-cutting introductory astrophysics course as the first course in the program. After a somewhat convoluted process the main recommendations of the committee were accepted and they will be implemented beginning in the fall semester of 2015.

While I strongly believe in the quality of our suggested, revised program I feel that the process leading to that outcome was less than ideal. The committee worked under severe time-pressure, subject to an unclear decision process with a task that was imprecisely defined and with options constrained by administrative levels both above and below. Particular points that could have been improved were:

- The establishment of the committee should have happened via a larger meeting that explicitly expressed support for the work and precisely defined the tasks of the committee and the decision making process. The committee could have included a person with the role of facilitator.
- The committee should have begun its work by gathering information from a variety of sources such as the pedagogical literature, people with experience of similar processes and available quantitative data. A longer period should have been available for this part of the process. Data on student satisfaction with the new program should be collected beginning now.
- Early on the staff that would teach the 4 bachelor courses should have been defined and these people should have been part of the committee. This would have allowed the committee to go into more detail with planning of the courses and to more confidently adress issues beyond content such as teaching and learning methods and assessment

Ultimately the proof of our work will be in the performance of the new program beginning in the fall of 2015. No doubt there is substantial work still to be done by teaching staff in the detailed planning of courses and no doubt the courses will evolve over the coming years. I am confident that the new program will be successful in attracting and retaining students, in giving students from other branches of physics a good basic insight in astrrophysics, and in producing specialized graduates with a solid grounding in astrophysics.

All contributions to this volume can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/2014-7/

The bibliography can be found at:

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