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Attrition and Retention in University Physics

A longitudinal qualitative study of the interaction between first year students and the study of physics

Bjørn Friis Johannsen – Doctoral Dissertation

Attrition and retention in university physics

Contents

1. Abstract, English

The underlying issue that is investigated in this thesis is students' strategies for engaging with their physics education that together with the substantive practices characteristic of the physics programme at the University of Copenhagen possibly introduces a potential source of conflict – a conflict that students need to find successful ways for coping with. By 'successful' is meant, that students are employing strategies that allow them to continue to want to stay in the physics programme.

To gain insight into students experience of learning in this programme and to gain insight into the possible conflict such students might cope with, this inquiry was designed as a longitudinal interview study with 26 individual students. The inquiry started before the students enrolled in the programme and was continued throughout these students' first academic year in physics. To answer a set of research questions, one which addresses the character of the students' successful coping strategies, the other which addresses the quality of the students' learning while coping, 18 individual interview sets are utilized – comprising 70 individual interviews and one group interview.

Using Bernstein's notion of a pedagogic device which is governed by a set of rules, approximately half of the students who are included in the analysis are found to be coping. The other half are characterised as thriving.

Results yield that the coping students employ a successful strategy for coping that begins with deferring their need for intellectual gratification. To reinforce this strategy students turn to transposing the rules of the pedagogic device, that is, they employ a personally relevant reinterpretation of institutional requirements and act on these. The more stable the strategy becomes, the more these students distance themselves from mainstream institutional life.

The students who thrive, do so because they reinforce their strategies for studying based on the grade they are rewarded for adhering to institutional requirements, by looking to their peers for confirmation that what they are doing seems right, and by feeling gratified by a curriculum that does not surprise them: it seems to be just an extensions of the curriculum they were used to, and fond about when they attended secondary school.

An analysis of the interviews that were performed with the coping students during their first year in physics reveal that these students who were initially disposed to engage proactively with their studies, gradually have this disposition subdued and replaced by their cumulative experience of learning in the physics programme – which is one, that only occasionally, and too rarely, offers substantial opportunities for proactive engagement. In effect, they gradually begin to adopt the same strategies towards learning that the thriving students utilize. This strategy is one that bears great similarity with strategies that research consistently report is not related to quality learning outcomes.

The result of this analysis is an empirical model of students coping – or engagement for congruence; which hold the potential of being valuable in informing how to prioritize future reform of this particular physics programme, and maybe even university science programmes in general. Importantly, the model suggests that efforts aimed at reforming the way student learning is evaluated is likely to have much greater effect than for instance reform aimed at changing the way physics is taught.

1.1. Short abstract, English

This thesis tells the story about a traditional physics programme where it was long forgotten why students are educated the way they are. A one year longitudinal interview study with 18 first year physics students uncovers the consequences or their learning. The result is that to cope, some students need to defer their need for intellectual gratification. The consequence of long term deference of intellectual gratification appears to be that initially proactively disposed students are slowly subdued and end by relying mostly on learning strategies that research reports consistently point out as strategies that cannot be associated with quality learning outcomes. The result seems be an empirical model that points to prioritizing an aim at the evaluative practices in future reform.

2. Resumé, dansk

Det der er denne afhandlings undersøgelsesområde er studerendes engagement I deres fysikuddannelse der tilsammen med de generelle praksisser der kendertegner fysikuddannelsen ved Københavns Universitet introducerer en potential konflikt – en konflikt som de studerende nødvendigvis må finde en god måde at håndtere på eller cope med. Med 'god måde' menes at de studerende benytter sig af strategier der tillader dem at blive ved med at have lyst til at læse fysik.

For at få indsigt i de studerendes erfaringer med at lære I denne uddannelse og for at få indsigt i den mulige konflikt disse studerende måske skal håndtere, er denne undersøgelse designet som en longitudinal interviewundersøgelse med deltagelse fra 26 studerende. Undersøgelsen startede kort før de studerende startede på fysikstudiet og fortsatte gennem hele de studerendes første studieår. For at besvare et sæt forskningsspørgsmål, et der vedrører karakteren af de studerendes gode måder at cope med studiet på, og et andet som vedrører kvaliteten af de studerendes læring mens de forsøger at blive ved med at have lyst til at læse fysik, benyttes 18 individuelle interviewsæt – i alt 70 individuelle interviews og et interview hvor to studerende deltog.

Ved at benytte Bernsteins pædagogiske device som er styret af et sæt regler, karakteriseres cirka halveden af de studerende der er medtaget i analysen som studerende der coper. Den anden halvdel ser ud til at trives.

Resultaterne viser at de studerende der coper benytter sig af en copingstrategi der tager sit udgangspunkt i en behovsudskydelse. For at understøtte denne strategi begynder de at transponere reglerne der gælder for det pædagogiske device, altså, de handler på en genfortolkning af de institutionelle krav som har personlig relevans for dem. Jo mere stabile disse strategier bliver, des mere distancerer de studerende sig fra det institutionelle liv.

De studerende som trives, trives fordi de bestyrker deres strategier ved at få gode karakterer for en indsats der fuldstændigt lever op til de krav der stilles fra institutionens side, ved at se at deres studiekammerater gør cirka det samme som de selv gør, samt gennem den tilfredsstillelse de oplever ved at have valgt et studie der ikke overrasker dem: Det synes blot at være en uddybning af det pensum de var vandt til og var glade for dengang de gik i gymnasiet.

En analyse af de interviews der blev foretaget i løbet af de copende studerendes første studieår afslører at disse studerende, som til at begynde med var disponeret for at engagere sig proaktivt i deres studier, gradvist undertrykker og erstatter denne disposition på baggrund af deres akkumulerede oplevelser med at lære i fysikuddannelsen – som er en uddannelse der kun lejlighedsvist, og alt for sjældent, tilbyder substantielle muligheder for at engagere sig proaktivt. Resultatet er at de studerende tager den samme strategi til sig som deres trivende medstuderende benytter sig af. Strategien er af en type der har slående lighed med andre typer strategier som forskningen konsekvent har vist, ikke fører til noget godt læringsudbytte.

Resultatet af denne analyse er en empirisk model for hvordan studerende coper – eller hvordan de sikrer sig bedre overensstemmelse mellem forventninger og virkelighed, som har et værdifuldt potentiale i forhold til at informere en målrettet prioritering i forbindelse med en fremtidig reform af denne uddannelse og måske endda naturvidenskabelige universitetsuddannelser generelt. I øvrigt peger modellen på at hvis uddannelsen skal reformeres kan det betale sig at rette indsatsen mod at ændre den måde man evaluere de studerendes udbytte på, snarere end at ændre den måde fysik undervises på.

2.1. Kort resumé, Dansk

Denne afhandling fortæller historien om en traditionel fysikuddannelse hvor det er længe siden man kunne huske hvorfor studerende uddannes som de gør. Et ét-årigt longitudinelt interviewstudie med deltagelse fra 18 førsteårsstuderende på fysik afslører konsekvenserne for deres læring. For at blive i uddannelsen bliver de studerende nødt til at udskyde deres behov for intellektuel tilfredsstillelse. På længere sigt aer konsekvensen af denne type behovsudskydelse at studerende der i udgangspunkt var disponerede for at deltage proaktivt i deres uddannelse ender med primært at benytte sig af overfladelæring, som er en læringsstrategi forskning konsekvent har vist ikke kan associeres med noget godt læringsudbytte. Resultatet synes at være en empirisk model der udpeger evalueringskulturen som det mest oplagte sted for en fremtidig indsats.

3. Framing the study

This thesis consists of a general introduction (Sections 1 through 9) as well as one journal article and two manuscripts (Sections 10 through12). Each paper addresses an important, but distinct aspect of the results of my PhD research. All papers were submitted to international peer reviewed journals and were written during the process of my research. Paper I was accepted for publication. Paper II is a manuscript that is going to be revised following review. Paper III is a manuscript still under review. This general introduction was written subsequent to the preparation of manuscripts, and thus aims to present a more coherent analysis of the empirical data that was collected in order to answer my research questions. Consequently, this part of the thesis draws on aspects of the results presented in the papers where appropriate.

The problem that I address pertains to the sequencing and justification of the physics courses that make up the physics programme at the University of Copenhagen. It is a 'traditional' physics programme and I believe it has come to be as it is, as a matter of tradition and because of certain assumptions about the nature of physics knowledge and physics practice that is also thought to concern how one is best inducted into this practice. One of these traditions is that students have to start their physics learning with a course in Newtonian mechanics. One of the assumptions regarding physics knowledge is that, one by one, elements build on each other. To learn physics, one must start at one end and work ones way through to the other end where a coherent whole emerges.

But what if Newtonian mechanics, as an isolated activity, is just inherently boring? What if the same goes for all the other physics courses that are taught in their proper historic order, one by one? What if a coherent whole does not even exist? What if physics is only exciting because of what you can do with physics? And what if students do not get to experience what physics can do and what they can do with physics for themselves, until they are done with their education?

Then students would have to figure out their own ways to make the content of their education interesting. And they would have to do so by other means, than those offered by the courses. But then, what if doing just this, takes means and abilities that have nothing to do with the means and abilities it takes to become proficient at doing physics? What if these abilities are just means to get by and get through a university physics programme? And what if this entails losing students who otherwise have the means to become talented physicists while retaining others by encouraging them to develop abilities not at all conducive to doing physics for real? I guess then we would be doing something that makes no sense at all.

To see, to which extent this argument bears merit, I have interviewed 26 new physics students during the course of their first year in physics and talked with them about what they do, to put themselves through their studies. The interviews reveal a rare and interesting view of the physics programme, its sequencing and its justifications, through the eyes of the physics students themselves. The remainder of this thesis is devoted to making sense of this view. And this is the problem or the challenge that has motivated me to write this thesis.

In the next subsection of this section, the framing of my study, I offer a general outline of the problem that my research aims to address and thus arrive at a set of research questions and some cursory remarks on the limitations of my study. Subsequently, a more theoretically directed framing follows.

3.1. Problem identification

The title of this thesis that presents the main results of my PhD studies is *Attrition and retention in university physics*. It is possible this title may be construed as misleading. The subject of the thesis is not the number of students who leave or stay in physics; nor is it about reasons for leaving. To some extent it is about reasons for staying, or rather it is about what students say they do in order to keep finding reasons to stay.

When you start studying physics, or anything else for that matter, you are bound for a surprise. Some aspects of your experience will be as you expected, others will not. Some of the things you thought were important when you started studying will turn out to be unimportant when you are done. This is the nature of learning: you gain new perspectives, you start perceiving the world differently and you become a different person (Marton & Booth, 1997). Education and learning is, at its core, the reshaping and constructing of identities (Lave & Wenger, 1991).

Since this is how I think of education and of learning, I also think that students will continually discover new reasons for studying as a natural course of their learning. However, it is rare that learning simply ‘emanates’ out of experience. Often we have to exert ourselves to acquire certain experience and to ensure that we prioritize our efforts well. We also have to try in various ways and rigorously to search out the circumstances that prove just right for allowing us the experiences we learn from. And we also have to learn to stay. Because simply having been put in a situation by someone else will quickly seize to be sufficient reason for staying there. And might this not be the kind of feeling a learning student will have just once in a while? Some will, some will not. One thing is sure, students who do not stay, will, except in rare situations, have to make the decision to leave, and students who do stay, might likewise have to make decisions about staying too.

And this is what this thesis is about. It is about learning to stay and it is about what students consciously do, to learn to stay. This, I call *coping*. Most importantly, it is about what students learn about the place they are staying at, as they make a conscious effort to learn to stay there. And if students learn what they need to stay through this effort and employ it as a strategy for engaging with their studies, I call it *a successful strategy for coping*.

The place the students learn to stay at is a 'traditional' physics programme at the University of Copenhagen. And the interviews I study are with first year physics students. That is where the *university physics* in the title of the thesis comes from. I will describe the programme in more detail at the beginning of section *5 Method*. To understand how these students cope I draw heavily on insights from studies of attrition – especially Tinto's (1993) longitudinal model of institutional departure that emphasises the importance of institutional integration. The reason this aspect is important to this study is that it draws attention to student-institution *interactions* as the central aspect of what students will have to learn about in order to learn to stay. That is where the *attrition* part of the title comes from. In section *4 Theory* I converge this model with Bernstein's (2000) pedagogic device to synthesise a conceptual framework suitable for analysing student interviews about coping. And finally, because there were far too few students in my sample who decided to leave in the period in which I was interviewing them, the interviews I analyse are about finding successful strategies for staying in physics. That is the *retention* part of the title. The setting of my study as well as methods employed in selecting students for interviews, for interviewing and for analyses are all described in section *5 Method*. The results of the interviews are analysed in section *7 Findings*.

Research question

Thus, the research question that has guided this, the main part of my PhD study is:

> *Based on individual interviews with first year physics students at the University of Copenhagen, (1) what successful strategies do students appear to employ to cope with their physics studies and what do these strategies tell us about the educational setting they are coping with?*

Since students might find successful strategies for coping by adhering to or setting aside certain of their interpretations of the educational requirements, there is no reason to believe that these strategies are necessarily congruent with strategies for learning associated with good learning outcomes (cf. Ramsden, 2003, pp. 79-83). Therefore I also use these interviews to inquire into how the students' strategies for coping compare with the same students' strategies for learning. To do so, I have been guided by a second research question that is tied to the first:

> *Compared to the successful strategies physics students employ to cope, (2) what might the consequences of these successful strategies for coping be for the quality of their approaches to learning?*

This whole study is a qualitative study of a longitudinal set of interviews with first year physics students. The second part of my research question was not one I had designed the study to answer,[1] but as I interviewed students about their reasoning and reflections on studying physics, the topic unavoidably also touched upon the aspects of their experience that were about their approaches to learning. Above, I have limited the notion of 'success' in "successful strategies for coping" to only encompass the extent to which students have found ways for staying in physics. While interviewing, however, I soon realized that a pattern between strategies for coping and the evolution of students' approaches to learning was emerging. This pattern seemed to offer a good way to better qualify 'successful strategies for coping' and to do so in more normative and well-tried terms. Besides, it is well known that students' approaches to learning are related to students' perception of task requirements vis-á-vis the context of learning (cf. Case & Marshall, 2009; Prosser & Trigwell, 1999), so

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[1] Nor had I, strictly speaking, designed the study to answer the first research question. This is a point I return to on page 7.

might not certain approaches to learning be intimately related to students' coping strategies – aspects of which are born out of their perceptions of the context for their learning?

It must be stressed, however, that what I offer is not a 'proper' study of approaches to learning, in that I do not employ phenomenographic methodologies, nor have I distributed approaches to learning questionnaires to large proportions of the physics student population as would traditionally be expected in such situations (cf. Trigwell, Prosser, & Waterhouse, 1999). Instead I use certain characterizations of approaches to learning as an analytical lens to evaluate and interpret students' individual stories about learning in physics. Thus my answer to research question two must not be perceived as anything but a way to further qualify and to cast more light on the systemic characterization of students' coping strategies that I aim to make.

Another important aspect of this study is that the research design was initially intended to capture and describe the process students go through when they decide to opt out of physics. For this reason I selected a large sample of students to interview in an on-going fashion, thinking that the sample for analysis could later be reduced to only include those students who opted to leave. Not many did; and what was initially intended as a data-set to serve as background for a focused set of cases on attrition, turned inside-out and became foreground. It is now the data-set I use for analysis of reasons for staying. It is an extremely rich data-set, and every time I revisit it, it opens up a lot more questions than it seems to answer. Thus, it has been necessary for me to focus on only certain aspects of the students' experiences in physics, and many a particular aspect of their experience I have had to save for later or leave untouched. One of the more obvious 'neglected' aspects, that are could have been addressed based on my interviews is the students' interpretation of the role of mathematics compared to physics. In this study I have mainly focused on how their relationships with physics develop and accepted that to certain extents mathematics is but a third companion in that relationship.

Meanwhile, before I go on to synthesizing a conceptual framework in Section 4, I offer an outline of my conceptual framing of the study. It serves both as a kind of revisitation of my initial thinking on what might be the problem that students need to cope with when they start studying physics – but in terms that match the theoretical framing of the remainder of the thesis – and it serves as a theoretical justification for the research design I have been relying on.

As is also indicated in the introduction to this section, I initially thought of students' possible problems with physics as a kind tension between physics-as-curriculum and physics-as-research.[2] Some students might have decided to start studying physics because of what they would be able to do once they were finished, thinking they would be taught how to do physics-as-research. Tension would then arise when instead they were taught something different, still related, but more akin to the physics they knew from school: physics-as-curriculum. In my mind, these two versions of physics are very different. They might not be to the students, though, which is an empirical question that can be answered. To answer it; to characterise students' need for coping with the structure of the curriculum and intentions regarding the knowledge the curriculum is designed to impart on the students, it is necessary to find ways to characterise these students' perception and expectations of the curriculum and the related activities in question. Such a way is framed in the next subsection. And as I end it, I conclude that the research design I have been relying on, all along the way, initially intended for something slightly different, is actually not at all that ill-suited for this purpose.

But it starts with knowledge and intentions.

3.2. The curriculum as a powerful experience

There is something to be said about the experience of coming to understand something difficult as the result of hard and rigorous work. It can be a powerful and gratifying experience. For most teachers this is probably what they hope many of their students will experience as a result of their teaching. To some, it is their main intention and all they can hope for: that their students will come to see the world just as they do. But in relying too heavily on this observation as the basis for learning and motivation, there is a danger that learning and knowledge becomes self-referential: suddenly learning serves a purpose in itself. Knowledge exists for the sake of the knowledge itself.

In the most extreme sense, the only role that is allowed the learning student, a young adult already well-versed in the world and society, is the role of the acquirer, not the user, of this self-referential knowledge

[2] Physics-as-research and as-curriculum are terms that I have borrowed from Ashwin (2009) who makes this distinction in more general terms (discipline-as-research and –curriculum) to emphasize that knowledge practices of research and of higher education disciplinary curricula are distinctly different practices.

– simply because this knowledge refers to nothing but itself. Of course, no knowledge element is completely self-referential nor is any knowledge-element absolutely not. But degrees to which knowledge domains are, or have come to be self-referential, vary.

In a recent review of *the sociology of the curriculum* Michael Young (2008) makes a distinction of knowledge that I find useful. He distinguishes between *context-dependent* knowledge (the knowledge we acquire during the course of our everyday lives) and *context-independent* knowledge which can only be acquired through schooling (because this is what the purpose of educational institutions is). Context-independent knowledge is the type of knowledge that has been made into the sort of conceptual knowledge that provides a basis for moving beyond everyday case-by-case experience (i.e. context-dependent knowledge) and towards a more general or context-independent understanding of the world. Of course, this is only an ideal meant to characterize representations of knowledge-stores – not cognisance. This is why the teacher's role is to help the students to move beyond their context-dependent knowledge and to acquire context-independent knowledge. They do this best, by helping students to recontextualize the context-independent knowledge in light of the students' context-dependent knowledge. As such, the teacher's role is to help students to 'reference' or *frame* knowledge-elements. And this is where physics appears in the picture: the stronger context-independent knowledge structures are framed, the stronger are their demarcation from context-dependent knowledge, and the more self-referential they are. And physics is traditionally strongly framed.

The physics curriculum

Bernstein (2000), who was concerned with understanding how learner identities are created in the boundaries between knowledge domains, uses this concept of framing to classify the physics knowledge domain as vertical. Figuratively speaking, physics knowledge is strongly framed, not necessarily segmentally on itself, but 'upward' opened up vertically towards higher levels of physics abstraction. One knowledge element builds on the next. The structure is logical, chronological or both. The German science educator, Martin Wagenschein (1999) drew a wonderful illustration of this and different ideas for framing the curriculum:

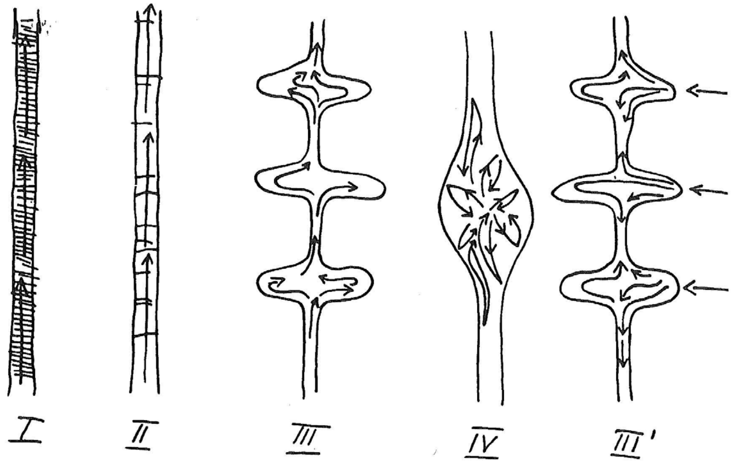

Figure 3.1 Illustrations of curriculum structures. (I) illustrates the intention to include all knowledge into the curriculum. This might be possible, but transparency is compromised – 'Durchblick ist verstopft'. (II) illustrates the solution to the issue of transparency: most content is removed while certain elements are retained to offer an 'overview', threadbare and insubstantial. (III) retains the logical or chronological structure, but curricular coverage is expanded at places that are deemed crucial at the expense of continuity: the pillars connecting 'platforms' have become slender. (IV) suggests that the curriculum is structured on an exemplary problem instead of on contents. The idea is that carefully chosen problems resonate with what is traditionally thought of as crucial curricular contents. (III') speaks to student motivation and contexts as prime candidates for ensuring quality learning. The curricular elements are structured to allow 'outside-in' access; not relying on preformed knowledge stores but on the ability to identify and use what is needed. From Wagenschein 1999, pp. 28-35, reprinted with the permission of the publisher: Verlagsgruppe Beltz GmbH & Co. KG

According to a conceptualization of the physics curriculum as logically and chronologically structured, physics education can be more (I and II) or less (III) strongly framed vertically in which cases is decided the amount of control that students and teachers have over the pacing of the content in the subject (Venville, Rennie, & Wallace, 2012). Richard Feynman for example, who was a famed physicist and physics educator, is notorious in his extreme, but humorous framing of physics knowledge domains: Einstein's theory of special relativity, which hugely impacts any a young physics student's perception of time, space and matter, he reduces to a mere correction factor to Newton's second law. To Newton's second law, he argues, we can add the law of gravity and "we shall have said everything required, for a sufficiently talented mathematician could then deduce all the consequences of these two principles" (Feynman, Leighton, & Sands, 1968, pp. 15-11 and 17-11). Had Feynman expected of his students to be talented mathematicians – and not introductory physics students at Caltech – he would probably not have managed to teach them anything on the consequences of Newtonian mechanics and special relativity. As it was, he did not: he did not maintain his initial framing but loosened it to continue his lecture by telling stories of discovery and by ensuring a thorough coverage of consequences and applications.

Physics: powerfully biased

For the sake of argument, let us stick with a scenario where Feynman had not loosened his framing. His pacing would then have been extreme. In this scenario he could have covered 'everything required for sufficiently talented students to deduce all the consequences of Newtonian mechanics' in just two minutes. Afterwards, those of his students who were sufficiently talented would then go home or work together to deduce mechanics. Those students who were not sufficiently talented would try anyway, but not succeed.

Feynman's framing of his teaching can in other words be associated with certain differences in outcomes. Depending on how you look at it, these differences might be construed as inequalities and his framing associated with certain biases towards his students. In an actual physics education setting, the issue at stake will be significantly more complex. Still the effects of systemic inequalities and bias can be systematically observed – for example as a pattern of disadvantage towards female students that "suggests a systematic culture in which males are privileged over females [as] a smog that surrounds us and that we constantly breathe in, though at times we may be unaware that it even exists" (Kost-Smith, Pollock, & Finkelstein, 2010, p. 15). Still it is possible to observe the effect of this biased culture directly as "patterns of repeated activities [that] appear to be social codes shared by some, not by others" (Hasse, 1998, p. 114) that ultimately function as mechanisms of inclusion and exclusion (Hasse, 2002a).

From the perspective of the individual, this 'smog' might be thought of as aspects of a weeding out process that is meant to test for both ability and character and identify those students that are most able and interested. This process is not one that is officially instated (any longer) and many will deny its existence – or at least point out that you only have weed-out systems where you need them, if you have more students than you need, for example. Still, it commonly exists[3] and is not exclusive to North American higher education. Perhaps the most comprehensive treatments of its effects on science, mathematics and engineering students is Seymour and Hewitt's (1997) study of interviews with 460 students about leaving their original Science, Mathematics or Engineering majors. They explain how weeding out processes is a system that "has evolved in an exclusively white and male context" and is inherently biased in favour of "qualities of character traditionally associated with 'maleness' in Anglo-Saxon societies", a system that is "based on motivational strategies understood by young men reared in that tradition" (Seymour & Hewitt, 1997, p. 132).

The point Seymour and Hewitt make, is that today of course, no student will have been 'reared in Anglo-Saxon traditions' why few will be able to understand the motivational strategies associated with these traditions. Consequently they are confident and very persuasive in concluding that attrition *and* retention in science, mathematics and engineering programmes can safely be repositioned as the result of a large set of problems experienced by *all* students "which arise from the structure of the educational experience and the culture of the discipline" (1997, p. 392) to which end student success in physics can be ascribed to their ability to successfully cope with a set of educational ideals that are long due for change.

Powerful knowledge?

Returning to Young's (2008) review of the sociology of education, however, he has a point that is important at this stage of my argument: the purpose of education is to pass on powerful knowledge, useful and hitherto unknown, to new generations. I agree when Young writes that knowledge is validated by its uses. Still, I can accept that he has good reason to caution against schools that make provisions to cater to their students' context-dependent knowledge to the extent they only validate their students' preformed knowledge. In such case the school would obviously cease to function as a place of

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[3] See for example this recent U.S. News & World Report on "weed-out" in Science, Technology, Engineering and Mathematics education: http://www.usnews.com/news/blogs/stem-education/2012/04/19/experts-weed-out-classes-are-killing-stem-achievement

learning. There is a thin balance here. We have to be very careful and preserve the conditions that ensure that students acquire powerful knowledge. At the same time we need to beware not to confuse powerful knowledge with knowledge of the powerful – which, with reference to Seymour and Hewitt's comment regarding the weeding out process, ought to make us immediately suspicious. All we know about this 'knowledge of the powerful' as a construct is that it was rendered legitimate by those in power. By extension, one can safely assume that the nature of knowledge of the powerful, as with power itself, more than anything, is self-preservation and thus inherently resistant to externally induced change. Granted, knowledge of the powerful can be powerful knowledge; but no one can claim that the reverse always holds true. "The key research issue will be distinguishing between forms of resistance," Young (2008, p. 17) consequently argues, referring to the tension he sees between resistance to change for the sake of preserving power, status, professional interests, privileges, and resistance to change conditions that ensure that students acquire powerful knowledge. "A good example of where this tension might be explored is when students are allowed to construct their own curriculum from within a bank of modules and, potentially at least, undermine the selection, sequencing, and pacing of knowledge that are the conditions for learning a subject" (p. 17). Is this not exactly what students do, when they find successful ways of coping with the problems that arise from the structure of the educational experience and the culture of the discipline? If so, the study of attrition and retention focused on students strategies for coping will be a study, not only addressing the question of whether modes of relaying knowledge to students are effective, but of the relay itself.

My study in perspective

My intention with my PhD study, the main results of which are presented in this thesis, is to better understand 'traditional' physics education at the university level as a particular relay of knowledge. To widen participation in higher education, Haggis (2006) recently argued, change is necessary, but it will be important to retain the positive aspects of traditional education by distinguishing these from those that might no longer be sustainable. An important step in doing so, will be to understand how 'traditional' higher education, or as in the present case, how 'traditional' physics education works and thus begin to distinguish between conditions inherent to this type of education which ensures that the knowledge students acquire is powerful knowledge, and not just the knowledge of the powerful. To gain insight that can add to this understanding, I have interviewed 26 students during the course of their first year in the physics programme at the University of Copenhagen. I have asked the students to account for their reasons for having decided to study physics and to account for those of their experiences in the programme that merits these reasons. I present an analysis of these interviews in a later section. But first, I synthesise a conceptual framework suitable for analysing which strategies students employ to undermine the 'bank of modules' that is physics education in order to ensure their own success: for this is a good example of where to explore the tension between physics as powerful knowledge and physics as knowledge of the powerful.

In other words: to inform us on how physics as a teaching discipline and physics as a research discipline reflects student-institution interaction at the programme level, I have framed my inquiry indirectly as an inquiry into the coping strategies students adopt as a reflection of their perception of this student-institution interaction.

4. Theory

In concluding the framing of my PhD study in the previous section, I wrote that this study is an indirect inquiry into certain aspects of the physics curriculum that is framed as an inquiry into the coping strategies students adopt as a reaction to their perception of the student-institution interactions. Before I continue by synthesizing an appropriate framework for interpreting interviews, I will write a little about what this focus on student-institution interactions is and is not. Because in approaching the issue of student learning in higher education physics in the manner I do, I adopt a way of perceiving the field that is somewhat different from the foci that have traditionally been adopted.

Section 4.1 outlines Tinto's longitudinal model of institutional departure, sometimes called Tinto's integration model. I perceive of this model as one that frames and guides my study: it is a model that allows me a direction and a background to my inquiry into students' coping strategies.

In Section 4.2 I draw on different perspectives on what is entailed by student coping to suggest what might be a central reason that students need to cope with university physics. This perspective is central to identifying student coping strategies.

In Section 4.3 I make the perspectives on institutional departure and coping converge with Bernstein's pedagogic device to synthesize a conceptual framework that I use to analyse and interpret student interviews. Together these two sections allow me to answer research question 1: *what successful strategies do students appear to employ to cope with their physics studies and what do these strategies tell us about the educational setting they are coping with?*

In Section 4.4 a perspective of learning and of the purposes of learning is described. This perspective is a necessary addition to answer research question 2: *what might the consequences of these successful strategies for coping be for the quality of their approaches to learning?*

Strands of research into attrition and retention

In Paper I (Johannsen, Rump, & Linder, 2012), *A critical attrition analysis* which accompanies this thesis as Section 10 in an 'author-created' version, we are inspired by Lawrence (2005) to make a distinction between three forms of inquiry into student attrition. One we call 'the assimilation strand', another 'the institutional services strand' and a third 'the interactions strand'. The latter is the one my work is primarily informed by.

The assimilation strand is a strand of research into student attrition that is primarily focused on associating student traits with student attrition – that is, identifying generic student types that do not easily assimilate to institutional requirements. This is not an easy task, however. As is already mentioned in the previous section, Seymour and Hewitt (1997) who studied attrition in Science, Mathematics and Engineering education at U.S. institutions of higher education, found that students who leave and students who stay are not different from one another. Instead, what make stayers and leavers out of students, are their individual coping abilities. This pertains to students who meet certain scholastic requirements, however. When no particular type of student is excluded from large scale surveys and statistics, factors like ethnicity, socioeconomic standing and the level of parental education do correlate with attrition. They are, however, factors that are severely entangled once gender, financial income as well as academic outcome and quality of primary and secondary education are also factored in (Tinto, 2006-2007).

If the best generalization we can make regarding students' difficulties is that they are individual, then the only viable solution must be to cater for these individual difficulties by for example seeking knowledge that can help institutions to better anticipate and react to student differences. One way to do so is to install certain academic services targeted at different oft-experienced problem types. This is the strand we call *institutional services*. Zepke and Leach (2005) have reviewed a large number of initiatives born out of this strand and provide a list of initiatives that seemingly are successful in addressing student difficulties associated with individual differences. These include variations over induction programmes, targeted supplemental instruction, pre-enrolment advice, peer mentoring services, academic learning communities and a focus on improving the quality of teaching. The latter two recommendations open up the possibility that the core of higher education, the already existing learning-enterprise, might not be taken as a given, but also be part of the problem that individual students react to, albeit differently. The other initiatives, we need to be cautious of. They seem to still be focusing on the student and work from the premise that the pre-existing educational framework is one we must necessarily help students adopt or assimilate to. But as Ulriksen, Madsen and Holmegaard (2010) conclude from a comprehensive review of research into attrition in higher education Science, Technology and Mathematics programmes: the programmes and the culture and values revered there, must be considered *part* of the problem. If so, student attrition is no longer the problem itself but rather an expression of the problem. Consequently, addressing the problem by helping students to adopt or assimilate to it would merely make even more people part of the problem. It would not resolve it or make it disappear (Tinto, 1997). A study from Adelaide, Australia of student and teacher perspectives on first year expectations and experiences, illustrates well the concern I have regarding the 'institutional services strand'. The study reports:

> Over 90% of Humanities and Science students responded that studying at university would be different from studying at high school, yet a high percentage still expected quick feedback (…), ready access to teachers, and feedback on drafts (…) as crucial to the university experience: a view not corroborated by their teachers' self-reporting of their practice (.…)[4]. By showing the disjunction between student expectations and their experiences our findings highlight a call for non-specialised transition programs to meet the needs of first year students, help inform them of the realities of university life and hence facilitate the transition from secondary to tertiary education. (Brinkworth, McCann, Matthews, & Nordström, 2009, pp. 169 & 170-171)

I agree that students need to be informed if they wrongly expect the University to provide access to teachers that give feedback. What worries me is that it appears as if this expectation of university teaching constitutes a problem because it exists rather than because expectations exist which the institution cannot meet. One might argue that it is a matter of perspective: what Brinkworth *et al.* offer is a pragmatic solution to a real problem while I remain stubbornly idealistic. This might be so; but the solution of Brinkworth *et al* is non-specialized transition programmes that propose to move the problem from its context by promoting what students perceive to be a problem tied to certain experiences of learning, to a general condition for their participation in higher education. Depending on the scales of such

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[4] It would not be fair to the authors of the cited paper not to also mention that in the part of the quote I omit, they emphasize the importance of timely quality feedback but acknowledge how teachers' increasing workloads make it difficult for them to deliver on their students' needs. As a practical solution the authors suggest that students be helped to become "better internal generators of feedback" (p. 169).

non-specialized transition programmes, they can too easily be construed by students as well as teachers as a legitimization of an institutional discourse that leaves students with only one option: to blame themselves if they find the conditions for their learning difficult (Johannsen, Rump, & Linder, 2012).

I think Ulriksen, Madsen and Holmegaard (2010) are right, when instead they recommend that we find ways to widen the array of student identities that find room and are made legitimately available *within* higher education Science, Technology and Mathematics contexts. This means operationalizing a socio-cultural and cultural-historical perspective on identity as "the meaningful action or practice that is available to the student, being embedded in a culture and bringing with him or her a history and experience of interpretations and practices" (p. 227). Such a perspective is encompassed by what we refer to as *the interactions strand* in Paper I. It is also a perspective that Vincent Tinto's (1993) longitudinal model of student departure speaks directly to.

Next, I lay out aspects of this model that has come to be most important to the framework I use to interpret student interviews with.

4.1. Tinto's model of institutional departure

In building a model of institutional departure, Tinto's (1993) concern was to capture how student-institution interactions are related to attrition and retention. He writes:

> Though [the model] accepts as a given the fact that individuals have much to do with their own learning, it argues that the impact of individual attributes cannot be understood without reference to the social and intellectual context within which individuals find themselves. (p. 113)

As such the model's primary focus is on what "occurs *within an institution* of higher education" (p.112, emphasis in original). Still the model takes into account both the students' prior experiences, and their aspirations and commitments since they might in part be conditioned independently of the institution. The model is depicted in Figure 4.1.

Tinto's model assumes that when a student enters university he or she will already be experienced in interpretational practices. The student has a background and acquired certain habits which will be used to interpret the new situation of university life, but also for being recognized as a student who legitimately belongs at that institution.

Aspects of who the student is, translates into goals and commitments that again translates into who the student (can reasonably) wish to become. The intentions and commitments thus exhibited by the student will reflect the student's institutional experience, both expressed through formal academic attainment and various forms of social engagement.

Tinto's insight is that none of these stages can be reasonably imagined without also taking into account the specifics of the situation the student is thus engaged in experiencing. Experiences of the specifics of the situation influence students' involvement in the life of the educational setting, they influence how students approach their learning, how their learning outcomes are going to be, their continued engagement and goal commitments, and ultimately their departure decision: "The more satisfying those experiences are felt to be, the more likely are individuals to persist until degree completion" (Tinto, 1993, p. 50) and "the greater students' involvement or integration in the life of the college the greater the likelihood that they will persist" (Tinto, 1997, p. 600).

Pre-entry attributes
Family background, skills and attributes, prior schooling
↓
Goals / commitments
Intentions, goal and institutional commitments,
External commitments
↓
Institutional experience
Academic System & Social System
(Classes, labs, studios)
Formal academic performance ↔ Formal extracurricular activities
Informal faculty interactions ↔ Informal group interactions
↓
Integration
Academic Integration ↔ Social Integration
↓
Quality of student effort and learning
↓
Goals / commitments
Intentions, goal and institutional commitment,
External commitments
↓
Outcome
Departure decision

Time

Figure 4.1 Tinto's longitudinal model of institutional departure
(Based on Tinto, 1993, p. 114; 1997, p. 615 adapted to highlight the role of academic and social integration in the model)

To characterise integration – or the various degrees to which social and academic integration is achieved, Tinto introduces the notion of incongruence (or lack of institutional fit) and isolation; both aspects of the institutional experience that one cannot expect students to avoid completely. But the concept finds many other uses. In a very literal interpretation of Tinto's model, academic integration is said to be fully achieved when students graduate to thus emphasize how important it is that international exchange students become socially integrated through social participation both within and outside the immediate context of the learning environment (Rienties, Beausaert, Grohnert, Niemantsverdriet, & Kommers, 2012). In another interpretation, Cabrera, Nora, Terenzini, Pascarella and Hagedorn (1999) reject as a fallacy the idea "that academic preparedness at time of high-school graduation is a key factor accounting for differences in persistence behaviour between African American and White students" (p. 151) to instead draw attention to the dominant impact that racism, prejudice and bigotry related to college outcomes has on both groups' institutional commitments and decisions to persist. And as mentioned in the introduction, yet other uses of Tinto's model allow opportunities to inquire into the construction of identities in science and technology environments (Madsen, Holmegaard, & Ulriksen, forthcoming a) where male chauvinist perceptions of the discipline permeates the student culture to only allow female students dichotomous identities as either girl *or* student physicist (Madsen, Holmegaard, & Ulriksen, forthcomming b). And finally in an altogether different alley, we find Jonas Forsman who has caught onto Tinto's mention of academic and social *systems* nested in different spheres that pervade and interweave academic and social life, to thus inquire into how retention relates to how students perceive themselves placed within social and academic student-networks (Forsman, 2011). To paraphrase Forsman and his colleagues: "The connectedness and interactions between the multitude of variables that are currently recognized as influential to student retention" are characteristic of Tinto's integration model (Forsman, Linder, Moll, Fraser, & Andersson, 2012, p. 2). The same can be said for the ways the model is being interpreted and applied: they are multitudinous, which, to me, is evidence of the strength of the model.

What I caught onto in Tinto's model, is his mention of incongruence when he explains what he means by academic integration.

Institutional fit and incongruence

Take for example a highly motivated student who was adept in acquiring good grades during previous schooling, who is self-confident and yet observant, and who is attentive and open to new experiences. Obviously he will be more likely to succeed in higher education compared to a student who is not. Notice however, that this characterization is indeed just a list of certain dispositions that each point to certain actions or potentials to act intentionally. The role of education is to harness, steer and help realize these dispositions to thus assist the students to intentionally develop the kind of competencies that are deemed 'right' in any one discipline (Barnett, 2007, cf. chp 8).

Another way to look at it is to be perceptive of the type of engagement that is required of different students to succeed, and attentive to issues regarding diversity during times of transition from elite to mass higher education. To do so, it is useful to conceptualize each student's choice of studies as "a process which is differentiated according to the distribution of relevant [social] capitals and which plays its part in the re-institutionalisation of social divisions within higher education"

(Reay, David, & Ball, 2005, p. 160). That is, to think of the choice as a process driven by intentions to improve one's institutional fit, steered and directed in part by the motivation to resolve incongruities: a process which is structured by academic and social systems that structures the student's social and academic commitment.

Both perspectives, whether you focus on how students commit to the institution or if you focus on institutional commitments towards the students, the one reflects the other. Individual student attributes play a role to student success as well as does the institutional make-up: students do, *do* social class when they construct their identities as physics learners (Danielsson, 2012) and studying and researching physics *is* a gendered practice (Hasse, 2009).

The aim of this study is to understand student strategies and attitudes in relation to the structure of the academic discipline they attempt to become *part of* by studying it. Thus, the focus of this study, as with Tinto's model of longitudinal departure, is on *academic integration*: that which has happened when student academic commitments match institutional commitments.

Thus construed, it is made evident that in Figure 4.1, the academic aspect of integration is central to Tinto's model. Part of what influences how the student is received (i.e. how his or her educational experience is going to be) is first his or her initial intentions regarding the decision of starting a degree programme at university and regarding his or her intentions and goal expectations regarding the choice of field of study. Naturally the student's reception also depends on the people already in place; and in interaction students and teachers will impact the student's formal academic performance. Now, learning at university is more than performing academically. It is in large parts a question of the student's involvement; of whether his or her involvement is recognized institutionally as 'the right kind' of involvement both in social and academic terms. Tinto (1993) refers to the properly involved student as one that is academically and socially integrated. Depending on the degree to which the student is involved based on his or her initial commitment to the study, the student might revise his or her initial commitment to better fit what appears to be required. Conversely the student can also revise his or her intentions or goal expectations to better fit the degree to which the student finds him or herself academically or socially integrated. Ultimately the student can also decide to leave.

This system of interactions that is delineated in Figure 4.1 is a relationship between students and teachers that naturally goes both ways:

"In a very important sense, institutional commitment to students and students' commitment to the institution are mirror images of one another," Tinto (1993, p. 201) reminds his readers.

If for some reason a student does not perform well academically, the student's performance can be improved given the right kind of commitment and involvement on the faculty's part. But of course there will be external constraints to the level any one teacher can commit to any one student. First there is the nature of the problem the student experiences compared to the nature of problems his or her peers have. There are economic considerations that decide how much time a teacher can spend on a student; but there are also constraints imposed by the curriculum. It goes without saying that a physics lecturer cannot start to teach the students something entirely different if they have difficulties understanding the topic of his course. He can, nevertheless, take a step back and explain a mathematical concept, if he and the students think this might help. He might also attempt to explain what role a given topic plays in the discipline at large, and so on. There are some things he *can* do, and there are other things he *can not* do. Every physics teacher is probably faced with making such decisions on a daily basis, and guiding such decisions among many other things are the sets of shared beliefs that make up the physics paradigm – among which are (informed) notions of what constitutes proper physics education at university level.

Exposing incongruence

No doubt, some of the problems that teachers and students experience, occur when students' beliefs about what constitutes proper physics learning do not match institutional beliefs about what constitutes proper physics teaching. Some of these situations may very well be due to paradigmatic beliefs about what constitutes proper physics education. When such paradigmatic beliefs are not influenced by students' involvement with their learning, we can see from Figure 4.1 that students must either leave or change their involvement with their education in order to resolve this incongruence.

As modelled here, this process seems straightforward. In reality, however, it is tremendously complex, and as Paper I illustrates, there is no reason to believe that it is conceptualized by students or teachers in any way that resembles the incongruence that is outlined here.

First of all, paradigmatic beliefs are sometimes expressed explicitly in daily institutional life, but most often implicitly and mixed together with all sorts of other beliefs about basically everything that can be rooted individually, locally and historically in and around the institution and the global society by and large (Snyder, 1973).

Second, as a species, one of human kind's foremost traits is our ability to adapt. We do it automatically, all the time, in response to every constraint we experience and are subject to (cf. Jenkins, 2002, p. 103ff). As such, this process of adaptation is one that is probably easier observed than talked about. As far as students' intentional actions based on experiences and interpretation of experiences is concerned, there is no way around the interview however.

Section 4.2 outlines the theoretical perspective that is utilized in this study to structure and analyse the conversation with students about the process of negotiating and renegotiating involvement or integration with the physics programme

4.2. Strategies for coping

The underlying issue that is investigated in this thesis is students' strategies for engaging with their physics education that together with the substantive practices characteristic of the physics programme at the University of Copenhagen possibly introduces a potential source of conflict – a conflict that students need to find ways for coping with. In my mind, the conflict exists when the justification for the particular sequencing and execution of the courses that make up the study programme is incongruent with constructivist notions of how learning takes place. At the heart of this notion, is the idea that to learn, students need to find ways to match their expectations with their experience. Tinto (1993) describes in similar terms how this conflict might be perceived from the individual student point of view:

> Incongruence, or what is sometimes referred to as lack of institutional fit, refers to the state where individuals perceive themselves as being substantially at odds with the institution. In this case, the absence of integration results from the person's judgment of the undesirability of integration [arising] from interactions and the person's evaluation of the character of those interactions (….) Incongruence is almost always an unavoidable phenomenon within institutions of higher education. (Tinto, 1993, p. 50)

What is so important about this quote, like my notion regarding constructivist learning requiring a match between expectations and experience, is that it is coined to allow the possibility that it is not necessarily the student who needs to change his or her commitment to personal goals in order to increase congruency. In my terms, a match between expectations and experience can also be achieved by the student if the person concerned redirects his or her attention to focus on learning related experiences that better match his or her initial expectations. Likewise with Tinto's formulation: the student can work to resolve incongruence through a reinterpretation of his or her *evaluation* of the character of learning related institutional interactions.

If this is 'coping', then it matches the definition of coping Eaton and Bean (1995) make use of to reconceptualise Tinto's model. They distinguish between two distinctly different coping behaviours that are called approach and avoidance behaviour. The difference is mainly perceived as either active or passive responses to a stressful situation that "draw from different motivational forces" why "individual are not exclusively approachers or avoiders" (Eaton & Bean, 1995, p. 619). If a student exhibits approaching behaviour, the student takes assertive action to deal with a stressful situation. In avoiding the stressful situation the student's response is more passive – by *not* doing something – but 'avoiding' can be active in the sense that certain actions need to be taken to avoid certain situations. Eaton and Bean (1995) utilizes this perspective on coping in devising a questionnaire to see how academic and social coping strategies (both of which can be conceptualized as approaching and avoiding behaviours respectively) influence social and academic integration. When they do, however, they tend to be too constricted in their interpretation of what is entailed by academic integration for my taste. They ask students a range of questions that primarily concern the students' perceived satisfaction with their grades, in-class accomplishments and how often they skip classes. Questionnaire items that concern student-faculty interaction solely anticipate situations where students need clarification or are disappointed with their grades.

Consequently I cannot help but be cautious of their use of 'coping' when they define coping as a behaviour that leads to social and academic integration, when at the same time they define academic integration in terms of academic competence (good grades?) and confidence (satisfaction with in-class accomplishment?). It is a utilization that, to me, subsumes that academic integration equates to conforming to educational standards. This is not what Eaton and Bean write however. They write that coping is a "general form of adaptive behaviour (…) by which an individual can either improve an existing situation or defuse a potentially dangerous one" (p. 619), which generously interpreted fits well with my initial conception of coping. But since I want to reserve the right to claim that more might be at stake in academic integration than grades and in-class performance, I much prefer to think of coping in terms of a particular response to 'dynamic interactions and processes through time that students find relevant to their learning in higher education' as Tamsin Haggis (2009, p. 389) almost coined her call for longitudinal studies that "find ways of standing outside of our histories, circumstances and fields, and of examining our epistemological and ontological assumptions." It is an elusive definition compared to that of Eaton and Bean's (1995), but more embracive and tolerant of diverse perspectives on what (ought to) constitute legitimate learning behaviours. It is one that conceptualizes adaptation, not "as the process by which an individual chooses to cope *with* a particular situation" (Bean & Eaton, 2000, p. 51, emphasis added), but one that conceptualizes adaptation as a process, through coping, in which the students form, frame, shape and reshape themselves, make room for themselves, squeeze themselves into an institutional framework that literally speaking was not designed to fit each particular student individually. Coping with education is not the same as surrendering to it.

Before I go further in developing the concept of incongruence and coping, I will expand on how the particular sequencing of courses in the physics programme may be construed as incongruent with constructivist learning.

Sequencing of courses

The courses that students are required to take during the three years it takes to qualify for a Bachelor's degree in physics at the University of Copenhagen are distributed according to a set of rules that presumably is institutionally recognized – including, at least to some extent, the physicists who teach and the students who pass these courses.

A glance at the programme structure reveals that the central physics courses appear to be distributed chronologically. First year students will begin by taking two courses in classical mechanics (originating in and adapted from Newton's work circa 1687, Lorentz and Einstein circa 1905), then an introduction to thermodynamics (which departs from the laws of thermodynamics, first stated as such in 1850) followed by a course in electromagnetism (aimed at developing

Maxwell's equations published in the 1860s). Second year students now begin with a course in electrodynamics (utilizing the second half of the text-book used for the electromagnetism course) followed by two introductory courses in quantum mechanics (starting with the wave function developed in the 1920's and onwards). At the end of the second year, students are introduced to statistical physics (taking a slight step back in history to the work of Bayes circa 1812 and Dirac circa 1926). In their third year, students are free to choose among an array of more specialized physics courses.

I do not think this chronology is a coincidence. Nor do I know of any reason that this, and only this, is necessary. Rather, I think it a product of tradition that might benefit from a rethinking. "Not because tradition is necessarily suspect" writes the 1969 U.S. Physics Survey Committee, appointed by the National Academy of Sciences, "but because it here embodies too rigid a subdivision of the field and thereby tends to obscure the unity of physics, which should remain a central theme in all physics education" (Physics Survey Committee; National Research Council, 1973, p. 1202) – whereby my original concern regarding physics education as a coherent whole (page 9) is reintroduced.

Furthermore, prerequisite requirements for any one course are sequenced as the physics programme is (with the notable exception of thermodynamics, which is only a requirement for statistical physics towards the end of year two). This means that one can make the argument, albeit crude, that the reason students are asked to take courses in classical mechanics at year one is to make them capable of taking quantum mechanics at year two. Following the same logic, the reason students are required to learn about classical mechanics, thermodynamics, electromagnetism and quantum mechanics is that these subdivisions of the field of physics form a basis that allows each student to make an informed choice regarding specializations at year three. Although I doubt that the historical sequencing of the physics courses is strictly necessary, I do not doubt that the courses are taught and have been structured in ways that makes it necessary to presuppose that students have acquired certain knowledge and skills during prerequisite courses. If, however, prerequisite requirements are only given purpose and justification by being prerequisite requirements for later courses, then this justification is empty.

Constructive alignment and congruence

When the reality is that the historical sequencing coincides with the prerequisite requirements, the justification of the physics programme structure seems based on the assumption that physics knowledge is hierarchically structured according to historical necessity: certain knowledge-elements exist, without which other knowledge elements could not exist, and thus cannot be taught and understood. These elements can be structured hierarchically, and when they are, they will appear in their historical order. In accordance with this line of thought, this hierarchical and chronological order can be used as basis for developing a curriculum, and a curriculum very much like that of the physics programme in Copenhagen results.

It is this hierarchical distribution of knowledge I believe introduces a potential conflict if we start thinking of each element in the hierarchy as *inherently instrumental* to the next level. Because then, the first thing a constructivist would require, to expect that any learning takes place across levels is that:

> students be given the reasons *why* particular ways of acting and thinking are considered desirable. This entails explanations of the specific contexts in which the knowledge to be acquired is believed to work. Such explanations are profoundly shocking to those who believe in 'Truth for Truth's sake'. (…) I am convinced, in general, students will be more motivated to learn something, if they can see why it would be useful to know it" (Glasersfeld, 1995, p. 177, emphasis in original).

Now, if seeing is believing there might not be a conflict between sequencing and potentials for learning at all. Any a student who wants to study quantum mechanics can 'see why it would be useful to know' about classical mechanics, since classical mechanics is one of the requirements for the introductory quantum mechanics course. From there, it is just a matter of believing that it is so. But if seeing is more than a surrender, more than a hollow acknowledgment of systemic rules and regulations, if seeing is experiencing, doing, being able, knowing, understanding – for one-self – then a conflict might exist. My assertion is that if students want to stay in the physics programme, if they want to ensure that their own learning takes place across the levels of their education, they either need to have this conflict resolved, or they will need to find ways of resolving the conflict for themselves.

At the heart of this possible conflict, may be issues pertaining to *educational congruence*, which is a term that for example McCune and Hounsell (2005) have used to widen Biggs and Tang's (2011) notion of an outcomes-based teaching approach they call constructive alignment. Biggs and Tang's concept draws on constructivist pedagogies and asserts that if teaching and learning activities that emphasize student-centred learning and assessment tasks are aligned to the intended learning outcomes, students are helped to achieve those intended learning outcomes more effectively. In interviewing students and teachers involved with a segment of courses in the biosciences McCune and Hounsell (2005) find reasons to suggest the concept widened to also acknowledge the ubiquity of opportunities and constraints across departmental settings. They suggest that alignment may be considered "an ideal that is well worth striving for but one that is seldom likely to be attained in any full or complete sense" (p. 259). Instead *congruence* appears a more appropriate term, thinking that a congruence of interests is probably the best we can hope for. Consider for instance how significantly students' backgrounds, knowledge and aspirations can differ in any one course or even across courses. The concept even fits snugly as a reflection of the individual's social and intellectual experience in Tinto's (1993) model of institutional departure, in that one can easily imagine how a lack of educational congruence can lead to feelings of incongruence among those involved.

Thus, this 'almost unavoidable phenomenon' of an individual state of incongruence that Tinto (1993) describes, is likely to originate in the ways student experience congruence within and between courses in the programme. Congruence, in turn, is tightly linked to aims and purpose at the centre of constructivist pedagogies' view on what help students achieve intended learning outcomes more effectively. Congruence is the degree to which the provision of teaching and learning activities fit "beyond specifics of knowledge and skills towards an understanding of the discipline itself and of the values of the profession" (Entwistle, 2009, p. 58) – which, pragmatically speaking, must be the ultimate aim of university education. One might thus think of coping as a way for students to achieve better congruence as a way to deal with their own state of incongruence.

This final bit brings back into focus the issue (from page 14ff.) of how the discipline-as-curriculum came to be: the question of how the programme structure, content and activities reflect the professional practice of physicists. This question is one that can be approached through Bernstein's pedagogic device.

4.3. The pedagogic device

Since the potential conflict that I have sketched here is thought to originate in the particular set of principles which give rise to the distribution of courses that is at the core of the structure of the physics programme in Copenhagen, I frame the analyses of interviews about coping in terms of such *distributive rules*. The concept is one I have borrowed from Bernstein's (2000) *pedagogic device,* which is neatly synthesized by Maton and Muller:

> The pedagogic device forms the basis of [Bernstein's] account of: the ordered regulation and distribution of a society's worthwhile store of knowledge, ordered by a specifiable set of distributive rules; the transformation of this store into a pedagogic discourse, a form amenable to pedagogic transmission, ordered by a specifiable set of recontextualising rules; and the further transformation of this pedagogic discourse into a set of evaluative criteria to be attained, ordered by a specifiable set of evaluative rules. (2006, p. 10, emphasis in original)

My intention by framing the analysis thus, is to allow for a more refined understanding of how students cope to resolve the potential conflict that I believe is introduced by a historically ordered hierarchical knowledge structure.

In paper II in Section 11 we seek to expose the frustration that some physics students in my sample feel by framing it as the result of a tension between their personal and situational interest. To explain this tension we bring out the difference between physics-as-research and physics-as-curriculum and illustrate the difference using Brousseau's notion of the didactic transposition. As such, the concept of didactic transposition serves its purpose well in Paper II, and as I explain in the following, the didactic transposition bears significant likeness to Bernstein's pedagogic device. An important difference, however, is that the latter better captures how students re-transposition or reevaluate the role of the physics they engage with in order to attain a better fit between their expectations and experience, but in a way that reflects crucial aspects of students' interactions with the institutional setting that is home to the physics curriculum they cope with. What is thus made visible is that the different ways students cope to resolve frustration very much reflect the students' relationship to physics expressed through their perception of the nature of the physics curriculum they cope with.

In the next subsection I explain my interpretation of Bernstein's pedagogic device, aspects of how it relates to Brousseau's didactic transposition, but especially how I see each of the components in the device relevant to understanding the physics curriculum in Copenhagen.

Distributive rules

The *distributive rules* concern principles for choosing among the store of physics knowledge, what seems appropriate for teaching prospective physicists.

At the beginning of this section, I wrote about classical mechanics (page 33) as if the only concern in deciding whether students need to learn it is that it is a prerequisite for understanding quantum mechanics. This position is of course so lacking of nuance that it must be considered wrong. It would only be fair to also mention that the obvious real world parallels of classical mechanics offers ideal settings for students to work on acquiring empirical, modelling and problem-solving skills; or for starting to get into the habit of thinking like a physicist. Or that Newton's laws are relevant for almost any situation that occurs in our immediate surroundings and thus serve superbly to illustrate the potential powers of physics and how they are utilized.

There are plenty of reasons for deciding that classical mechanics is a good way to introduce new students to the field of physics, including reasons that go beyond direct concerns about alignment throughout the programme. Some reasons refer to tradition, in that certain physics models functions to "supply the group with preferred or permissible analogies and metaphors" (Kuhn, 1996, p. 184). Yet other reasons are political. The Cold War between the Western and Communist world, for example, left behind deep traces in our current educational system. A year after the Soviet Union successfully launched the first satellite into space the United States Congress passed a public law named the National Defence Education Act. In the introduction it says:

> The security of the Nation requires the fullest development of the mental resources and technical skills of its young men and women. The present emergency demands that additional and more adequate educational opportunities be made available. This requires programs that will give assurance that no student of ability will be denied the opportunity for higher education because of financial need; will correct as rapidly as possible the existing imbalances in our educational programs which have led to an insufficient proportion of our population educated in science, mathematics, and modern foreign languages and trained in technology. (P.L 85-864, 1958, p. 1581)

This demand to 'correct existing imbalances' in the U.S. educational programmes also meant a demand to correct existing imbalances in physics programmes. Ultimately the demand:

> led to a kind of colonization of undergraduate physics, a pressure to standardize the undergraduate curriculum so that students entering graduate schools can be assumed to possess the same level of training regardless of the undergraduate program in which they studied. This pressure (…) had by the 1960's produced a national standard for the number and type of courses considered appropriate in undergraduate programs (.…) The sequence in which the courses could be taken also became standardized" (Nespor, 1994, pp. 30-31).

In 1973 a Physics Survey Committee together with the U.S. National Research Council evaluated trends in U.S. physics education and identified a 'canonical sequence' that "typically includes classical mechanics, electricity and magnetism, optics, thermal physics, electronics and quantum physics" (p. 1201). They commented: "The time may well be ripe for a review of (…) conventional courses, such as mechanics (should and could classical and quantal mechanics be combined?), electricity and magnetism (should there be more account taken of plasma physics?), and optics (the renaissance of which is only beginning to be acknowledged in our teaching)" (p. 1203).

The physics programme at the university of Copenhagen anno 2012 is remarkably like the sequencing of the U.S. standardized curriculum anno 1973. Today, though, one can safely posit that U.S. and NATO affiliate Cold War geopolitical concerns do not offer Danish students much incentive for studying the canonical physics sequence of the 1960s. Other incentives might be present though, and this is where the pedagogic discourse, ordered by a set of recontextualizing rules, becomes relevant.

Recontextualizing rules

With reference to Bernstein (2000), Ashwin (2009, p. 93) writes that "recontextualizing rules govern the transformation of legitimate knowledge into pedagogic discourse, that is to say the transformation of disciplinary knowledge practices into 'teachable material'."

It might thus be worthwhile conceptualizing the *distributive rules*, described previously, together with the *recontextualizing rules* in terms of the didactical transposition from Brousseau's (2002) theory of didactical situations in mathematics. If so, tacit elements of the pedagogic discourse, with its recontextualizing rules, might be thought of in terms of the didactical contract. Both are concepts that serve well to characterise and understand class-room activities in physics with (cf. Buty, Tiberghien, & Le Maréchal, 2004; Johannsen & Jacobsen, 2010). As already mentioned, it is also Brousseau's didactic transposition we use to explain some students' coping strategies with in Paper II in Section 11.

Well in line with my emphasis on justification and constructivist learning, Brousseau (2002) writes that the teacher's prime obligation is to recontextualize and repersonalize those scientific knowledge products or original discourses that have been selected for dissemination through teaching in ways that ensure student learning as "a fairly natural response to relatively particular conditions [essential] to make sense of this knowledge" (p. 23). Bernstein (cf. 2000, p. 173) talks about this process of recontextualization and repersonalisation in terms of a de- and relocation of knowledge producing discourses into pedagogic discourses that are reordered according to its own principles. These principles, we can think of as recontextualizing rules.

While there is significant overlap between the two conceptualizations of the mechanisms that produce curriculum and certain modes of engagement with this curriculum, Brousseau's theory of didactical situations in mathematics focus on describing mathematics teacher practices and responsibilities prescriptively in ways that assume the teacher to be in a position of significant means to control the preparation, orchestration and execution of the learning situation. Brousseau's aim is to suggest particular 'means' that the teacher might (learn to) value.

Bernstein, on the other hand, operates on the more general level, offering a characterization of disciplinary knowledge practices in terms of discursive practices that both encompass the teacher and learner, but situates the teaching-learning situations in the broader institutio-political discourse that might be subject to other concerns than those strictly related to teaching and learning.

Bernstein, for example, writes that by the processes governed by recontextualising rules "the original discourse is subject to a transformation which transforms it from actual practice to a virtual or imaginary subject" (2000, p. 173), thus situating the student and teacher well within the relocation of power relations. Brousseau also maintains this virtuality of the situation, but describes it as a game between student and teacher: "The didactical contract is the rule of the game and the strategy of the didactical situation. It is the justification that the teacher has for presenting the situation" (2002, p. 31), thus placing the justification for the learning situation *with* the teacher, as something the teacher *has* and can base his or her instructional discourse on; in a way that tend to subsume the curricular content while still retaining the teacher's possession of justifications. From Bernstein's perspective, this assumption, that the teacher has both the right and plight to justify the contents of his or her teaching, is not necessarily true. Rather it is a characteristic of the pedagogic discourse and part of what makes the situation and the people subject to the situation imaginary. And how could it be any different? Think for instance if a teacher was to justify to his pupils why physics is taught, true to his own personal experience. It would sound: "Being taught physics allowed me into a college of education that allowed me to teach physics to someone like you." We have to be aware that to properly justify activities related to teaching and learning, it takes imagination and a keen awareness of potentials. To me, it seems like Brousseau makes a distinction between content-knowledge and the values that the teacher can impose on it to encourage that learning takes place, at the risk of mistaking learning and teaching for the creation of a situation where perhaps the better term would be that teaching and learning is the staging of a situation.

In this manner, Bernstein digs deeper and is explicit in not presuming that values and justifications can be distinguished clearly from instructional discourses. Thus "the processes through which the framing of disciplinary knowledge discourses into curriculum takes place are again the sites of struggle between academics, institutions, disciplinary and professional bodies and the employment field, as well as government agencies," writes Ashwin (2009, p. 96) about the pedagogic device – thereby emphasizing that if a separation between justification and instructional discourse exists, then such a dichotomy may very well exist far out of reach of any one teacher or student. I take this situation to be what Bernstein refers to, when he explains how the instructional discourse is imbedded in regulative discourse (2000, pp. 34-35). Still, from a constructivist perspective, justifications will have to be made in order for learning to take place.

From the individual student's and teacher's perspective such justifications might align – or they might not. But in coping, the students will have identified some that are meaningful. Some that to some degree or other will be congruent with institutional requirements. These may or may not encompass the same wide spectre that Ashwin delineates; or they may depart and originate in unique personal experiences and personal meaning-making unique to each student. Retaining Bernstein's perspective on the pedagogic discourse, the possibilities are endless. The extent to which these justifications that students find in coping are meaningful, however, can be evaluated against a set of evaluative criteria – or *evaluative rules*.

Evaluative rules

One might think of evaluative rules in terms of the explicit set of rules that is reflected by criteria used to grade students with. In fact, only in certain situations, the situations Biggs and Tang (2011) advocate for in delineating constructive alignment, do these criteria fully reflect the evaluative rules. This is when student evaluations test for the intended learning outcome. In Bernstein's view, evaluative rules are at the dead-centre of pedagogic discourse, why one might be better off thinking of these rules as the set of criteria that are used to validate legitimate practice and reproduction within a pedagogical setting. Much of what Snyder (1973) describes in his book about the hidden curriculum at MIT concerns those aspects of the evaluative rules that ought to be overtly accessible to students, but are not. They are regulative cultural codes; and sometimes they are misread or not read at all. And together with the rest of the pedagogic device, the evaluative rules are "a condition for the production, reproduction and transformation of culture" (Bernstein, 2000, pp. 37-38) – in which case, the emphasis must here be placed on 'the reproduction of culture'. Again, I think of justifications and aims and want to ask 'whose culture? To which end?' These are questions that physics students, too, will have to answer. They might not necessarily have done so, nor posed the question or even formed an opinion; but in operating within the regulative rules that is physics education culture in Copenhagen, they will have operationalized their own interpretation of the sets of evaluative rules that essentially consolidates the entire pedagogic device that has transformed the substantive practice of physics at the University of Copenhagen into a more or less coherent physics programme.

Summing up

In summary, the pedagogic device is regulated by three sets of rules. These rules are hierarchically dependent, in that the evaluative rules (responsible for the reproduction of knowledge) are derived from the recontextualizing rules (responsible for the transformation of knowledge), and the recontextualizing rules are derived from the distributive rules (responsible for the production of the 'curricular/contents' knowledge). For a student to attain a better sense of congruence, one might very well imagine how this can be attained through adjusting, questioning, challenging, changing or rejecting any a subjective interpretation of one, two or all of these sets of rules. Any an interpretation of the regulative rules will in one way or another have base in experience, why, in a very real sense, regulating ones interpretation of the pedagogic device can be thought of simply as learning to learn in specific settings. In certain situations, learning to learn will entail learning how to ensure circumstances for oneself that better facilitate one's learning. If these circumstances are not already institutionally provisioned for – which they can never fully be – students learn how to cope. One way to cope is to settle – for example, by settling with a meagre learning outcome which in itself constitutes a certain interpretation of the evaluative rules: some students learn more than others.

My intention here is not to equate coping with learning (although I might be inclined to), but to demonstrate the power of the pedagogic device as a tool for identifying and characterising important aspects of coping. We all cope: that was Piaget's whole premise for using biological adaptation to describe human cognition. No, my intention is to make a case for using Bernstein's pedagogic device for modelling or focusing interpretations of how students cope in ways that renders credible how these interpretations relate to the structure of the educational setting that students may need to cope with. Still, a more pedestrian definition of coping is needed to make analysis of student interviews practical, because in this thesis, not all students are perceived as students who cope. I do so, in Section 5, Method.

4.4. Student learning

Today it seems almost self-evident that the outcome of learning is determined by how the learner perceives and interprets the learning task, and that this perception in turn is determined partly by the student's prior experience, and partly by the context of the task. As a consequence, empirical studies have been able to show that "students' and academics' perceptions of teaching-learning environments are consistently related to the quality of their learning and teaching and to the quality of students' learning outcomes" (Ashwin, 2009, p. 5).

This relationship between perceptions, context and outcome is often referred to as the 3P model: Presage, process and product:

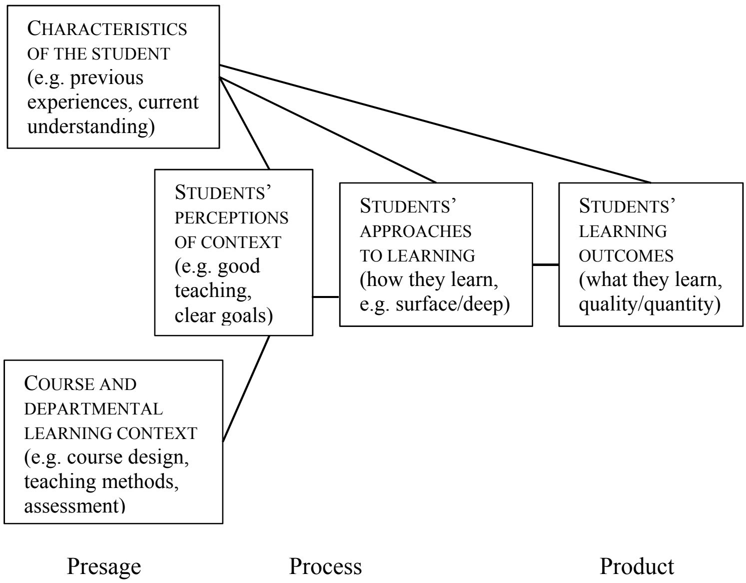

Figure 4.2 The 3P model of student learning. Adapted from Trigwell and Prosser (1997, p. 242)

In literature, this model is primarily used to illustrate how a student's ways of engaging with the content, is an issue that is closely tied to situational experience (cf. Marton & Säljö, 1976b). In the context of this study, the 3P model was used to guide my interviews with students about their involvement with their education – which I will describe in further detail in Section 5.3. As a consequence a pattern emerged in the data, which research question 2 (see page 12), Section 6.4, Section 7 and Paper III in Section 12 address. In this section I outline a perspective on how these ways of engaging with the contents can be perceived as distinct and particular approaches to learning.

Approaches to learning

Before Marton and Säljö (1976a, 1976b) published their papers on *qualitative differences in learning*, research on student engagement was primarily concerned with student characteristics, such as personality and motivation (Case & Marshall, 2009). What Marton and Säljö had done differently was to place an inquiry into student engagement relative to distinctly different tasks, and thus showing that students approach their learning in qualitatively different ways depending on their perception of task requirements, thus suggesting that students' inherent characteristics were not as important to the quality of their learning outcome, as had previously been assumed.

The methodology they used is called phenomenography, and in essence this is a method that does not focus on individual attributes but instead on phenomena that exists among individuals, with the purpose of categorizing these phenomena as qualitatively different interpretations of the same phenomenon. Even more importantly, when it comes to learning, such qualitative differences in experience can be tied to the quality of the learning outcome (Marton & Booth, 1997).

Marton and Säljö's original finds have gradually been refined, and what was previously described in broad terms such as "students had sought a thorough understanding of the author's message, while others had relied on 'question spotting'" is now thought of in terms of deep and surface approaches to learning (Entwistle, 2000, p. 3). Several interpretations of what is meant by surface and deep approaches have been suggested. One is Bigg's (1993):

<u>The surface approach</u> "is based on a guiding principle or intention that is *extrinsic to the real purpose of the task*. The strategy arising from that is 'satisficing', but not satisfying, task demands by investing minimal time and effort consistent with appearing to meet requirements. In the academic learning context, the strategy of rote learning selected content without understanding it is one of the commonest ways of doing this, but it is not the only way" (p. 6). <u>The deep approach</u> "is based on interest in the subject matter of the task; the strategy is to maximise understanding. The focus is thus on underlying rather than on the literal aspects of the task; the intention is to *engage the task properly*, on its own terms. It is thus not possible to say what 'the' deep approach is, beyond the fact that it is funded in intrinsic interest in that *particular* task, and an intention to extract maximum meaning from it" (pp. 6-7)

Along the way several suggestions for a further elaboration of this dichotomy have also been suggested, one of which entail a strategic approach, in which the learner focuses on achieving high grades by employing and developing organizational and time-management skills, by monitoring his or her own study effectiveness and by being alert to the assessment process (Entwistle, 2000). There is however a later development to the elaboration of learning approaches which has caught my eye. It rests on the distinctions between deep, strategic and surface approaches, but takes into consideration too, that when learners are engaged with a particular phenomenon, one perception of learning may also entail relating this phenomenon to other phenomena relevant to the wider realms of the learners' education, learning and aspirations. This elaboration came from the hand of Fyrenius, Wirell and Silén (2007) and they call it sifting, holding and moving. I have synthesized their description and inserted it in Table 4.1. To structure this synthesis I draw on two dimensions that was used by Marton, Watkins and Tang (1997) to capture the variation of ways learning is experienced. These dimensions comprise a temporal facet and a depth dimension. The temporal facet is made up of 'acquiring', 'knowing', and 'making use of' – which I have interpreted as 'learning act / process', 'intention / goal' and 'expected outcome / relevance'. The depth dimension is comprised by variation in the experience of the temporal facets – in this case, 'sifting', 'building: holding and moving'. Fyrenius, Wirell and Silén (2007) offers a third dimension that I also use in my synthesis which comprise the learner's interpretation of the relational aspect between 'details' and 'wholes'.

Table 4.1 a synthesis of Fyrenius, Wirell and Silén's (2007) characterisation of approaches to understanding

Approaches to reaching understanding	Temporal facet		
	Learning act (process)	**Intention (Goal)**	**Expected outcome (relevance)**
1: Sifting *Linear:* knowing details equates to understanding	'Take in' understanding from books and teachers. Copying and condensing	Verification	Those that the system demands
2: Building	Constructing knowledge through relations.	'Owning' understanding	Ownership
2a: Holding *Competing:* Details and wholes are studied separately.	Structured reorganization of information	Reaching a final goal. Sealing knowledge against threatening alternatives.	Control in the learning act. Ability to explain properly.
2b: Moving *Collaborating:* Details and wholes are studied simultaneously.	Strive for variation using multiple learning modalities and inquiry techniques.	Refining understanding in an open ended process.	Ability to apply knowledge in novel situations

To me, understanding entails the ability to act and react in certain situations: to identify, apply and make use of relevant knowledge, which is essentially also how the concept of competence is operationalized in the Organization for Economic Co-operation and Development's (OECD) discourse on scientific literacy used to develop the Programme for International Student Assessment (the PISA test) (Dolin & Krogh, 2010). On the concept of competence, Dolin, Krogh and Troelsen (Dolin, Krogh, & Troelsen, 2003) elaborate:

> The concept of competence combines abilities with intentionality. The concept thus transcends the educational system or makes a demand that the educational system adapts to its environment to allow room for activities that require action. (p. 69, my translation)

Such a conflation of intention, action, knowledge and understanding allows for a situated perception of what is entailed by understanding: It is relative to the learner's intention with acquiring an understanding of the knowledge in question, and is not at all normatively restricted *'to the real purpose of the task'* like Bigg's (1993) interpretation of deep and surface learning is. One might disagree with a students' intention in learning, thinking that it is inappropriate. For instance, a student who equates understanding of certain knowledge with the ability to solve problems of the type that are institutionally required is to me an irrelevant expression of intention compared to a student who equates understanding of certain knowledge with the ability to apply it to a problem that carries subjective relevance and purpose. But it might not be to a student, why I also perceive of a conflation between approach to learning, approach to understanding and engagement with learning; which is the primary insight I see reflected by Fyrenius, Wirell and Silén's (2007) categorization of three approaches to reaching understanding. They describe the approaches thusly (p. 155):

<u>Sifting:</u> "Understanding is acquired from books and teachers and is verified by tuning the demands of the system."

<u>Building:</u> "Understanding is constructed by actively relating to previous knowledge and by making the understanding your own", as well as through:

> <u>Holding:</u> a "reorganization of information with the intention to reach a final goal. When understanding is reached, it can be threatened by new input and is sealed and held on to. The ability to explain properly" is used to verify understanding.

> Moving: "a striving for change in perspectives of the phenomena by using multiple learning modalities and inquiry techniques" in an open-ended process, verified through application.

Individual student engagement as 'sifting' and 'moving'

In operationalizing Fyrenius, Wirell and Silén's (2007) characterisation of what students do to learn, I apply their categorization to interpret individual student interviews. This means that inherently, I defy the ontological claim that phenomenographic methodologies make regarding the validity of the results they yield. The phenomenographic claim, is that no one phenomenon will be entirely characteristic of any one person's behaviour, understanding, interpretation etc., but instead that the qualitative phenomenographic characterization is valid to only the extent it can be used to characterize aspects of any one person's disposition. Thus, in my use of approaches to learning characterizations, I use the descriptions these categorizations offer as a particular analytical lens that allows me to "come to grips with the storied quality of human experience" (McCormack, 2000, p. 285), which in my case is the storied quality of first year physics students experience of studying physics at the University of Copenhagen.

This also means that I am employing a certain interpretation of Fyrenius, Wirell and Silén's (2007) characterization of learning approaches. First, I disregard their characterization of a 'holding' approach, considering it an in-between aspect of learning approaches that can be grouped together with variations of strategic approaches as well as other approaches I might know of. Instead I look for expressions that can be interpreted as either evidence of a 'sifting' approach or a 'moving' approach. I disregard all notions, that 'intrinsic' interest necessarily belongs in the deep end of the 'depth dimension', thinking that intrinsic value is a matter of perspective.

The 'sifting' approach I primarily think of as an approach to learning that is not focused on transcendental aspects of the task or on action, one that accepts as a premise that a task, a knowledge element or understand can serve a purpose in itself: that knowledge can be thought of legitimately as self-referential. Sifting would thus entail engaging in a course without any significant reflections regarding the purpose and aim of the course or reflections regarding the value of learning in the course relative to other courses.

As does Entwistle (2009), I mainly conceptualize the 'moving' approach as one that is focused on acquiring understanding of knowledge in a proactive perspective – why I henceforth refer to this approach as proactive, or as proactive engagement. My main focus in identifying situations where there is evidence that a student employs a proactive strategy, is if the student is concerned with how the knowledge he or she is engaged in understanding applies to the furthering of an ability to identify, apply and make use of this knowledge in various and different situations.

In short, I interpret the sifting approach as one directed at gaining understanding for the sake of learning, and the proactive approach as one that is aimed at gaining competence.

This means that sifting can take the form of a surface approach directed at rote learning, but allowance is also made for the situations where students equates these types of engagement with understanding and with intrinsic motivation often derived from the feeling that the strategy employed corresponds to institutional requirements.

Similarly, the relationship between proactive engagement and deep learning is also retained: a student might very well be intrinsically interested by the task, and engaged in a way that seems presupposed by what would widely be interpreted as 'the real purpose of the task', but I add to this, that engagement must also be grounded in wider purpose and aim. Because, as Perkins (2008, p. 5) formulates it: "Knowledge needs to function proactively, if it is to function at all." This means that the proactively engaged learner is very likely to be engaged in learning to understand something because understanding serves as means to an end that transcends the purpose of the task itself, and because it inherently translates into an ability to do something that is important to the learner to be able to do. Such a strategy might be congruous with institutional requirements, but if so, this is secondary to the purpose of the task.

A description of how this perspective is utilized to interpret student interviews is offered in Section 5.6

5. Method

My study is an analysis of a longitudinal set of interviews performed with first year physics students at the University of Copenhagen. In total, 26 individuals were interviewed. Of these, 15 were interviewed once before they started studying physics, and then on a regular basis throughout their first year. Another 11 students were interviewed once at the beginning of the first academic quarter, and of these, seven were interviewed again at the end of the year.

In this section I am first (Section 5.1) describing how I selected students for interviews, as well as explain the reasons for the particular size of the sample. In this section there is also a short overview of the physics programme that the students I interviewed were studying under.

Then I describe my interview method in Section 5.3. In Section 5.4, I describe the reasons for reducing my initial sample of interviews with 26 individuals to an analysis sample of interviews with 18 individuals.

In the Sections 5.5 and 5.6 I describe how I have engaged with the interview data to answer my research questions.

5.1. Selection of interview participants

When I designed the interview study my intention was to interview students in an on-going fashion in order to capture their negotiation and renegotiation of their involvement as they progressed through their first year of studies in the physics programme. The aim was to link this continuous re/negotiation to the students' interpretation of the particular structure of the programme, and ultimately to link early departure to such interpretations. Instead I now link coping strategies to this continuous re/negation of interpretations.

My aim was not to capture *certain* students' ways of interpreting their experience, but to capture the *ways* that students interpret their experience. It was thus important for me to select a sample that resembled the larger group of students who started studying this particular year. Although I have attempted to identify a sample that resembles the larger cohort of students who started this particular year, the sample is not a representative sample, because any one group of people are never truly representative of another group of people (for a persuasive discussion of this issue see Howe, 2004).

Interview sample

In my design I anticipated a certain rate of attrition, and decided that a large sample would be preferable to a small sample – not knowing how many students would leave the programme, nor when they would leave, and unwilling to risk not having a sample at all.

Another aspect that went into deciding the sample size was time. I could not contact students until they had received their letter of acceptance from the university. They did so, on the last of July and would commence their studies at the end of August. I wanted to interview as many as possible before they started studying. I started out with a potential sample of 30 students. I interviewed 15 of these before they started (interview group A), and another 11 during the first months of the academic year (interview group B). At that point I decided that I could not manage to interview a larger sample longitudinally, why I settled for a total of 26 students. I also decided that I could only manage to interview 15 students on a regular basis, why I intended to re-interview the other 11 students only once, at the end of the year. Unfortunately, I only managed to re-interview seven of the students in interview group B.

My main criterion for deciding which students to interview was that, as a group, they should resemble the larger group of students who started studying this particular year. I was in possession of the same information the institution had received from the students for application purposes. I knew their names, age, gender, addresses, their year of graduation from secondary education, their grade-point average and the type of secondary school they had attended – the latter two, being what the institution needs, to decide if a student can be accepted into the physics programme – the students do not motivate their application in any way. But I would also like to know something about their reasons for having decided to study physics, why I had a letter attached to their letter of acceptance from the university. In this letter I urged them to go to a web-page and give replies to a qualitative-style questionnaire I had designed for the purpose. Within a week after the students had received their letter of acceptance, I phoned those students who had not yet answered the questionnaire to ask them to do so. All in all, I managed to secure a response rate of about 70%.

It is not uncommon in Denmark that some of the people who are accepted into a university programme never turn up and enrol. Thus, at that point, I was only sure that the 70% who had answered my questionnaire intended to begin to study physics, why these were made the basis of my sample:

Table 5.1 Sample distribution compared to the cohort that started this particular year. STX, HTX and Other are indicative of the type of secondary education these students had attended. HTX is a technically oriented, while STX is the ‘regular’ type.

Gender	Male	Female		
	All: 66%	All: 34%		
	Int: 69%	Int: 31%		
Type of secondary education	STX	HTX	Other	
	All: 72%	All: 19%	All: 9%	
	Int: 69%	Int: 23%	Int: 8%	
Gradepoint average	High	Medium high	Medium	Low
	All: 30%	All: 29%	All: 27%	All: 14%
	Int: 35%	Int: 35%	Int: 15%	Int: 15%

Since my sample comprise approximately a third of the students who enrolled this year, I had opportunity to select between individual students as long as it did not change my sample distribution. For this purpose I used the replies the students had given to the questionnaire, and mainly selected those students who had given replies that were indicative of reflection and thoughtfulness. This method of selection was based on a purely subjective evaluation on my part: a way to identify individuals that might be best suited to engage in a one year longitudinal interview-study with me as the interviewer. I then phoned each of the students I had decided would fit in my sample, and if they answered the phone, they always agreed to participate.

The physics programme at the University of Copenhagen

The programme these students enrolled in, I have termed a traditional physics programme, and described cursorily in the introduction. Below, I will offer an overview of the three years of the Bachelor’s programme in physics at the University of Copenhagen.

Each year of studies are divided into four academic quarters (AQ). During each AQ students are required to take two courses. The first year of studies are characterized by mandatory courses. During academic quarter 4, however, students need to choose between cosmology, introduction to biophysics, climate physics or mathematics for physicists 2. None of these electives require that students continue a specialization in the disciplines these courses represent, but usually students do. During year two, students are required to specialize in either mathematics, astronomy, biophysics, meteorology, biophysics or geophysics (or other specializations that are not relevant here). Year three is mostly comprised of elective courses. Students can choose between most courses offered by the faculty of science, and in some instances students also choose to take courses outside offered at other institutions – for example from other universities. During the final half year of their studies, students are required to do a supervised Bachelor's project. This is a thesis project.

Table 5.2 The Bachelor's programme in physics

AQ1	AQ2	AQ3	AQ4
Introductory mechanics and relativity theory	Classical mechanics	Thermodynamics & first year project	Electromagnetism
Introduction to mathematics	Linear algebra	Mathematics for physicists	Specialization
AQ5	AQ6	AQ7	AQ8
Quantum mechanics 1	Electrodynamics and waves	Quantum mechanics 2	Statistical physics
Elective course	Theory of science and ethics	Specialization	Specialization
AQ9	AQ10	AQ11	AQ12
Elective course	Elective course	Bachelor's project	
Elective course	Elective course	Elective course	Elective course

Since I did the interview study this programme structure has changed slightly, in that Electrodynamics and Waves are now taught in AQ5, which means that students are now introduced to Quantum Mechanics in AQ6. More information about the programme in Danish can be found at: www.studier.ku.dk/bacheloruddannelser/fysiskefag/. Unfortunately no information about the programme is available in English.

In the interview quotes that I bring throughout this thesis, students often refer to these courses and the disciplines they cover, why I have used a standardised abbreviation:

CM: Classical Mechanics (either of the courses, otherwise CM1, CM2)

TD: Thermodynamics (this abbreviation does not include the first year physics project)

EM: Electromagnetism

LinAlg: Linear Algebra
MathP: Mathematics for Physicists
MathP2: Mathematics for Physicists 2
QM: Quantum Mechanics

5.2. Interview design

The study I have done rests on a longitudinal interview study with first year physics students from the University of Copenhagen. The reason I chose to do a longitudinal study is based on my experiences doing a research project on student attrition at the University of Uppsala in Sweden (see Johannsen, 2007). There, I interviewed students who had already decided to opt out of physics, with the intention of gaining insight into aspects of the Uppsala physics programme that might be a contributing factor to their decision. When I interviewed the students, however, I was surprised to discover that they resisted offering any critique of the programme as such; instead they offered substantial retrospect critique of their own ability and engagement as physics students. Neither during the interviews, nor afterwards was I ready to accept that the students were as disengaged and bad at doing physics as they claimed – especially not considering the staggering 50% attrition rate at the institution at the time. Instead I decided that the premise of the inquiry design was wrong: In retrospect, it is difficult for students to contemplate institutional circumstances, and by far, easier to contemplate, reflect upon and recall subjective interpretations of the experience; especially considering that the process of deciding to leave a study programme is one that at its outset, is one that revolves around contemplating ones institutional fit and lack of social and academic integration (Tinto, 1993).

I thus envisioned the process of deciding to leave as an on-going negotiation and re-negotiation of factors that had been influential on the choice of studying physics informed through on-going experience in physics. Thus, to gain insight into the reasons for leaving physics studies, I would have to make a design that would allow for the possibility of gaining insight into the process, as just that: an on-going process of negotiation and renegotiation. A longitudinal interview study seemed to be the answer. And it had to start well before the process started. It had to begin with interviewing students before they started studying physics. As it turned out, this strategy did not work for gaining insight into student attrition, because very few students in my sample actually left. Instead, the design allowed my insight into the struggle many of the students I interviewed went through, to keep on wanting to study physics. Thus the study turned into a study of retention. In the next section I describe the method I employed in interviewing the students.

5.3. Interviews method

As you study you get wiser. You become better at knowing your own interests, your reactions, your preferred modes of engagement, what it takes for you to learn, what you want to learn, need to learn, and are required to learn. You learn how to perform at examinations, and you learn how you are received and perceived by others when you attempt to perform. It is all very complex, and not at all separable into distinct parts of a modelled process. For guiding an interview conversation however, both Tinto's (1993) model of student integration and the 3P model are useful. First, both models must be perceived as depicting an iterative, complex process. The student will strategize his or her engagement in learning based on certain expectations of programme, content, environment, requirements etc. Depending on how this strategy appears to work out in practice, momentarily, the student will refine this strategy continuously as a sort of process of learning to learn. Second, as time goes, everything changes. New teachers, new courses, new learning experiences; self-perception changed. Still, some things, continuously informed, remain the same in the larger perspective: a strategy that worked in one course might work in consecutive courses too, but the student's own satisfaction with the learning outcome might gradually deteriorate. Or the other way around. Or not at all. Given sufficient time, one might think of this continuous refinement of strategies as a process of negotiation and renegotiation. Sometimes the process might even be consciously deliberate and lead to affirmative action or dispositional changes – in which cases the outcome of this process might be thought of in terms of a coping strategy. If the strategy works and continues to work, it is a successful strategy for coping, but I will return to this aspect of the interview in Section 5.5.

By repeating interviews over time, one gains information about the more general aspects of the students' learning experience, and not merely the aspects that can or will be ascribed to the unique situations only. The student's engagement viewed over time provides information about the student's involvement in the institutional setting and *about* the educational setting. Several students, interviewed over time, provide information about various ways that students experience their involvement constrained; and might thus offer general systematic insight into how students experience the particular structure of programme in terms of their own engagement, and how they interpret this structure in terms of adopting certain educational ideals and ideologies. Over time the interviews will also reveal how students revise and renegotiate their strategies and their attitudes to ensure congruence in their learning experience. In turn, the bulk of this information might systematically reveal otherwise incongruent aspects of teaching-learning interactions in the particular context of these interviews.

Thus, by making the topic of the interview just right, one might gain insight into the structural conditions particular to the student's experience of studying physics, which is also the reason I chose the interview as a method for inquiry in the first place: only through interviews is it possible to gain insight into students reflections about their reaction to their experiences. One might have considered focus-interviews as a viable alternative, although this would introduce an obstacle to gaining access to the truly individual reflection on institutional experience. Besides, such interviews require a level of structure, that I am convinced would not have been conducive to this study; an important point I elaborate next.

Interview questions

As is also mentioned in the introduction to Section 5.3, I designed my interviews to solve the anticipated problem different premises: the student's contribution to the interview would take at its outset the student's subjective interpretation of reality, while my purpose for conducting the interview would be to gain insight into the institutional circumstances that are at the root of the student's experience. In Paper I, in Section10, I investigate this problem further and find that the problem can be illustrated as one of causation: from the student's perspective, he or she will always be the centre cause for his or her experiences, while an outside observer may perceive the situation somewhat differently.

To solve the problem a viable option was to get the students as involved in the interviews as possible. The best way I could think of, was to empower them as co-constructors of the interview inquiry. Thus, the first interview was designed as an inquiry into the students' reasons for starting to study physics, and an inquiry into which obstacles and difficulties the student expected to meet during his or her studies in physics. Towards the end of the interview, the interviewee and I constructed a set of themes that the student could take home, and use for deciding what the topic of the next interview should be. In constructing these themes I offered some suggestions and guidance based on what I had gradually sketched on my notepad during the interview. The result was that we could end the interview having constructed these themes together based on what we both thought of as potentially relevant to the student's on-going experience in physics.

After the interviews I structured and elaborated slightly on the themes, and e-mailed them to the student, asking him or her to keep them in mind, and be ready for informing them further at the next interview.

Because the themes were constructed based on specific expectations, hopes, worries and aspirations, they are somewhat implied. Nevertheless, I offer as an example below, a translated transcript of the themes that Bertil (student A12) and I agreed on. (Bertil turned out to need cope, to stay in the programme.)

- To make physics marvellous (self-motivation)
    - The lecturer's responsibilities
        - "to make things work, the curriculum is relevant and that we are given some relevant problems" –does that expectation hold?
    - Own responsibilities
        - "to make physics marvellous, interesting and visualize inside the head and come up with examples myself" Does this still work for you, as your own job?
        - How to you find the sparks and inspiration to keep the marvel going?
    - What does what to your motivation?
    - Does physics the physics you learn add to a "coherent form of understanding" opposite isolated elements you can use in particular types of problems/contexts?
- The structure of the physics programme
    - The practical perspective on use, in the particular educational elements
        - When do you realize the practical dimension?
    - Inspiration for the future
        - When are you inspired by what the education can be used for?
    - To learn to think like a physicist
        - Communication across physics disciplines
            - Where does that happen?
        - Ability to problem-solve like a physicist

                - Where does that happen?
        - When do the elements of the programme get exciting because the purpose of the elements get obvious?
        - You expected that physics would be sufficiently easy for you, to be able to spend more time on mathematics. How does that go?

Each time I interviewed a student, I had printed the themes, and asked the student which one he or she wanted to talk about. Sometimes they had already decided and at other times they decided on one or more themes at the beginning of the interview.

This aspect of my interview design seemed to work very well although the participants did not necessarily do as agreed. With an apologetic air a student could start the interview with a “sorry! I haven’t had time to think about the themes at all. We’ve been so busy,” at which point it was sufficient to ask “how so?” to get the conversation going in a direction that informed the themes. At other times, the student was not able to decide on what theme to talk about “because they are all too relevant”, “because, none seem relevant right now” or “not much has happened since the last time. We are just doing problems right now.”

In this manner the themes seemed to ensure that the longitudinal interviews resembled something like an on-going conversation about expectations, experiences and about getting wiser, about trying something different, about being frustrated or about being happily surprised, discovering that things were not as difficult as expected, that the future was bright. And about physics! To me, it seemed like the rapport we were building, was a sense of shared excitement in finding out what would happen next, but far too often the sense was of a shared consternation in the gravity of confusion. Most often however, the situation was a little calmer. I was confused or critical of the physics programme, and the student would patiently explain to me, the sense of it all.

The initial interviews typically lasted roughly an hour. My intention was to keep consecutive interviews down to 20 minutes, which was possible in some rare instances. The final interview was a redo of the first interview. Before each interview I had prepared by listening through all previous interviews I had done with the student I was going to interview, why the students’ storied experience during his first year of studies was used as a recuing theme that served to structure the final interview. This, I started by explaining to the participants, that although I was aware that they were going to continue in their studies of physics, I would like to conclude the interviews with a look back at what had happened during the preceding year, and thus reflect on "What it is about your experience of studying physics, that makes you want to continue studying it?" These interviews were typically just as long as the initial interviews, but sometimes longer. All together we did 93 interviews. Not all are analysed methodically for this study (I explain why in Section 5.4), but all interviews serves as a background for the analysis. A complete list of interviews, dates and durations of interviews used for analysis is printed on page 66.

Interview structure

I like to think of these interviews as loosely semistructured individual interviews (see Kvale, 1996, p. 127ff, for a description of the semistructured interview). To guide my inquiry I used my knowledge of students learning (e.g. the 3P model) to direct my questioning. But the students themselves decided on the overall questions that I asked – or rather, based on the themes, the students asked and answered the questions themselves. My role during the interviews was to prompt the students and to offer a critical perspective on their interpretations of their experience.

I am aware, that supposedly a qualitative researcher must aim to be as unbiased as possible, must construct an aura of objectivity and knowledgability, that bias and idiosyncrasies are considered a weakness (cf. Johnson & Onwuegbuzie, 2004, p. 20). In terms of longitudinal interviewing however, I found it important to establish close rapport with the students who participated. To do so, I needed to be and show that I was genuinely interested in their story, and especially interested in their interpretations of their stories. From my perspective the best way to show and ensure this genuine interest and to avoid the ethical problem of "instrumentalizing the warmth and caring" (Duncombe & Jessop, 2002; Kvale, 2008, p. 24), was to be prepared and to ask them questions about themselves and their doings in ways that clearly showed them that the topic of our conversations was something I had been thinking about and had my own opinions about. And in fact, in the context of physics education at the University of Copenhagen, this aspect of my interview technique is not at all new. Cathrine Hasse enrolled in the physics programme in Copenhagen as an anthropologist with the intention of studying gendered approaches to studying physics, and she writes:

> Apart from the comments by the other females in the group I found another way of deepening my understanding of the generality of my experiences, and thereby the fieldwork data springing from experience. I began to present small analyses dealing with fieldwork data to the interlocutors themselves and this was in itself a new kind of feedback on my being anthropologist and the analysis I could make from this position. At the beginning this method of presenting participants in the field for my analysis was not part of my methodological considerations, but simply sprang from my positioned relation to the field. Contrary to many other kinds of fieldwork, my interlocutors were not only knowledgeable academics, but also professionally curious about an anthropologist's work and results – so they started to urge me to present my fieldwork analyses. Giving this feedback enhanced my field of analysis. At the same time these presentations became my feedback to the field. The presentations as feedback opened up for new discussions. (Hasse, 2000, p. 8)

As it did for Hasse, it worked splendidly to allow a partnership to evolve during the interviews, by allowing the student a role in the construction of the inquiry, in the on-going analysis and in the decisions made regarding the direction of the inquiry.

Presented this way, it might seem that I let go of a lot of responsibility for ensuring the quality and outcome of the interviews, and instead let it be up to the participants to take over and ensure that I was properly informed. To some extent this is true, but to some extent it was also purposefully so. In a not insignificant sense I intended for the interviews to be a co-constructed inquiry into the learning of physics, interesting to both an educational researcher and to a physics learner, thinking such a construction likely to be the most effective way of maintaining interest and incite motivation (cf. Polanyi, 1962, p. 64). As to the issue of responsibility, and who should bear it, Kvale (2006, pp. 485-486) writes:

> In social science research, the interviewer generally upholds a monopoly of interpretation over the interviewee's statements. In daily conversations, as well as in philosophical dialogues, there may be a conflict over the true interpretation of what has been said. In contrast, the research interviewer, as the "big interpreter," maintains exclusive privilege to interpret and report what the interviewee really meant and to frame what an interviewee says in his or her

> own theoretical schemes. The power asymmetry of the research interview needs not be as one sided as [this]. […] A Socratic approach to interviewing [for example] would imply emphasizing conflicts in interpretations and an approximate egalitarian power distribution. It would entail a mutuality where both parts pose questions and give answers, with a reciprocal critique of what the other says. […] The research interview is then no longer understood as via regia to an authentic inner self of the interviewee but becomes a conversation that stimulates the interviewee and interviewer to formulate their ideas about the research theme, potentially increasing their knowledge of a common theme of interest.

This description of the Socratic interview is of course merely an ideal that guided my ‘daring’ to counter and be slightly opinionated during interviews. In fact, I am not sure that all the interview participants would recognize my description of how the interviews were framed. In many cases I kept to my prepared notes and the interview proceeded as eventless as any a semi-structured interview. And of course there were limits to my involvement too. As a guiding principle I never spoke with the students about what other students did. Of course I never told one student about what another student had told me, but I tried to discourage students in speaking in detail about other students too, to thus impress on them that other students I interviewed did not do this either: that I was not in possession of any other personal information, than the information they had themselves volunteered. In the case of three students, however, I did not manage to keep with this intention. They were all part of the same study-group, they were all participating in the interviews, and they knew about it. It thus served the purpose better, to let go of the pretend and allow the students to speak freely of one another instead of pretending that I did not know who they referred to when they spoke of their lab-partner, project-partner, homework-partner and two best friends. Towards the end, however, this ‘slip’ was the cause of an incident where I inadvertently disabused their trust to do an ‘inquiry experiment’. For this reason there are parts of the interviews that I have not been able to bring in this thesis, although at places they would have served well as illustrative examples. I describe the incident in the next-subsection which is about this and other inquiry experiments I ventured into along the way.

Inquiry experiments

During my interviewing I also ventured into some experimentation, to explore other facets than the students own experience of studying physics to see if other ways of informing my inquiry would be fruitful. None, but one were particularly successful.

At one point I ventured out, “into the field”, to visit and interview the students in their ‘natural habitat.’ This was somewhat successful, but extremely uncomfortable. I had sworn to the students that no-one would know of their identity as informants, unless they told people of it themselves. I had of course agreed with a couple of students that I would visit them in the laboratory, but when I arrived, other of the students whom I interviewed, where present. I had not remembered to warn them, that I would show up. However, I think I was the one who felt that this was a problem, though: it was really difficult for me to figure out how to react to them. Did I acknowledge that we knew each other, or ought I to just play stranger? I only did this once, and for this reason decided not to start observing teaching, which might otherwise have been very informative too.

Perhaps, the biggest catastrophe was when I decided that it would be interesting to get ‘both sides’ of a particularly complicated conflict, and ventured to interview one of the lecturers I trust. The interview was extremely interesting in terms of the alternative perspective it offered to my student interviews; but as any caring person would do, the lecturer went and apologized to the students afterwards and completely obliterated the trust I had earned with the students. I am still very sorry about this blunder. I should not have done this, and never attempted to again.

To ensure that participants would want to participate I thought it prudent to give them something for their troubles. First, I had bought 40 tickets for the movies that I gave away by lot to 20 of those who replied to my questionnaire before a certain date. As it turned out, people did not mind getting the tickets, but it was of no consequence to their choice of replying to my questionnaire. I have continued distributing this questionnaire to consecutive cohorts and have not offered anything for answering the questionnaire, and people in large numbers still answer it each year. Also, as a way to retain students in interviews and show my appreciation for their participation, I promised to buy them one textbook of their choice. Close to Christmas I also surprised them by giving them another book I thought they would find interesting. My impression is that, mostly, it weirded them out – and me too. They had been very open and frank about their experiences in physics, and had not spent more than 10 hours telling me about them. For that, I gave them a book. It felt like I breached an implicit understanding by introducing a material obligation. Once I had given them a book, they would need to give something back, and what I asked for, was their honesty and private experiences. A sincere 'thank you' is much to prefer, and I can recommend to no-one, to show gratitude to informants by giving them things – unless this is an explicit condition for participation, maybe.

The one 'experiment' that worked very well, was interviewing a teacher about his attempt to teach laser-optics to two first year students in an integrated laboratory setting (see Henningsen, 2011). I interviewed him about his thoughts and intentions, and I interviewed the students about their experiences during the project. Aspects of this mini-study are used to inform a set of papers that are not included in this thesis (Jacobsen, Johannsen, Rump, & Jensen, 2009; Johannsen & Jacobsen, 2010). I believe the reason for the success of this inquiry is that all participants were aware that they were participants, and all were interested in informing and documenting their work through interviews: that there was no need for anonymity. In the other situations, this need for anonymity seems to be the one major problem that limits the possibilities for alternative exploration of the field of inquiry.

A legal note

The data I work with in this study are confidential and subject to some rules and regulations. In Denmark, however, it is not necessary to obtain written permission from neither university nor participant to use recorded interviews in research. As a matter of good faith though, I asked each interview participant at the beginning of the first interview to give consent to the use of the recordings for research purposes, only made public in anonymized form. In turn I pledged to ensure anonymity.

5.4. Analysis-sample selection

As already mentioned, the interview inquiry which this thesis is based on was initially designed to capture negotiations and renegotiations of reason and purpose regarding the choice of studying physics that precede students' choices to opt out during their first year of studying in the physics programme. By interviewing students in an on-going fashion, the intention was to capture and make explicit the negotiations and renegotiations that take place – at least in some situations –

when students, based on experience, change their mind and turn reasons for studying physics into reasons for leaving the programme.

The 26 students I have interviewed are divided into two groups:

Group A: 15 students, interviewed regularly.

Group B: 11 students, interviewed once or twice.

For the analysis-sample I have retained sets of interviews with 18 individual students (see Table 5.3).

The reason that only 18 interview sets are retained is that after one year of interviewing two of 15 students in interview group A had left the programme. Furthermore, one student in interview group B had also decided to leave at the time of the re-interview and yet another left the programme at the beginning of the second year. Of the three students who had left during the first year, two declined to participate in an interview about their decision to leave. If not reconceptualised, a study of attrition based on this dataset would thus be meagre.

Since most students who had been contributing to my data had found successful ways for staying, the sets of interviews are instead perceived of as a rich source for gaining an understanding of *successful* strategies for coping. Terming the strategies "successful" is solely to point out or emphasize that the aspect of coping strategies that are of interest here, are aspects of strategies that appear to have been successful, only to the extent they allowed for the students to find reasons for staying in the programme (I will return to this subject in Section 5.5).

Reconceptualising the use of the data in this manner makes it necessary to create a sample of interviews from the data that might add to identifying and understanding successful strategies for coping. An overview of the resulting number of interview sets with individual students that are included in or excluded from the sample used for analysis is presented in Table 5.3.

Table 5.3 An overview of the sample decision

Sample basis: 26 student interview sets	
Included in the sample: 18 student interview sets with students who stayed	
Sample A: Students interviewed in an on-going fashion	13
Sample B: Students interviewed at the beginning and end of their 1st year	5
Excluded from sample: 8 student interview sets	
Students who opted out during their 1st year	3
Students who opted out at the beginning of the 2nd year	1
Students who were not re-interviewed at the end of the 1st year	4

Creating a sample of interviews for identifying and understanding successful strategies for coping means including all students who stayed in the physics programme for the duration of the interview inquiry, and excluding those who did not. The sample used for analysis thus draws on interviews made with 18 out of an initial 26 students. Of this sample, 13 students had been interviewed in an on-going fashion: they had been interviewed before they started, a number of times during their first year, and again during the summer after the first academic year had ended. I call this sample, Sample A. Another 5 students out of the original 26 had been interviewed twice: Once during the first academic quarter and once after the end of the fourth academic quarter. I call this sample, Sample B.

Excluded from the sample are three students who did not stay in physics for the duration of their first year, and interviews with one student who opted out at the beginning of the second academic year. Although interviews with these four students who opted to leave might offer a contrasting perspective on coping strategies, there are good reasons for not including these interviews: Of the four, the first and second interviews are with two students who declined to be interviewed about their decision to leave. I take from this that they would feel uncomfortable knowing that I used the interviews they did participate in, in my analysis. Another two interview sets exist with students who decided to leave that might have been of value, had the two final interviews been of a better quality. They were not: One is with a student who insisted that if an interview about his/her decision to leave was to be carried out at all, it would have to be right away, over the phone and without any recording equipment turned on. The other set of ‘leaver’ interviews that are excluded from the final interview is an interview set with a student who had not decided to leave at that particular time. Nevertheless there was no indication that he/she had identified any viable coping strategy, nor acknowledged that the ones he/she was employing did not work. Although important and informative, drawing out a convincing argument from this one case would take a level of analysis that is not suitable for the ‘mere’ purpose of comparing and contrasting successful and unsuccessful coping strategies. Thus, the four students I encountered who opted to leave while I was interviewing or shortly after, are excluded from the analysis sample.

Another four students are also excluded, thus totalling eight students. They are excluded because they were not re-interviewed due to scheduling difficulties – in part because securing interview appointments with every student in interview group A took precedence over securing appointments with individuals in interview group B.

This leaves 13 students in an analysis-sample A and five students in an analysis-sample B. Together the samples consist of 70 individual interviews with 18 students (and one interview done with two students at the same time). To answer the first research question about coping strategies, only initial and final interview sets from both samples are used. To answer the second research question about the quality of learning, the interview sets in sample A that were performed during the academic year, are used. Table 5.4 offers an overview of time and duration of all interviews in sample A and B.

Table 5.4 Overview of the interviews (intvs.) used to answer research questions 1 and 2. Initial and final interviews are employed to inform research question 1, while interviews performed during the 1st, 2nd, 3rd and 4th academic quarter (AQ) are used to answer research question 2. The duration of each interview is indicated by hours (h) and minutes (‘). The ‘ID’ serves in part to identify which sample the student belongs to: A or B

Student identifiers			# of intvs.	Coping strategies interviews					
					Quality of learning interviews				
ID	Alias	Sex		Initial	1st AQ	2nd AQ	3rd AQ	4th AQ	Final
A01	Isac	M	5	11-Aug 1h25’	09-Oct 0h28’	29-Jan 0h47’	03-Mar 0h29’		13-Jul 2h03’
A02	Eric	M	5	12-Aug 0h55’	09-Oct 0h56’			06-May 1h18’ 3-Jun 0h28’	21-Jul 0h52’
A04	Asta	F	4	12-Aug 1h33’		29-Jan 0h57’		07-May 0h50’	23-Jul 1h21’
A05	Emil	M	5	12-Aug 1h10’	08-Oct 0h31’		24-Feb 0h41’	21-Apr 0h35’	24-Aug 1h01’
A06	Julia	F	4	13-Aug 1h13’	22-Oct 0h36			05-May 0h29’	15-Jul 1h03’
A07	Conrad	M	5	14-Aug 1h02’	10-Oct 0h32’		10-Feb 0h36	19-Jun 0h51’	10-Jul 1h39’
A08	Tor	M	5	14-Aug 1h21’	08-Oct 0h23’		19-Feb 0h38’ 09-Apr 0h32’		24-Jul 0h33’
A09	Gustav	M	6	15-Aug 1h37’	07-Oct 1h42’	27-Jan 1h07’	20-Feb 1h24’	05-May 1h25’	20-Jul 1h46’
A10	Jon	M	4	15-Aug 1h22’	09-Oct 0h36’			07-May 1h18’	28-Jul 1h30’
A12	Bertil	M	4	17-Aug 2h02’	07-Oct 1h42’			11-May 1h14’	14-Jul 1h12’
A13	Tania	F	7	17-Aug 1h02’	22-Sep 0h23’ 24-Oct 0h34’	03-Dec 0h42’ 12-Jan 0h20’	03-Mar 0h48’		29-Jul 0h55’
A14	Niels	M	4	17-Aug 0h52’	06-Oct 0h26’		05-Feb 0h13’		22-Jul 0h46’
A15		M	4	18-Aug 1h09’	09-Oct 0h42’		04-Feb 0h38’		19-Aug 1h07’
B17		M	2	30-Sep 1h11’					16-Jul 1h09’
B19	Bob	M	2	01-Oct 1h25’					12-Aug 0h48’
B21		M	2	03-Oct 1h18’					04-Aug 0h47’
B22		M	2	06-Oct 1h18’					03-Aug 0h49’
B25	Albert	M	2	11-Nov 1h10’					13-Aug 1h12’

5.5. Identifying a need for coping

Here I offer a 'more pedestrian' conceptualization of what is entailed by coping strategies as previously promised:

> For the purpose of this analysis, the term *coping* denotes what you do, to make 'it' work despite of circumstances that makes you expect that doing something else, was probably what the institution intended. Likewise, the idea of *thriving* is used to describe, when you do what circumstances make you expect you ought to do, in ways that seem personally meaningful.

Another way to think about coping is in terms of gratification. If a student thrives with being educated, the circumstances that are offered institutionally are of a quality or type that is immediately gratifying to this student. The experience of studying as a whole is gratifying because the experience is significantly congruent with the expectations this thriving student had, and used as reasons to start and continue his or her studies. Furthermore, going to lectures is likely to make sense to a thriving student in light of the activities that are planned for the recitations – or calculations classes as they are called in the Danish physics programme – which in turn make sense in light of what the student knows about the demands that are posed by tests and examinations. Also, the laboratory exercises might add to this feeling of immediate gratification, as well as might other activities going on, in- and outside of class.

On the same terms, coping would be an expression of a deferred form of gratification in the sense that the experiences of circumstances that are offered institutionally are *not* of a quality or type that aligns well with the expectations a coping student had and uses as reasons to continue his or her studies. Instead, such coping students have found other ways to find meaningful reasons for continuing their studies.

Usually, when we think of deferred gratification, it has a temporal aspect: if not now, then later. But one could also think of a deferred form of gratification that has a spatial component: if not here, then there. This is especially relevant if we think of education as a form of situated practice. In this case the spatial component would sound: if not in, then outside of legitimate practice. I call this type of gratification, *transposed gratification*, thus referring back to the aspect of Bernstein's pedagogic device that share likeness with Brousseau's didactic transposition.

If we think of education as a situated practice, this transposed gratification will say more about what is considered legitimate educational practice than it will say about physical space. A student might decide not to go to lectures, because these lectures offer him or her, a space for learning that is incongruent with what he or she requires of his or her education. Instead such a student might sit outside of the lecture hall together with other likeminded students to go over contents similar to the content that is covered inside the lecture hall. A few moments later, when the lecture ends, these students might be joined by the other students, and together they might find a place to continue work on that week's contents in various ways. Here, the issue is not as much about physical location, but about situated location. It is about having made a different choice from what one might presume was institutionally intended. Whether this choice is perceived of as legitimate or illegitimate – whether sitting outside of the lecture hall is considered as placing oneself outside of legitimate practice or merely outside of 'usual' practice – is a an issue of perspective and opinion. It is also an issue that can be investigated empirically. The same goes for the dichotomous nature of a categorising of students as some who are *immediately gratified* or some who rely upon *deferring* or *transposing* a gratification of their learning needs.

To inquire into whether aspects of a student's educational experience of studying physics can be categorized as either coping or thriving, one needs first to ask why this student is studying physics. An answer to this question will rest on two fundamental premises that I call *need* and *gratifier*. Put simply, answering the question "why study physics?" will mean finding out which personally relevant reasons for studying physics (needs) are thought to be fulfilled by studying physics (gratifiers).

Practically, these premises are not readily distinguishable or, for that matter, easily paired, because as reflexive beings we do not necessarily distinguish ourselves clearly from our circumstances. Think for instance about a 'need' for studying physics that sounds: "I study physics because physics is fun and interesting." First of all, the need/gratifier premises are collapsed into one. A separation could sound: "I need to study something fun and interesting, studying physics proves to be fun and interesting." To carry conviction, however, the answer would also need to be elaborated on: "a lot of things are fun and interesting to study; but what makes physics an especially suitable candidate for fulfilling this need are the following…" and "physics prove to meet my need for studying something fun and interesting specifically in these and these situations…" Because such is life, it is likely that elaborations of this prove divergent or even contradictory. Constructing 'premise trees' in which several premises – needs and gratifiers – are paired with actual or hypothetical counterparts to be compared and contrasted, allows for making a case; either for categorising each student or for elaborating on the coping categories accordingly. Or both simultaneously, until one or the other seem to stabilize either as a category or as a categorized student.

Coding for coping

To identify students who cope and students who thrive, I began by searching for students who had a tendency to defer their need for intellectual gratification and those who did not have this tendency.

This process was done, purely by listening through interviews and by revisiting interview notes and the postscripts I had continually been writing during the year of interviews. Then I started engaging with the data in an interpretative manner. I wrote papers for conferences to present and get feedback on early analyses (Johannsen & Rump, 2009, 2010a, 2010b), and as a process of scientific inquiry, writing has something going for it (cf. Richardson & St. Pierre, 2005). This process ended when we had written the manuscript attached at the end of this thesis as Paper II, *Deferred gratification.* When I wrote this paper, I did so in an effort to situate my findings in the broader context of science education research; in this case, attempting to place the issue of students who defer their need for intellectual gratification as an addition to an on-going discussion about personal and situational interests in the journal Nordic Studies of Science Education.

For this thesis I revisited the interviews yet again. I had already identified students who cope and students who thrive, based on the distinction between deferred gratification and a sense of which students were immediate gratified by their studies. This time, using ATLAS.ti, I coded each audio file containing the final interviews separately, identifying places in the file where students made use of the 'need' premise or 'gratifier' premise to explain about their engagement with their studies. I then transcribed these segments, and worked out a premise-tree for each student, to some extend informed by earlier interviews and my writing on each student's storied experience during their first year.

Then I engaged with these premise-trees to sort out how they worked: how each individual student talked about his or her 'needs' in studying physics, and how the students ensured that these needs had been, or would be met by a corresponding 'gratifier' premise. In the case of 'thriving' students, I found that their 'gratifiers' where mostly about experiences that were institutionally provisioned for. This part of the analysis is illustrated in Section 6.3. In the case of the 'coping' students, the 'gratifiers' that corresponded to certain 'needs' where most often of a kind that the students themselves had provisioned for parallel to the institution or simply by deferring this 'need'. These parallel gratifiers, I then interpreted using Bernstein's (Bernstein, 2000) pedagogic device. This analysis is illustrated and substantiated in Sections 6.1 and 6.2.

The result of this analysis is used to answer my research question 1:

> *Based on individual interviews with first year physics students at the University of Copenhagen, (1) what successful strategies do students appear to employ to cope with their physics studies and what do these strategies tell us about the educational setting they are coping with?*

In the next section I describe the analysis that is basis for answering the other research question.

5.6. Identifying student engagement strategies

To answer my second research question:

> *Compared to the successful strategies physics students employ to cope, (2) what might the consequences of these successful strategies for coping be for the quality of their approaches to learning?*

I engaged in a process much like I did to answer the first research question. While I had been interviewing the students, and had revisited the interviews in my process of writing conference papers, I noticed how a pattern was emerging: Coping students seemed to be primarily proactively engaged during the beginning of their studies, and slowly the level of this type of engagement was decreasing. A completely different picture was emerging regarding the thriving students: they seemed to be consistently engaged in sifting, and seemed to be intrinsically motivated and feel gratified by it, albeit reinforcing their strategy by looking to what their fellow students did, by comparing their grades to their strategies for studying, and by their feelings of reassurance in studying a discipline that to all purpose and intend was a continuation of the physics they knew from secondary school. As a matter of definition, what they exhibited was a sifting strategy, to large extends reinforced by being successful in employing surface approaches to learning (as is evident from a number of quotes reprinted in Section 6.3).

We then wrote the manuscript that is attached to the end of this thesis as Paper III. When I engaged in writing this manuscript, I did so in an effort to situate my findings in the broader context of higher education research; in this case, attempting to place the issue of the evolution of students' proactive engagement as an addition to an ongoing discussion about approaches to learning research that is taking place in the journal Studies in Higher Education.

The analysis for this paper was done by listening through all interviews from one end to the other in long stretches while I noted down particular instances that I judged to be central to each student's overall approach to learning during any given interview. At that time I had not yet decided to remove the two of the students from the sample who had decided to leave, why the dataset comprised 20 students. Those of the notes I felt was particularly distinct in their correspondence with Fyrenius, Wirell and Silén's (2007) characterisation of approaches to understanding (described in Section 4.4), I categorized according to 'depth' and pinned to a set of bulletin boards to *see* if the same pattern I had seen emerge from the interviews while performing them, would again emerge. It did, and I picked out particularly illustrative examples which I transcribed verbatim, translated and used as illustrations of student engagement in Paper III.

For the analysis presented in Section 6.4, I revisited the interviews performed with 'coping' students during their first academic year. I listened through the interviews, while making time-stamps and writing down the particulars about instances where students explained about what they had done to learn in particular situations. Afterwards I categorized these actions according to the same characterization of approaches to understanding that I used for writing Paper III, although this time, I only coded two approaches to understanding: sifting (including surface learning) and the variation of the moving approach that I have characterized as proactive engagement. All other types of approach to learning, such as the 'holding' approach, and instances of deep approaches that seemed to be directed at and contained in single tasks only (i.e. offering no evidence of a strive for variation, or acquiring the ability to apply knowledge to new situations), I coded as 'neither or'. Thus piling them together as a uniform set of approaches that served the only purpose of indicating the total number of times students had explained about what they had done to learn during each interview.

Finally I transcribed and translated those parts of the interviews that are used in Section 6.4 to illustrate and substantiate my analysis.

5.7. A note on translation

All interviews were performed in Danish. This means that every quote that is used in this thesis and in Papers II and III are my translations of verbatim transcriptions. A word-for-word translation would completely obscure the quotes, why I have rewritten the quotes to large extents. For one, I had to drastically rewrite and reduce the use of English profanities that have come to be appropriate in everyday spoken Danish language, but which would not at all be appropriate in written English. I have however translated in attempt to retain the way the students constructed sentences, and of course to retain the meaning I have understood these sentences to carry. If in some places the wording seems too polysyllabic or archaic to be authentic, it is not necessarily a sign that I have been reconstructing the sentences too much, but rather a sign that English and Danish are different languages. Some words or expressions that seem odd in English might not be in Danish.

Thus, if any quote seems strange, it is either because I have made a mistake translating it or because the sentence was strangely constructed during the interview – in which case my translation was successful.

6. Data analysis

This part of the thesis outlines the overall results from an analysis of a sample of interviews. The sample consists of multiple interviews with 18 individuals. These individuals were selected from a larger sample of interviews with 26 individuals who were initially included in the interview sample. For various reasons explained in Section 5.1, interviews with eight students have been excluded from the sample that is used for analysis.

This sample is utilized in two different ways, in order to answer the two aspects of the overarching research question that has guided the research inquiry that is reported on here:

> *Based on individual interviews with first year physics students at the University of Copenhagen, (1) what successful strategies do students appear to employ to cope with their physics studies and what do these strategies tell us about the educational setting they are coping with?*
>
> And
>
> *Compared to the successful strategies physics students employ to cope, (2) what might the consequences of these successful strategies for coping be for the quality of their approaches to learning?*

The results of my study are illustrated and substantiated by offering a rich description of the analysis I have performed and by offering illustrative interview quotes where appropriate. Sections 6.1 through 6.3 offer a background to answering my research question 1 while Section 6.4 adds to answer my research questions 2.

First, Table 6.1 offers an overview of my findings. From the 18 student interview sets that were analysed, I find that eight students are substantially employing strategies for coping to achieve and reinforce a sense of congruence between their personal aims and aspirations related to their physics studies and their interpretation of the institutional regime they cope with. These strategies range from deferring the need for intellectual gratification to transposing the recontextualizing rules of the pedagogic device. Another seven students appear to be thriving in their studies. They experience virtually no incongruence between their own aspirations and institutional requirements, and seem to feel gratified in utilizing strategies for studying that bears great resemblance to a ‘sifting’ approach. This approach is reinforced by grades, and by a perception of a hierarchically structured curriculum that elaborate on the type of physics they knew from secondary education. Also, they are reinforced in these strategies through their perception of significant similarity between theirs and their peers' strategies. Finally, three sets of student interviews where difficult to categorize. One student (A02) copes by deferring his need for intellectual gratification, but reinforces this strategy in a way that cannot be captured using Bernstein's pedagogic device. Two other students defy categorization for reasons briefly described towards the end of Section 6.3.

Table 6.1 Overview of overall results.

Student identifier	Pseudonym	Student characterization	End engagement
A01	Isac	Coping	→ Proactive
A04	Asta	Coping	→ Sifting
A05	Emil	Coping	→Sifting
A07	Conrad	Coping	→(Proactive)
A09	Gustav	Coping	→Sifting
A10	Jon	Coping	→Sifting
A12	Bertil	Coping	→Sifting
B25	Albert	Coping	Not available
A06	Julia	Thriving	
A08	Tor	Thriving	
A13	Tania	Thriving	
A14	Niels	Thriving	
B19	Bob	Thriving	
B21	?	Thriving	
B22	?	Thriving	
A02	Eric	(Coping)	
A15	?	(Thriving)	
B17	?	(Thriving)	

6.1. Coping: Deferred gratification

The coping strategy described here as deferred gratification, is one that two students in particular employ by drawing on an ability to defer their gratification of learning needs, expecting ‘things’ to look better at later times. In essence these students explain how their intentions with studying physics are not, and cannot be expected to be fulfilled until later stages of their education.

Asta (A04)

I start by offering an example from the final interview with student A04 who is very obvious in employing and explaining this strategy. This explanation is illustrated by Table 6.2 in full length. Table 6.3 shows the same need/gratifier pair, but in the condensed form that is used henceforth to illustrate my analysis of central gratifier pairs. The same table also includes another ‘branch’ of the premise tree, in order to underline how the premise of her need has not actually changed during her first year, as she initially states, but is indeed deferred, but only to the extent she has found an immediate outlet for her need.

Table 6.2 Full-length gratifier pair from the final interview (denoted F) with student A04 – Asta. In this excerpt the premises ‘need’ and ‘gratifier’ are interchangeably part of the argument she is making, but have been separated out, to illustrate graphically how the analysis was performed. Some segments of her explanation have been removed (denoted […]) because they are of no immediate consequence to the rest of the argument.

Gratifier Pair 1 (full length)			
	Need, F-1		Gratifier, F-1
I	Can you tell me what interests you about studying physics?		
		I	You’ve tried it now.
Asta	It’s definitely changed.		
I	It has?		
Asta	A bit yes.		
		Asta	It has probably occurred to me that this thing about understanding the world and stuff is romanticizing the old natural philosophers who sat around and revealed the secrets of nature,

Asta	And I’ve found out that I can’t take the courses I want in particle physics, until my fourth year. This means my whole BSc will be compulsory courses.		right.
		Asta	Not that I don’t find these to be fun. But I don’t think I would do it, had I not had those courses coming.
Asta	Because, it’s oh so easy to get, whatyamacallit, fascinated by nature! It’s just oh-so-fantastic to understand, right? But there’s just so much complicated mathematics in it, and well. Often this sense of a higher purpose just disappears in mathematical technicalities and formalism. I don’t know that I’d call it disappointing, but I think, maybe, many had a more romanticized idea of how it was going to be when they started. Especially in EM. […] It was a lot like: now we have to do integration; insert a closed interval and […] not much of this intuitive stuff that is actually fascinating about physics […] I think the focus is on mathematics and not so much on physics in many of these courses. But obviously you need to be able to do mathematics and have that background in mathematics to understand it at all. That’s only logical. It not strange at all.		
		Asta	But we won’t get that kind of understanding until two, three years from now, when we know all about the

	compulsory stuff. […] So this big revelation has not really come to me yet. Of course, I'm only in my first year.

The argument Asta is making, is that she has come to see differently on what her 'need' must necessarily be. Initially she started studying physics because of a deep-rooted interest in particle physics. She explains how she has come to realise that particle physics is not part of the introductory curriculum offered during the BSc part of the physics programme. Instead she is re-examining her idea of how her interest in physics can be aligned with what seems to be the conditions for studying for a Bachelor's in physics. To make her interest feel aligned, she will have to mobilize a feeling of gratification in learning what mathematics can do for physics, rather than what physics can do for her understanding of how the world works. This realization is very close to Bernstein's (2000, p. 164) characterization of the acquisition of a hierarchical knowledge structure like physics: "What [is] important is mastering the procedures of investigation and instruments of observation and understanding the theory; developing the imaginative potential of the language [of physics, for example] comes much later if at all." It is clear from what Asta is saying that she works to accept the evaluative rules of the pedagogic discourse she is (was?) struggling to cope with: "that's only logical. It's not strange at all" that she needs to work through a lot of mathematical formalism when she sits down to learn about physics. Any other idea she might have had, she dismisses as romantic; and when she does, she is gratified by it. One interpretation of the reason for this feeling of gratification is that it is an act of practicing mastery of the grammar of the pedagogical discourse of physics. That grammar entails acquiring a certain perspective of the physics curriculum, "a perspective that a *Hierarchical Knowledge Structure* is the only and sole pathway to 'truth'. Its procedures the only valid way to 'truth'" (Bernstein, 2000, p. 165, emphasis in original). In this respect, Asta is on the right track.

Still, while Asta works to realign her learning needs to better fit her circumstances, she also seems gratified by having realized that she had been getting ahead of herself in her initial need. She is gratified by believing that what she started studying physics for, is still part of the programme – although it will not be until she starts studying for her Master's in physics. In this case, one might start thinking of what Asta does, as deferring a transposition of the evaluative rules. That it is not until two or three years hence, that the students can start evaluating the outcome of their learning in terms of “that kind of understanding”, or their ability to ‘sit there and reveal the secrets of nature’.

One might wonder why Asta has not prepared herself for the fact that particle physics is not offered until the later stages of the programme. As is evident from the extra gratifier pair that is included in Table 6.3, however, she *was* aware that the ‘pathway’ towards particle physics would turn out to be more like a journey.

Table 6.3 Gratifier pairs 1 and 2 from various communications with student A04 – Asta.

Gratifier pair 1.			
	Need, A04-F-1		Gratifier, A04-F-1
I	Can you tell me what interests you about studying physics? You’ve tried it now.	Asta	It probably occurred to me that this thing about understanding the world and stuff is romanticizing the old natural philosophers who sat around and revealed the secrets of nature, right. But we won’t get that kind of understanding until two, three years from now, when we know all about the compulsory stuff. So this big revelation has not really come to me yet. Of course, I’m only at my first year. But I don’t think I would do it, had I not had those courses coming.
Asta	It’s definitely changed. I’ve found out that I can’t take the courses I want in particle physics, until my fourth year. This means my whole BSc will be compulsory courses. Not that I don’t find these to be fun. There’s just so much complicated mathematics in it, and this sense of a higher purpose just disappears in mathematical technicalities and formalism. Especially in EM. It was a lot like: now we have to do integration; insert a closed interval and not much of this intuitive stuff that is actually fascinating about physics. I think the focus is on mathematics and not so much on physics in many of these courses.		

Gratifier pair 2.

Need, Initial Questionnaire reply		Gratifier, A04-F-2	
Asta	I'm one of those people who will go crazy eventually if I'm not allowed to work with the existential part of physics (particle / cosmology). That's why I've readied myself for the many topics I'll "just have to learn" during my studies although I won't find them interesting (ex. thermodynamics). My interest for my field will hopefully help me endure my journey towards CERN :)	I	And how about that existential part of physics that you are just saving for another time? Are you going crazy?
		Asta	.. yes I am. I get restless and desperate. But then, what I do is, I practice it as far as I can manage it at the level of popular science. And that keeps me together. I cannot, not do it. And if I did, well, I would go crazy.

It is curious to see from Gratifier pair 2, that already before Asta started studying physics (the written reply she gave to my questionnaire, inserted as 'need', was collected before her first academic year began) she was considering how she might deal with the predicament she was placing herself in, given her very specific interest. At that time she did not expect to be allowed working with the kind of physics she was interested in. Instead she expected to 'have to learn' certain parts of the physics curriculum even though she would not find it interesting. Nevertheless, Gratifier pair 1 indicates that still, somewhere along her first year, she had needed to come to terms with certain circumstances regarding studying physics. Interestingly, these aspects do not concern the physics contents of the physics courses. Instead they concern her feeling that mathematics was allowed too dominant a role in these courses. This, she was not prepared for. But as the extended gratifier pair 1 in Table 6.2 reveals, she accepts it and feels that it is 'only logical' that mathematics must take up such a central part of the Bachelor's part of the physics programme. This attitude leaves no other alternative than to defer her need for academic gratification. Of dire need, and literally to take care of her mental health, she turns to popular science to the extent she can find time to, between her studies.

Thus, Gratifier pair 2 might be an indication that deferred gratification as a coping strategy is not a stable one in itself. It might involve a second component to be stable.

Jon (A10)

In Table 6.4 aspects of Jon's final interview are separated into need and gratifier premises (with one exception) and paired up. His story is one of feeling frustrated about not being able to make himself do what it takes to get a good outcome of studying physics. Still, he does not doubt that, one year ago, he made the right choice when he decided to start studying physics. Jon also makes use of deferred gratification as a coping strategy, but reinforces it with something that resembles stubborn optimism.

Table 6.4 an excerpt from the premise tree constructed from quotes in the final interview with Jon, student A10.

	Gratifier pair 3.		
	Need, A10-F-1		Gratifier, A10-F-1
I	The first time I asked you what was interesting about physics. But from the perspective you have now you know a bit more about what physics really is?	Jon	I've come to get a feeling for how you work on a daily basis as a physics student. And maybe later as a physicist. I think, for one, the first year project gave me a really good impression of this.
Jon	But I don't think it has changed much.		
	Gratifier pair 4.		
	Need, A10-F-2		Gratifier, A10-F-2
Jon	I hope that I won't have to do the same thing all the time when I finally get a job. That I will be allowed to do different things. It'd be awesome to teach *and* do research.	Jon	I think there's been room for working with it in different ways. And it was cool that we didn't have to be stuck in theory all the time and cool that we didn't have to be stuck experimenting all the time. That we didn't have to do the same thing all the time.
	Gratifier pair 5.		
	Need, A10-13		Gratifier, A10-11
Jon	I am slowly getting there somehow, but it won't do if I get more behind than I already am.	Jon	It's really good that we're allowed to have different ways of learning. It is not necessary to use every method all the time to understand what goes on in a course. You can make do with some of them, find
I	For whom? All right, I already know there's something about the administration, but how		

about for yourself?

Jon For me? Uhm, I know I'm not about to lose faith in any way that's for sure. So *I'm* not in the picture at all. I'll keep on going till they kick me out. I'll undoubtedly see if I can evade them, if they try, by doing whatever it is they want of me.

those that suit you and focus on those that work for you in any given course. I thought the lab was fantastic in EM but horrible in CM2 for example. And I think I've become better at making sure I don't fall apart completely if there's something in a course I can't figure out – instead I find the aspects that I can figure out.

Gratifier pair 6.

Need, A10-F-16

I Have you noticed situations that just motivate you automatically? I assume doing your first year project did that for you?

Jon Yes! Man that was something! But really, it wasn't that deep and wise and ingenious. But it was an awesome toy. I won't emphasize our first year project. It was really fun, but really more of a distraction than – ah, I did learn something from it. I really did, but we didn't really finish it. It would have been better if it had just been an exercise on writing a report.

I Really!?

Jon Yeah Really. I needed to learn how to do a report.

Gratifier, A10-F-15

Jon Doing the first year project was to a large extent a way for me to unwind. To get away from theory and do some experimenting. Which was cool. Setting the books aside for a while gave me some head-space back. Just watching the experiment and see what came out of it – and thinking about it. Ways to improve it. Figuring out what really happened.

Gratifier pair 7.

A10-F-18 (the pair is not separated into need and gratifier)

Jon A lot of the enthusiasm I feel for this programme – it's a really cool programme; I can't think of any that would be more exciting for me – but a lot of what I look forward to, is what I will *come* to be able to. It's like learning to play the guitar. A lot of people want to learn how to do it. You think it would be super nice to be able to play, and you think it's so cool. But to find a way to pull yourself enough together to actually learn it – that's something entirely different. I think some people are immune to carrots. I think I am. At least as long as it's *so* far away. And when that's the case I start thinking: maybe the whip is actually better. Gosh-darn, sometimes it is! And it's not like it's that far. If I just pull myself together. It won't take that long until I'll be doing my BSc thesis. And that – man, that will be awesome! I look *so much* forward to be working with someone, and I really hope – now, I don't know how this works – but as I've understood you'll have an opportunity to take part in some research. Or make a part of it. Or participate in it. And that is *awesome*. I can't *wait*! Like, *really*. And I won't even have to wait that long. I just need to get my act together, and get stuff done. And then it'll be great.

Gratifier pair 8.

	Need A10-F-12	❖		Gratifier A10-F-13
Jon	The thing I fear is that I've gotten behind on the fundamental basics, and that this is a problem that will hound me for many, many courses to come. I feel that was the case in EM, because at the time, I still hadn't really latched onto the mathematics from MathP.		Jon	But I'll just need to pull myself together and read more thoroughly when I study. And that's how it's been right from the start. Every new quarter I've intended to start fresh and really make an effort. And I've probably not succeeded doing this. I don't really know if I'm just making excuses for myself, or if I'm actually realistic when I say: I would like to finish moving into an apartment closer to uni, and not have that hanging over my head too.

When I interviewed Jon the first time, before he had started studying physics, he told how he expected the physics programme would take up a place in his life as "a new world, and a new direction." He started with certain expectations and with certain knowledge of the different fields of physics. He knew that quantum mechanics might cause him problems, but still he was intrigued by what he calls the 'contra-intuitive.' He knew about modelling, and he knew that all models are in one way or another wrong, but also power- and purposeful. He was not one who expected things to be easy, and although he was concerned that he would have to face a pressure to engage with courses and contents he would ultimately find uninteresting, he still felt motivated by the challenge: a challenge of a new world and of letting his life take on new directions.

Upon interviewing Jon a fourth and final time, one year later, his commitment to studying physics has not changed. As Gratifier pair 3 illustrates, he seems to feel that he is starting to learn the rules of this new world of his, but also that he was starting to learn about its demarcations, in that he distinguishes between the practice of physics students and that of physicists. Here he highlights the first year project as a source of such insight. In Gratifier pair 4 the need-premise shows that when Jon envisions what professional life might follow from having studied physics, he emphasises a need for variation. The gratifier premise neatly brings testimony to an alignment between this aspiration and his take on his experience of studying physics: variation is pretty much the order of the day.

Bearing Jon's emphasis on variation in mind brings out an important contrast between the premises of Gratifier pair 5. In the gratifier premise Jon uses a notion of his, of different modes of legitimate operation within each course – he calls them methods – by which he makes a distinction between laboratory exercises, lectures and calculations classes. It seems like he thinks of these modes as parallels that offer students different ways to work with the same contents. Students will not necessarily have to work through all modes, but can decide to focus on the one or two modes that seem to suit each student best. In the need component of this gratifier pair he implicitly draws on this view of the role of in-course activities as an 'escape way.' Jon knows that there are certain requirements regarding the number of courses he needs to pass to continue studying; but this is just a requirement imposed on him externally. Although he has experienced difficulties passing previous courses, he feels confident that he can find ways to live up to these requirements – and also, given the gratifier, that the programme seems to have provisioned for these situations by designing each course around a number of parallel in-course activities. He ends this gratifier premise by stating how this realization has made him able to 'not fall apart completely' if he encounters aspects of one course that are difficult to work around.

In light of these first three gratifier pairs, one would think that the first year project could be allowed a prominent position among his experience of his first year in the physics programme – besides being a rich experience, the grade on this projects also counts towards the grade on the thermodynamics course.

Nevertheless, in Gratifier pair 6 he seems to be going back a little on his original position regarding the role of the first year project. Although he felt gratified by doing the project, he is not convinced that this experience counts legitimately towards his physics learning. In the need premise of this gratifier pair he explicitly states that he does not want to bring out this project as an example of experiences of studying physics that motivates him. One interpretation could be that he is not really convinced that what he and his group did constitutes proper physics learning practice. He ends the need premise in a way that suggests that had the whole exercise been about learning how to write a physics-report, then he might have considered the activity legitimate. But as it is, this whole experience is not. One reason might be that he makes a clear distinction between doing physics as a physics student and doing physics as a physicist. In parts of the interview that has not been included here, Jon concedes that this project might be conceived of as the very early part of something that could one day develop into research. Listening to him explain how they worked in the laboratory however, makes me wonder why he does not think that such a small step is legitimate for a first year student. Especially considering how much energy they lay down on developing it. Every time I confronted him with this notion, however, he turned the argument around to explain how his experience with this project is an example of what they did not learn. And one thing they did not learn was to write a report that was sufficiently well written to satisfy their own expectations. They did get a reasonable grade on it, however.

The reason I think of the contrast in Gratifier pair 5 as important, is because it hints at a certain way of distinguishing between knowing and doing that Jon seems to make use of. In believing that learning electrodynamics, for example, is something you can *either* do by studying the text-book *or* focusing on the laboratory exercises, one would either need to reject that different *ways* of doing might lead to different learning outcomes or think of these different learning outcomes as extraneous or inconsequent. In doing so, one might instead commit to a certain view of the in-course activities: it is the same content that is covered, but by different modes of operation. The end-goal or purpose of each operation is still the same: to cover the contents. Which of these modes of operation that actually leads to a learning outcome, to some sort of internalization of the contents in a way that can be reproduced to satisfy the people that would otherwise 'kick you out', is purely an individual matter. Jon's job as a physics student is thus to identify and focus on those modes alone that lead to a learning outcome – and thus avoid facing more resistance in his studies than he can withstand.

When Jon and his group made a choice about what project to do, they did not choose one that aligned with Jon's notion of "deep and wise and ingenious" physics. Instead they chose a project that was fun; one that offered a pleasurable distraction. In terms of physics learning, however, it was apparently not a gratifying distraction. Instead Jon is exerting himself tremendously to defer his need for gratification, as Gratifier pair 7 is meant to illustrate. I have not separated it out into need and gratifier premises, because as it is, Jon compares and contrasts the two very well. It is necessary to stress that the part 'come to be able to' in the third line was translated very carefully. There is no hint in the original Danish quote either, if he means 'able to do' or 'able to understand'. Nevertheless, what he points at, is what you are able to, once you are done with the first, second and third year courses. At that point he hopes that he will be able to legitimately take some well-defined part in a physics research project. His major complaint is, however, that he is not good at deferring his need for practicing physics in this manner. He talks about it in terms of being immune to carrots – by which he most likely means that it is very hard for him to be motivated on a daily basis, purely based on the knowledge that if he succeeds getting through the first years of the physics programme, he will be rewarded accordingly. His answer is not like Asta's, that he has found an outlet for this need. Instead, he will try his best to 'pull himself together' and keep on reminding himself that a two years wait is not that long of a wait. Still, as Gratifier pair 8 reveals, there is a lot of hoping and wishing going on. What sense of agency he conveys in this respect concerns his own capacity for changing his level of commitment to studying what the programme offers, or in influencing circumstances external to the programme – like finding a place to live nearer the university.

Thus, when Jon explains why he is going to stay in the physics programme he draws on hopes and expectations about how future circumstances might be. These hopes and expectations are not reinforced by actual experience, but primarily by something that resembles stubborn optimism despite his experience of his circumstances. When he is interviewed at the end of his first year he defers his expectations of getting to feel gratified in his choice of studying physics to the third year of the programme. At that point he is going to start writing his Bachelor's thesis. Again, like in Asta's case, there is no indication that the component that reinforces his coping strategy is stable. He might be able to keep up this optimism of his. But if he cannot, he will be left hoping that his near-future studies allow him an experience that can help justify it. Alternatively he might develop a capacity to engage with his studies on his own, in ways that gratifies him.

In terms of Bernstein's pedagogic device, what Jon does is slightly different from what Asta does. I will not go as far as saying that he is re-interpreting the evaluative rules, but he is definitely interpreting the rules differently than most, when perceives the different modes of learning – lectures, laboratory exercises and calculations classes – as parallel means to the same end; amongst which each student can choose the one that serves his or her learning the best. This interpretation of his, I think is strongly tied to his coping strategy, in that it allows it. First, he defers his need for intellectual gratification. To do this, he must rely on his resolution to be able to do this for quite a while. To be sure that it will not take too long for him to get where he needs to be arriving at (the Bachelor's project) he has to make sure that he does not fail to many courses along the way. What reassures him in this need is that the programme has a built-in legitimate contingency for this situation: it provides three different ways, for learning the same contents. I think the reason that Jon rejects the first year project as a good example of what motivates him in his studies, is that the type of engagement that is required in this work would otherwise constitute a radical break with his idea of what is entailed by the legitimate pedagogic discourse of physics. One might speculate that in thinking back on this project his interpretation of physics-as-curriculum learning is invalidated. This is what Gratifier pair 6 shows: here he reminisces on the role and value of the experiment which provided him opportunities to think and see differently on the problem they were faced with while legitimately having put aside theory and books. The two perceptions of his, of the role of the experiment in the first year project, and of the role of laboratory exercises as just one of several ways for engaging with theory, are just not congruent. To cope, he needs to rely on the latter interpretation of pedagogic discourse and thus have to dismiss (or defer) the former as illegitimate. Or rather, he dismisses it as ill-conceived, in that if properly executed, the first year project should have been an exercise in writing a proper physics report.

Summing up

If placed relative to each other, Asta (A04) and Jon's (A10) both cope with their perceived incongruity between expectation and experience by deferring their need for having their choice of studying physics gratified. Both strategies appear fragile; they are not self-sustaining but reliant on external future change, and both do they rely heavily on the institutional setting for validation. The difference between the two seems to be in their approach to interpreting the evaluative rules of the pedagogical discourse.

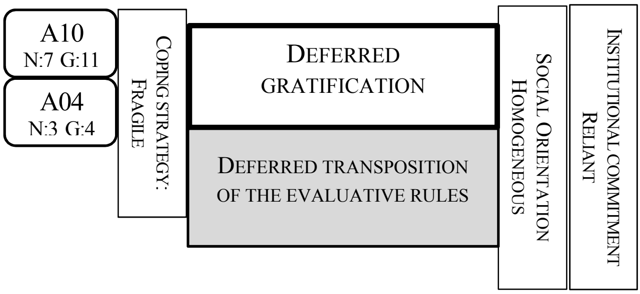

Figure 6.1 A processed illustration of Jon (A10) and Asta's (A04) coping strategies, placed to illustrate relative variety among coping strategies.

As to the institutional commitment, Jon does not acknowledge that the ways of the institution are sensible as such. He feels alienated by them (but not by the physics-profession), but sets his personal positions aside to acknowledge that he absolutely has to abide by the rules of the institution. He needs to pass courses to get where he wants. He shapes his strategy for coping around his notion of what the institution is and does. Asta relies on the institution too. She does not shape her coping strategy around the institution as Jon does, though. She lets her strategy be informed by it, and renegotiates her position on the role of the institution and its pedagogical discourse accordingly.

I have also put a sticker on the figure that says 'social orientation: homogeneous'. When Asta explains about her coping strategies she does so by interchangeably referring to herself, first personal pronoun, and to 'most people', third personal pronoun (cf. p. 76). It might be a psychological phenomenon in the sense that she finds reassurance in her claims in the interview-situation by generalizing them, and thus not putting herself dead centre of tales of frustration and disappointment, but this is inconsequential: when she explains her coping strategy she does so without distinguishing herself from other students. It is simply not necessary, while at the same time, the opposite seems to be the case. Jon too, explains about his coping strategy by relating to other students as if they all belong to a homogeneous group. In parts of the interview that is not brought here, he tells that he finds it his prerogative to not get up in front of the blackboard during calculations classes, but that he understands and respects those who do. For the same reasons he does not ask his fellow students any questions when they are in front of the class, because he would not like that himself if he was in that situation. Besides, one of the reasons that he dismisses his experience of doing the first year project might be that he compares it to the projects his peers were doing (Gratifier pair 6), and compared to those, theirs “wasn’t that deep and wise and ingenious”.

I have placed Jon above Asta, slightly off, of the box that says ‘Deferred Gratification’. Jon defers his need for intellectual gratification in physics, but he does so relying on something that resembles just a stubborn resolution to be able to do so, and by relying on a notion of in-programme activities that are somewhat at odds with other students’ I spoke to. This interpretation of his is not one that I can easily capture using my conceptual framework for successful coping since I do not think his interpretation of the evaluative rules is a conscious reinterpretation or transposition. Instead I think it is a misunderstanding. This is also why I have placed him as I have, away from the second box that says ‘deferred transposition of the evaluative rules’.

This box, on the other hand, is relevant to explaining the second component of Asta’s coping strategy: the component that she imagines can help sustain and reinforce her ability to defer her need for gratification. Asta is leaning towards reinforcing her ability to defer gratification by expecting (or deferring) a shift or different transposition of the evaluative rules of the physics discourse to come. Through this deference she finds support for feeling gratified in practicing the immediately relevant pedagogical discourse inherent to a hierarchical knowledge structure that she is now practicing. In this way a significant shift has happened since she started. Initially she dismissed this hierarchy as something she would find boring, but would just have to learn (an argument similar to Jon’s). At the time of the final interview, however, she is rehearsing an embrace of her interpretation of the pedagogical discourse, very similarly to how Bernstein characterizes the learner’s obligation towards the grammar of such a discourse.

6.2. Coping: Transposed gratification

In placing Asta and Jon’s coping strategies relative to a secondary component that I characterize by drawing on the concept of evaluative rules from Bernstein’s pedagogic device, I also hint at the way I am going to proceed with this analysis. In this section, I will go through more interviews and characterise the coping strategies certain students make use of, gradually identifying the more and more stable and self-sustaining strategies, and characterising them in terms of the sets of rules Bernstein says governs the pedagogic device. This section is called ‘Transposed Gratification’ because it is about the ways students consciously adjust, question, challenge, change or reject their subjective interpretation of one, two and ultimately all of these sets of rules – and thus cope, by transposing them, to better suit their purpose of learning physics.

Seven students are brought out in this section to illustrate four different aspects of a coping strategy that some students use to support feeling gratified in their studies.

I end with an analysis of interviews with Isac and Albert who work hard and consistently at finding contents and gratifying ways to engage with it in their physics learning. As a first step the two students have transposed the evaluative rules, autonomously deciding to what end their physics learning is taking place. One student goes as far as transposing the distributive rules to the extent he almost invents his own physics curriculum, while the other is contend in *changing the recontextualising rules*, happy at being in possession of the power and necessary insight to decide when and how to learn.

Bertil and Gustav's strategies are somewhat different. Like Isac and Albert, Bertil rejects the evaluative rules to challenge the recontextualising rules. But since he is uncertain that what he does constitutes a legitimate practice, he does so only in a case-by-case fashion and end up with an occasional *transposition of the evaluative rules*. Gustav on the other hand, does not challenge the recontextualization rules as such. Instead he emphasizes that what he takes away from his physics learning is different to what his peers seem to get out of their learning. In this manner, Gustav seems to find gratification in a personally relevant *transposition the evaluative rules*.

To do all this requires, to certain extends, the ability to *see through* the curriculum in order to form an informed opinion of what it is that motivates, and to what end. Bernstein calls this ability *gaze.* Thus, the first two aspects of the coping strategy I call *transposed gratification*, has to do with acquiring gaze. Emil has acquired one. Conrad is frantically searching for somewhere to direct his. Eric has directed his to ensure his social integration.

Gaze

I start this section by bringing excerpts from the premise tree that I constructed from quotes in the final interview with Emil. During much of the year I was interviewing him, we were negotiating how to get on the same terms regarding the premise of the interviews. I wanted him to reflect on his experience of learning in relation to the setting of his learning, but as with the students we report on in Paper

I, Emil preferred to make sense of his experiences introspectively. I told him about the study I had done in Sweden, and about how hard it is to draw out valuable knowledge about the setting of his studies, if he did not reflect on his experiences in relation to that setting. He told me, that to do this he would first have to have made the setting his own. It is like cooking. You are raised not to be critical about other's cooking, but it is no problem being critical about your own. And thus far, he might have had troubles digesting the food he was offered but it did not mean he was ready to draw any conclusion about the quality of the food. It was not a conscious decision he explained, we would just have to wait it out. Wait until he was confident in thinking of the physics programme as a place he belonged to, a place he felt at home at and could be critical about. We had to wait until he had developed a perspective to base his evaluation on. Wait until he had developed a *gaze* - or rather, wait until his gaze was sufficiently developed for him to be confident in applying it to his evaluation of the physics programme. At the final interview, he had and was. In fact he had developed two that each serve different purposes. In Table 6.5, Gratifier pair 9 and Gratifier pair 10 each illustrates one of these gazes.

Table 6.5 an excerpt from the premise tree constructed from quotes in the final interview with Emil, student A05

Gratifier pair 9.			
	<u>Need, A05-F-1b</u>		<u>Gratifier, A05-F-1a</u>
I	Now you say [Profession] again. Is that *it*, or what is it? I mean, one can become a [Profession] with biology too, right?	I	So, why do you continue with physics? What's so interesting about it?
Emil	Yeah, sure. But I know very well that there is little chance or opportunity for becoming a [Profession]. But I would still like to have something to do [with the Profession] and it seems like physics is the way forward. A goal [like the Profession] allows you to avoid having to make decisions all the time: if what you do is right or not. Now that I've made up my mind about my goal, I might as well go for it although it	Emil	Well I think it's still - I just had time to think about it now. I arrived ten minutes early so I could just sit here a bit. And I think it's the interest. The curiosity about what's happening.
		I	Where?
		Emil	In the world: how come things fall down and stuff like that. I actually remember my thoughts when I had to choose what to study. Because then, you don't have a clear picture of what it is you want, but you have kind of a rough idea about

may well be that I won't reach it. You can still be realistic about it and still it is worth going for, and if so, it's good to have physics under your belt. Then the path is set and the rest is just about planning how to get to the end. Otherwise there're boundless paths to choose between. There're so many options. It's crazy. So for my part, I need to walk a set path, otherwise I'd start doubting what I was doing and whether it was right for me.

what kind of direction you want to take. I could sense where I wanted to go. I had a-levels mathematics, physics and chemistry, so my choice was almost already made. My plan was always to study to become a [Profession]. I think it's better for me to have some kind of final goal that I can go for. And I don't mind if I almost reach the goal and find out: "shit that was really wrong. I should never have done that."

Gratifier pair 10.

<u>Need, A05-F-9&10a</u>

I There's something about having to believe in what you are being told?

Emil Yeah, it certainly takes that to attend here. But of course, you can still take a critical stance, but a lot is based on stuff we don't have any say about. "Okay, observations say this." I'm not in any position to say "yes, but I think not." Or: "that observation? It can't be." I have to take it at face value. Later, maybe, then I can call it what it is. I mean, we've only ended our first year, and there're a lot of people who've been doing this for a really long time. And you have to be confident that they did their job properly. And, of course, be critical of it. But it's only later you can begin to really re-evaluate what you learned so far: was it really right? Because it's so

<u>Gratifier, A05-F-10b</u>

I Is it okay if I conclude that in reality it is just a question, not about time, but perhaps more about depth? That you just need to continue as you do now, but for a longer time?

Emil Yeah.. or at least return to it again later on. Not necessarily for long stretches of time. But to come back to it. Use it again. Because a lot of this stuff can be linked. I mean, it's no problem to use mechanics to understand galaxies. And I bet I will. Rotations and gravity that's pretty much what mechanics is. So in that sense, I think Galaxies are going to be good for me. It's going to be a chance to think about mechanics again. And use what I already have. And I think that's really important. That it is not a closed course you work

	convincing when they say "we have a million data that says it!" "Well, all right then.." I don’t gain by questioning it	with for a certain short while and then continue with something completely different. Because in time, I think you can easily link it or weave it together to achieve a higher understanding.
I	But the ability to just accept that this is how it’s going to be? That it's sufficient to get the job done, and fine with that?	
Emil	I think it takes up two different parts in my studies. One part is to do their problems and pass the exam. And that's fine, I can do that. It doesn’t take me much effort to do that well. And then there’s the other side of me: the one that wants to study physics. Because plug and chug for the exam hasn’t got anything to do with physics. It has nothing to do with my understanding and desire to do physics. The part that is understanding, it comes in hindsight. That’s how it is for me.	

“Where choice of theory is possible such choice may well have a social base” Bernstein (2000, p. 165) continues from where I left off on page 77. “[I do not] deny that any one *Hierarchical Knowledge Structure* may entail a principle of recontextualization for its transmission which is influenced by interests which may well relate to advancing social, economic and cultural capital or simply survival. But the recognition and construction of legitimate texts [i.e. evidence that aspects of the curriculum has been acquired] in a *Hierarchical Knowledge Structure* is much less a tacit process than is the case of a *Horizontal Knowledge Structure* (…) In the case of the *Horizontal Knowledge Structures*, (…) ‘truth’ is a matter of acquired ‘gaze’; no one can be eyeless in this Gaza” (p. 165, emphasis in original). Here Bernstein had sociology in mind, when he referred to ‘horizontal knowledge structures’. And either he overestimates the role of the instrumentally ordered hierarchy of physics knowledge structures relative to the evaluative rules, or he falls prey to the same self-contradictory representation of physics, as did Traweek's (1988) high-energy physicists who conceives of their community as a 'culture of no culture'. I agree with Bernstein that, as a student, the process of figuring out what counts as a legitimate outcome is significantly more transparent in physics compared to for example sociology. As Emil explains about the examinations in Gratifier pair 10, it is the result and not the process that is evaluated. True, it is infinitely easier to decide if the result and ways to arrive at an already known calculation is 'right' compared to evaluating a student's interpretation of a sociological text, but as Emil also explains, it is no problem getting to the right result. The problem is to understand both the result and the process that lead to it. And the evaluative rules of this regime is of no help. In sociology on the other hand, one might expect that working for understanding, crafting the argument, is the inherent object of evaluation. But in physics, where one knowledge element is assumed instrumental to the next, the assumption might have become that knowing and understanding is the same thing. To Emil it is not, and that is why he must set his own standards for what constitutes legitimate knowing and understanding: he has to develop and employ a certain gaze.

To cope, Gratifier pair 9 tells me that the primary strategy Emil employs is placing his motivation for being in the programme well outside of the programme. This is his first gaze: he has a long term, virtual goal. He thinks it is unlikely that he will ever reach it, but it allows him the opportunity to just *be* in the programme. It is a goal that allows him to recreate himself as a virtual subject that belongs in the physics programme no-matter where he happens to end up on or along the many, many paths it offers. He does not have to re-evaluate his every move, and he does not have to make sure that whatever path he takes, leads him to the right place. He could have studied biology if he liked, and it would still get him as close to his goal as will physics. As it happens, he likes physics, and that is why he stays in physics. But to be gratified by studying physics, Gratifier pair 10 tells me that he has to rely on a more localized version of deferred gratification compared to Asta and Jon. He has changed the evaluative rules and reckons that applying classical mechanics in novel situations (the course on galaxy formation is a fifth semester course), will offer him the opportunity to, not only validate his understanding, but to expand it. He generalizes this principle, and makes it a central aspect of his strategy for learning: understanding arrives with him, in retrospect, he suspects. This is Emil's second gaze, the second way he shapes the recontextualising process to ensure it stays subjectively relevant and motivating to him.

Emil is not frustrated by his studies. At least not like Asta and Jon are. He regrets that the examinations cannot measure understanding, but he does not complain about it. Instead he draws on his experience that problem-solving really serves a purpose when he works to understand. The viable alternative, to just sit at home and think about physics until you understand something is hard, he explains. Instead problem solving serves as a good way to get engaged with doing physics:

> Emil: If I have the physical understanding, doing problems is not just about calculating physics. It is doing physics. But doing it that way takes some more work, compared to what happens if you just do a lot of problems. Then understanding can suddenly materialize. So I think doing problems is really good for me. It helps me learn to remember or to remember how you do it. Of course, I can't remember the problem afterwards, but the way I did it, it kind of stays with me. And then, when I contemplate an aspect of physics, it gets easier for me to relate to it. It's like doing problems is the only way you can get involved with physics in a way that makes you think about it. It's a lot harder to just sit yourself down and think physics.
>
> (Emil, A05-F-10c)

Emil's coping thus serves to exemplify how certain gazes can be applied, on the one hand to avoid feelings of incongruity, and on the other hand to help ensure educational congruity.

As an illustrative contrast, I also bring gratifier pairs compiled based on quotes from the final interview with Conrad. His main concern, to cope, is that he needs to find a place to direct his gaze.

Table 6.6 an excerpt from the premise tree constructed from quotes in the final interview with Conrad, student A07

Gratifier pair 11.			
	<u>Need, A07-F-1a</u>		<u>Gratifier, A07-F-1b</u>
I	What do you think has been interesting in your first year here, and how is that going to add to your	I	I: What gave you that insight?
		Conrad	For example, our first-year project. It provided

next year in physics?

Conrad: Oh, it's a big question, where do I start? I was actually thinking about that, yes. I mean, if I was to summarize what I got out of this year. Argh, it's hard. Because I got so much. I think I mentioned to you the last time: a tremendous insight into what physics is. I mean, like studying and how to engage with physics. What it means to engage with physics. Both experimentally and theoretically.

an extremely good insight into what it means to work with physics.

I: Yes, you talked about the huge amounts of data.

Conrad: Yes. It's a bit like it's the revelation you have been waiting for. To have your eyes opened, and see the world in a new way. I actually think this is what they are trying to achieve with the first year. And I think, at this stage, I think I more or less have arrived there reasonably well.

Gratifier pair 12.

<u>Need, A07-F-2</u>

I: What does it take for you to feel good at doing physics?

Conrad: Well you... you must have an understanding and knowledge of what you're talking about. You must have an understanding of what it is about and what applies to the problem, or the theory you talk about. You have to know it in, well, your guts. I mean, it's all right if you need to look things up to refresh them. But it kind of has to be stuck in there.

I: How isolated is such a problem? I mean, is it possible to be good at one problem and bad at another?

Conrad: It sure is.

I: and still be good at physics?

<u>Gratifier, A07-F-3+4</u>

I: Have you found such a place?

Conrad: Not yet. But ah.. You know, we began talking about how the year was and where I wanted to go with the experience I have so far. So I've started to look into what is happening around the world. What people are talking about, and what things are to come. There are committed and these fiery souls out there who really have some ideas and there is much to build on. Somehow, you need such fiery souls to look up to. Some role models for what it is you want to do in the future. What you're after.

I: When you say 'you' is it you?

Conrad: It's me, yes. But also in

Conrad	Ah. Yes. Just because you're super good at astrophysics doesn't mean that you can do geophysics as such – although it'd be nice.
I	Yeah, it would be cool being good at everything.
Conrad	It's just not something you should expect to be. Well, yes, I guess you should. That's not the issue here.
I	Does that mean that even if you have difficulties with these standard physics courses, but not with geophysics courses, then you are still allowed a clear conscience if you think you are good at physics?
Conrad	Sure, I'd say. It is about finding the place where you fit.

general. When I look around me and when I know how I feel, I think it looks a bit like, well, there is not really any role models who are brought out in any way. In the world of physics there are some brilliant minds here and there, and some projects coming out that are wildly brilliant. And some research that appears genius. But there are never any names put to it. When you think about it there are never any people that make you say: this person, he's really doing something! (…) I know what it is I want to study. But I don't have any role model. I know what direction I want to take, but I can't put a name to it. I kind of know my direction, but I can't find a role model. Not yet. I might have lost my goal. And I'd prefer not to grope around in the dark any longer, although it can be educational.

The need and gratifier component of Gratifier pair 11 from my interview with Conrad, can at first glance appear to have been reversed. In the need component, Conrad explains how his first year experience has allowed him insight into how you study physics and how you engage with physics. As such his statement is one of feeling gratified by his first year. On the other hand, I also perceive it as being a statement of intent. What the first year in physics was supposed to give him was an intimate experience of what physics is, by which he might be thinking of what the professional practice of physics is like. In this light, placing the need premise as just that, serves a purpose compared to the gratifier component where he explains what situation gave him such insight. Here he brings out his experience doing the first-year project, an experience Conrad and I have been talking about extensively during previous interviews. To Conrad, this experience is almost a revelation. On one hand, it was a gratifying experience involving physics that provided him with a new perspective to see the 'world' with. On the other hand, this premise can also be thought of in terms of a need premise, since Conrad continues to explain how he thinks that from the educational planners' perspective, the intention with this first year was to provide him with just such a perspective. A perspective he feels he has 'more or less' attained. Perceived as a gratifier premise though, this means that Conrad feels that he has almost achieved congruence between his own retrospect experience of this year and what the institution intended.

The very important part of Gratifier pair 11 is that he says 'more or less' when he explains the degree to which he feels that he has achieved what he was supposed to. Because now his first year in physics has left him with this astonishing perspective of the world, a kind of broad gaze that he does not know where to direct. He needs and anchor or a role model, as he explains in Gratifier pair 12. I think it unwise to interpret Conrad's need to literally, that is, I do not think that he is looking for a particular person. Rather, he is looking for someone who personifies the kind of community of people who work towards a goal that Conrad can relate to. At the time of the interview Conrad's newly attained gaze only allows him to perceive his own incompetence relative to the world of physics, and he is implicitly asking for help to name what his interests in physics are and what, as a consequence, his goal thus might be. I have placed this as a gratifier premise, because it is a gratifier unfulfilled. He has several good ideas for what his aspirations might be, but is severely confused by all the possibilities that exist for feeding into and informing his interests, and for allowing him to aim to acquire the expertise that will one day turn out to be crucially relevant.

Conrad's initial reason for starting his physics studies was informed and further developed during his first year in physics. The result is that at the time of the final interview he conceives of this interest as too vague to be viable for motivating him in his further studies. Still, he keeps the idea at the back of his mind as something he might later revisit, but as Emil, he has no reason to think that he can make wrong choices during his next year in this regard. But contrary to Emil, Conrad's aspiration is not guiding him in his studies any longer because it is also changing. He is left where Emil made sure not end up: at a place where all possible paths must be evaluated relative to his ambition. Furthermore, Conrad has arrived at a place, where he can no longer formulate what his ambition is. He has a sense of it, and figures that maybe he will recognize it for what it is, if he finds or discovers someone else who works with it professionally. And this is now Conrad's coping strategy: he wants to continue in physics, but first he needs to name his ambition. To get there, he explains in the interview, he is going to go hunting on the internet. At the time of the final interview Conrad is reasonably certain that it will prove a successful strategy.

A final example of how gaze can take shape is Eric's. Although I interviewed him three times between the first and final interview, much of what we talked about was the social setting of his studies. In effect it was not until the final interview that he really got to reflect on his retrospect experience of learning physics. I am not going to divide quotes from his interview up into need and gratifier premises, because Eric's gratifier is his social engagement with the programme and not of immediate relevance to my attempt to characterize successful coping as it relates to academic integration. Eric's main coping component is related to his social integration, and in fact, he had been so occupied with his social engagement that he appears to have forgotten to reflect upon his academic engagement at:

I: How are your studies going? Are you happy with them?

Eric: Yes.

I: Are you passing your courses?

Eric: Yes.

I: Without any problems?

Eric: Yes. Without any problems.

I: Why?

Eric: I don't know. Yes I do. I guess I'm good at it. That's mainly it. I think I had a pretty good handle on physics from secondary school, so I haven't been doing much till now. But it's starting to get back at me. 'Cause this quarter was actually pretty hard.

I: When did you notice?

Eric: Four or five days before the final exam. I had been focusing on the mathematics course because at first, I thought it was the most difficult one. And [I didn't like the lecture in EM], so I didn't really go. I didn't start on EM till the math exam was done and then discovered that it was not at all an easy course and that suddenly I was in trouble. But then, the exam this year wasn't that hard and I made it.

I: You got a bad grade then?

Eric: No, I got a C, but it was bad compared to my other grades. But very good compared to how much I've worked for it. When I was cramming I thought I'd be lucky to pull a C. I did problems and read for twelve hours a day and completely mashed up my brain.

I: Do you think you've understood the subject?

Eric: Well, yes, I think actually I have. But I'm a little annoyed by myself because it was actually the one first-year course I had been looking forward to the most. And then I didn't make anything of it.

(…)

I: Okay, so I guess you can't tell me much about your experience with EM because you didn't attend the lectures much, right?

Eric: No, that's generally a problem with the courses. I haven't really gone to the lectures.

I: No? The same goes for TD?

Eric: Yes. Well I have. I don't know. It seems a little surreal somehow, because actually, now that I'm looking back, I haven't been to any lectures at all it seems. Maybe five in each course or something.

I: You've just kind appeared once in a while to see what was going on when it suited you?

Eric: Yes.

I: What about calculations classes, did you go?

Eric: Those I went to a little more, but not at all regularly.

I: Where do you do physics? Is it at home and before the exam, then?

Eric: ...

I: I mean, if you don't go to the calculations classes – well, some of 'em you do – but the ones you don't go to. I guess you don't go if you've already done the problems, right?

Eric: No.

I: And if you haven't prepared for the calculations classes I guess it's even harder to get yourself to go, right?

Eric: .. I think I'm just sitting here and realizing that I've done virtually no physics.

I: So I guess it's something like doing old exams right before the examination then?

Eric: Yes. And that's usually something I do together with some of the others. We've been doing this the last two quarters and it's worked out really well.

(Eric, A02-F-1+7)

Eric is going to be a research physicist and is completely confident in this plan. He is not really sure what field he is going to be researching, but he is alert and at the look-out for something that might really catch his attention. He knows that some parts of physics seems extremely boring at the surface, but he is also aware that often he is either surprised or disappointed by his own interests when has the chance to explore them further. Everything is open to Eric except his choice of one day doing research physics. My interpretation of Eric's take on studying physics is that he perceives the community of students around him partly as future potential colleagues but primarily as members of a community he is part of and need to be able to relate to for a very long time ahead. Eric's first priority was to engage in, as well as shape and add positively to the culture of this community. For authentic learning purposes, it is important for students to develop a discursive identity that displays membership of and mastery of community discourses associated with their learning (Allie et al., 2009).

Thus, Eric's strategy seems completely sensible – had it not been for the fact that he got caught up in this mission to the extent he finished his first year in physics by being slightly disappointed in himself because he forgot to pay attention to the physics studies he had been so looking forward to engaging with.

Although Eric's gaze was focused on the social aspect of his institutional commitment, it is still a coping strategy that starts with deferred gratification. He started in physics, feeling that he was academically ahead right from the beginning and thus focused his attention elsewhere. A year later he encounters a hard physics course for the first time. If he is not going to continue year two as year one he will have to reinvent himself as a physics student who also studies physics. If so, one might suspect that he will also have to re-evaluate what constitutes understanding.

Summing up

Figure 6.2 expands on Figure 6.1 to illustrate Conrad, Emil and Eric's coping strategies relative to Jon and Asta's:

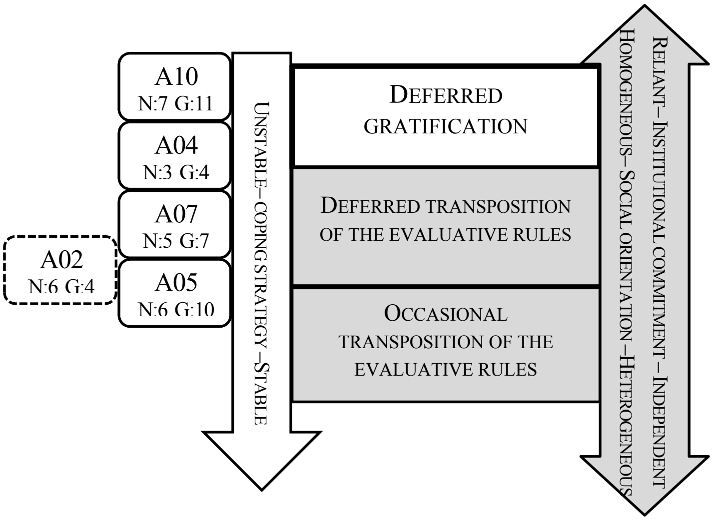

Figure 6.2 A processed illustration of Conrad (A07), Emil (A05) and Eric's (A02) coping strategies, placed to illustrate relative variety among coping strategies.

I have placed Conrad (A07) right below Asta (A04) although Conrad's strategy for coping is radically different from Asta's. Their main communality is their strategies' dependence on the external. While Asta's strategy depends on institutional conditions for learning to change over time, the stability or viability of Conrad's strategy hinges on him being able to locate what he calls a 'role model' but which can be interpreted in terms of a search for a motivational construct or a substantial purpose in learning physics, a gaze. If Conrad is successful this gaze will allow him to interpret the evaluative rules from a perspective of personal meaning-making, -aspiration and -drive (hence the 'deferred transposition of the evaluative rules' attached to characterize his coping strategy). While Asta is very explicit in the volatility of her coping strategy, Conrad is more upbeat in the way he describes what he needs to do. He does not feel he has to wait for the circumstances to change. Instead he needs to find ways for changing how he perceives his circumstances. To this end, he has already got a strategy in place. Interestingly, as a strategy for developing or informing his gaze, he directs it outside of the institution, taking on a global rather than localized perspective on the applicability of physics specializations. Alternatively he could have been looking towards his peers and be inspired by what inspires them – which he has also done. During the interviews I did with Conrad during his first year in physics, he does explain how he looks to his peers for inspiration. His choice of first year project for example, was not made based on the subject of the project, but based on which of his peers might be inspiring to work with. What he realizes, however, is that he is inspired by his peers' inspiration more than by what inspires them, why he realizes that he must find his own way. One might thus describe his perception of the social environment as a perception of himself and his peers as made up of a heterogeneous field of people who have unique personal aspirations and motivational drives. His choice of searching globally for inspiring cases of physics application also tells me that neither Conrad nor his coping strategy is as institutionally dependent as are Asta and Jes'. Still, he accepts the premise of the physics programme, which in part sets him aside from Emil (A05).

Emil is explicit in making a distinction between the activities of the physics programme and of physics learning. He acknowledges that the ways of solving problems for understanding that are institutionally encouraged potentially offers him a shortcut to understanding. It is a shortcut compared to the only, but difficult alternative he knows of which is to study the textbook and think-for-understanding. Still, he rejects this as a reasonable way to engage with physics, because to learn physics, he says, you need to be involved with it. But also, he makes sure to stress how he, himself, is the one responsible for ensuring that he is properly involved to achieve understanding. Taking on this responsibility himself, without rejecting institutional practices, lends legitimacy to his coping strategy: it will never be at odds with the institution. Nonetheless doing what is institutionally required in itself, far from guarantees understanding – albeit the grades Emil receives on his examinations are fine. For Emil it takes an extra effort to achieve understanding; an effort he will have to make sure to make on his own: first he does problems as he is supposed to, by which some understanding might arise. Afterwards, he is wants to build on this understanding at home, 'contemplating' what he reads in the textbook. This is why I have placed Emil halfway into the 'occasional transposition of the evaluative rules' – because Emil occasionally takes a look back at what he has achieved, and evaluates this achievement in different ways than does the institution. Still, I have also placed Emil in the box that says 'deferred transposition of the evaluative rules' because Emil also offers a suggestion for a future way of evaluating the outcome of his first year of studies. He expects that in a later course on galaxies he will find opportunity to validate his knowledge of classical mechanics by applying it to new situations. To this end, Emil feels that he, himself, is responsible to ensure that his future learning take shape much like III depicted in Figure 3.1 on page 16. Had he been explicit in talking of this strategy as a way to learn (more) classical mechanics – or physics in general – in other first-year courses, I might have categorized his coping strategy as one that is also reinforced by a transposition of the recontextualizing rules. When Wagenschein (1999) describes the difficulties associated with the structuring of a curriculum into platforms connected by pillars (III, depicted in Figure 3.1), he points out that the difficulty lies in connecting the pillars to the platforms. He likens the activities in platforms to flying a glider, and utilizing the connecting pillars to the art of searching out and making use of the thermal uplift that is necessary to continue the slow gliding descent and tranquil view from above of the landscape below. Without the ability to search out and use thermals, you cannot fly a glider for long. Searching out thermals are instrumental to gliding and no gliding instructor in his right mind, would expect the novice glider to figure out how to search out and utilize thermals on his own. Metaphorically speaking, Emil expects he can, will and is supposed to. But it does not seem dangerous to Emil simply because it is of no consequence, where he might land.

Eric (A02) is different in his coping strategy compared to all other students I have interviewed and categorized as 'successful copers'. Although he started his first year deferring his need for intellectual gratification, he did not consciously turn to transposing any of the rules of the pedagogic device. This is why his coping strategy is set to the one side, and dappled – because in some sense, my description of his coping strategy is hypothetical. What I want to indicate is that, from what we know of other coping students, there is reason to believe that he too might begin to employ a coping strategy that relies on an occasional transposition of the evaluative rules. The reason I think so, is because when Eric was approaching the final examinations at the end of his first year he realized that the course he was studying for was harder than he had expected. During our final interview, after he had passed his examinations, he also started realizing how it did not feel as if he had been doing any physics during the preceding year. I accept that this is his subjective experience, but still disagree with him. Pragmatically speaking, he had done physics, and he explains what he did, when he did: he did it shortly before every examination, and his strategy for making sure to pass was on one hand by relying on physics abilities he had acquired during secondary education, and on the other hand by doing a large number of the types of problems that are sure to come up on the written exams. Instead of thinking of this in terms of not doing any physics, I think a more accurate description is that he had not been engaged to learn physics to any degree bearing personal significance to him, during his first year. To still feel gratified in his choice of studying physics, he had instead occupied himself in what was significant and subjectively meaningful social engagement. At the final interview, though, he looks back on his first year and because of what he sees, is slightly disappointed with himself. He seems to have arrived at a figurative crossroad which makes me suspect that henceforth, he is going to work to apply a new coping strategy – and most likely, that this strategy to some extend is going to resemble Emil's.

Transposition of the evaluative rules

From the interviews it is evident that a central aspect in coping is also feelings of frustration. In fact, frustration seems to initiate and to some extend drive successful strategies for coping. With reference to Tinto's (1993) longitudinal model of student departure one might have expected the opposite to be the case: that a feeling of frustration drives attrition, and to address attrition one will be wise to look for causes of student frustration. But in fact, Tinto's model of student departure, does not predict whether a student will desists or persists. The model predicts that the student will have to make a 'departure decision'. While one might easily be able to sympathise with students who decide to desist because of feelings of frustration, it is not as straightforward to understand how feelings of frustration drive students to seek out strategies that will ensure their persistence. I asked Bertil (A12) why:

> I: When you have a hard time doing physics how come you wonder why? Why don't you wonder whether, in fact, you are actually interested in physics or not?
>
> Bertil: When you sit and do physics problems they are always very small, isolated problems. You do calculations on things that have been simplified down in every aspect. There is never any air resistance and things go towards infinity and all sorts of stuff like that. That's how physics works. It boils down the world into simple relations that you can calculate. But the great thrill in physics, it's not – it's always nice to finish a problem, get the right result

> and feel you have accomplished something – but what really matters are those moments when you get a glimpse of the totality. I mean this impression becomes more and more pronounced the more you know all around and about physics. But sometimes there're a few pieces that fall into place. You collect pieces of the puzzle that together assembles into a coherent impression of one part of reality, for just a moment. And then it disappears again. And then you get this sort of wonderful feeling of having understood a part of the world. And become gloriously optimistic because of what we humans are able to understand with these things we call mathematics and physics. It cannot be compared to anything. It is something completely different from all the other facets that are life, and which are also funny and wonderful in each their own ways.
>
> (Bertil, A12-F-6)

In the quote above I ask Bertil to explain to me if he knows why, in the face of the frustration they feel, it is that he and his fellow students never seem to doubt their own interest in physics. Bertil explains that frustration is an intrinsic part of the ardor of studying physics and that a certain feeling of frustration is what drives him and ultimately confirms him in his choice of studying physics.

When he describes what it means to him to do physics I take it to mean that doing physics necessarily entails an inherent frustration. Doing small, inconsequential problems on a daily basis is what physics is about. It is about removing every extraneous aspect of context from the problem to make it into a something tangible that can be treated mathematically. In themselves, isolated, none of these problems are interesting because this is the nature of physics practice: you can solve the problems, and some satisfaction often arises out of being able to do so, but each problem alone, does not tell you much substantial about the natural event you might be interested in understanding. But doing this often, rigorously and by attending to different aspects of the part of reality you are treating, ensures that suddenly the natural event will reveal itself in its entirety as a coherent whole; in a sudden flash of insight and perception of perspective: discovery, almost transcendental, but just for a moment.

This process does not have much to do with the advancement of human knowledge but has everything to do with the advancement of personal knowledge. The component that drives this struggle is the frustration that comes from not knowing, but knowing that you can come to know. That is the reality of being a physics student if you are Bertil. In time he will have developed into a physicist, and we can predict that he will still be engaged in the struggle of furthering the limits of what he knows. What will drive him as a physicist at that point is still the struggle, but one that has developed into “a struggle, in which the ardour of discovery is transformed into a craving to convince, (…) a process of verification in which the act of making sure of one’s own claims is coupled with the effort of getting them accepted by others” (Polanyi, 1974, p. 171). Thus, it is of absolute importance not to confuse this tacit component of physics practice, the healthy frustration, with inopportune aspects of the pedagogic device that might be criticized because they too lead to student frustration; and vice versa: not all frustration felt by physics students are signs that they are growing into proper physicists. One such inopportune aspect is the feeling of being forcefully pulled through a curriculum that you have not had the chance to properly get to know, as Bertil explains. As a way to cope, he flunked his final examination in EM on purpose:

Table 6.7 an excerpt from the premise tree constructed from quotes in the final interview with Bertil, student A12

Gratifier pair 13.			
	Need, A12-F-2&10		Gratifier, A12-F-1&3
I	Can you keep on doing that?	Bertil	I let myself fail. Right from the beginning of the course I thought it was one of the most exciting so far. And when I feel that way about something, I think it a shame to only touch the surface. So I found a way to study where I did it really, really thoroughly and sat and, yeah, really studied it and practiced it to make it stick. I only wanted to get as far as I got. And if I didn’t get through it all I would have to take the re-exam. I like it better this way. But of course, it obviously isn’t smart if it happens every time. And it hasn’t. But on some cours-
Bertil	No, I don’t intend to continue to do so. Hopefully it was the last time it happened, and I want to try to adapt [my mode of studying] to what is happening [in the courses]. But if I hadn’t done it now, when would I ever get to do it again, and do it thoroughly. It really is now or never, as I see it, because there are new courses all the time. And after that, you have to specialize and so on. It's either now or never that you have the chance to get a really good grip on this stuff. If you		

only touch the surface now. So I guess, although in principle, you are free to do it anytime, you won’t turn back as soon as you’ve passed the exam.

(...)

Bertil I could have passed EM. I just wouldn’t have had a feeling of understanding what was going on. I would instantly forget about relations, laws, units, constants and definitions and why equations looked as they did, and where all this stuff came from. I just don’t want that to happen. Then you are just not an educated physicist. Any amateur can sit and cram for three months. If you are interested in physics you have to do it. It takes a higher level if you want to work with physics. It takes saying that now we are really going to study it and not just learning it quickly.

es I’ll just have to admit that if I’m not getting through all of it by the way I’m studying, I’ll just have to allow myself some more time by taking the re-exam. I made it through the first three chapters super-thoroughly, but the curriculum was seven chapters. So it goes without saying that I knew all about electro, and nothing about magnetism. I guess I could have spent two evenings before to make a lightning-cram of the fourth, fifth, sixth and seventh chapter. But what would I gain?

(…)

It's just fun to think about electricity, magnetism, electric fields: all these invisible things one can describe with mathematics but just not touch. In some way they hit right at home - struck a nerve as they say in English - at the time they found what has now enabled us to create all this technology that surrounds us. I mean, this is the stuff I think is the core of physics and what I really find fun about physics: electromagnetism. I guess this is the major reason I went so crazy on it as I did. But yes, it's a little like giving up and saying that the ones who planned the course decided this pace, at this level and in this depth. And then here I say, no, I don’t care. I’ll do it like this: If I make it through:

		great. If not: hello, welcome re-exam.
	I	Why do you think it is like giving up?
	Bertil	It's giving up compared to those who say that it should be possible during this time-span to get an adequate level of understanding. You kind of give up on their plan: You weren't able, not to.

In Table 6.7 Bertil tells about his experience studying the electromagnetism course. It is a course that addressed a part of physics that he could really relate to, and to make sure to get the most out of it, he decided to study in his own pace. His primary objective was to make sure that he would keep on remembering everything that he feels is important about the discipline. To do so, he had to object to a central aspect of his take on the governing recontextualizing rules; the rules that govern the conditions, under which physicists are 'allowed' to transmit physics knowledge to their students. The aspect Bertil had to object to was the pacing. He wanted to make sure to allow the contents of the discipline to leave a deep impression with him. Because in none of the circumstances he can imagine, would he ever get a chance to work this thoroughly with these aspects of electromagnetism again. To realize his objection to the pacing of the contents he would have to transpose the evaluative rules. First, he needed to deny that the result of the examination validates his understanding and instead work hard on his own to ensure it; and work differently compared to what is institutionally encouraged. Second, he would have to allow himself an extra few months of engagement with electromagnetism. To do this, he made sure to fail the examination and thus be allowed to take the re-examination during the summer vacation.

At an apparent level, this strategy is pretty much the opposite of deferred gratification. However, a more accurate description is that the secondary component he uses to reinforce his ability to defer intellectual gratification, is to decide on a few instances where it is crucial for him, to achieve 'instant' gratification. In other situations he is content 'going along' with everyone else:

Bertil: I didn't pass linear algebra, and I won't until sometime during my second year. And I've completely come to terms with the fact that I just need to make it work. I don't have a firm grasp of linear algebra. This is one of the areas where I can accept that I don't get a deep understanding the first time around. Here I just have to accept that this is how it works, and then allow understanding to come later. I'll get it at some point, but it doesn't have to be right away.

(Bertil, A12-F-11)

Interestingly he does not blame pace, when he explains why he did not get 'a firm grasp of mathematics the first time around'. In Danish the quote sounds like, instead, he thinks of it as an issue of his own ability. Nevertheless, there is something about mathematics that does not make it necessary for Bertil to gain a deep and full understanding of the subject right away. One aspect might be that Bertil does not think of himself as good at mathematics. Another might be, that if anything, linear algebra is thought of as instrumental to learning physics in the physics programme, why one might expect that it has a role to play in physics courses to come. Like Emil, Bertil might expect that other chances for learning mathematics will present themselves. The same is not true when he thinks of electromagnetism. At the apparent level, it does not seem as if Bertil thinks of this field of physics as instrumental to other fields. Or more likely, he does not think of it as instrumental to the particular field of physics he imagines he is going to specialize in. For Bertil, electromagnetism serves a purpose in itself. The purpose it serves is, a) it is the cause of all the technology we make use of on a daily basis, and b) it is a marvellous example of the power of physics modelling. None of these reasons for teaching electromagnetism are sufficiently addressed for Bertil's taste at the current pacing of the course.

At this point it seems prudent to dwell on Bertil's characterisation of what physics learning is to him and on Polanyi's description of what passion is to the scientist. Might these descriptions be the 'romantizesed idea' that Asta rejected on page 76? Although we might sometimes be inclined justify the cost of basic research endeavours with reference to the value earlier accidental discoveries turned out to have today, grants are only bestowed a research project when it clearly outlines and accounts for a specific and plausible outcome. Science is no longer chance discovery (if it ever was). It is a coordinated activity that leaves as little room to coincidence as possible. To this end, it is romanticizing when Polanyi's states that the scientist's passion can be derived from his need to make others see, what he has seen. The reason scientists adopt clear methods and goals, is because we cannot afford it, if they do not. So why does Bertil think that it is any different when you *learn* science? Why does he believe that understanding is supposed to arrive with him suddenly, as a product of a process that defies prediction? All he knows is that it does, once in a while, when he is engaged in doing problems. And so does Emil when he explains how understanding kind of emanates out of problem-solving. How come the act of reaching understanding is not thought of as an intentionally coordinated process? Why does Bertil not explain that each physics problem is a mean to a specified end? I think the plausible answer is that each problem is not: An institutionally reinforced assumption exists among both students and teachers, that if students do a sufficient number of problems of certain types, they will have understood why they did the problems. This is what I mean when I write about self-referential knowledge in Section 3.2: it seems like the justification for doing physics problems, is that doing physics problems allows students to understand why they do physics problems.

But if students actually do end up understanding why they do what they have been made to do, there might not exist a problem at all. That depends on how the students arrive at this understanding. In Bertil's case, I think it reasonable to think of his strategy as unfortunate.

What is unfortunate about Bertil's coping strategy is that he thinks of it as illegitimate. During the interview it is clear that the only distinction he makes between physics-as-curriculum and physics-as-research, is that the former is supposed to prepare him for the latter. When he reflects on why he needs to ensure a deep understanding of the various physics disciplines, he does so from the perspective of a student who feels that he has an obligation more to the field of physics than towards himself. He is sure he lives in an age where once again, new ground-breaking discoveries are going to be made in physics. And "you won't have a chance to improve on Einstein's general theory of relativity until you have understood both relativity and classical mechanics really well," he explains. But he feels that he and his fellow students are all "dragged through everything as fast as possible" to ensure that they come to know a little of everything, "but not a little, well." Like Emil, Bertil seems to be in favour of Wagenschein's third alternative curriculum structure (see Figure 3.1, III page 16), but to his regret, his experience is of the second alternative (see Figure 3.1, II page 16).

I am not certain as to the reason why Bertil is not able to take ownership of his own learning to the extent he can also think of it as legitimate. But I think a large part is that he does not distinguish between his teachers and the representatives of the scientific discipline he respects and admires so much. He speaks of his alternative strategy as of giving up. But on what? I understand how it can be hard for Bertil to give up on physics. But how about giving up on an institutional activity that proves not to have been planned in a way that serves his subjective purposes? I think this would be possible for Bertil, had he not confused the one with the other. But apparently this is a misunderstanding that is institutionally instated on day one, but never addressed again: "Those speeches they give when we enrol, the department heads and directors of studies '[making the sound of a fanfare] we follow in Newton's footsteps! Now we are starting to become physicists!' They don't have to stop that right after we've started. I mean, the programme doesn't automatically retain physicists just because we survived week one and two. It's permanent: each for himself and motivation for none." Upon enrolling, the students are told that now, they are going to work to become physicists; but apparently they are not told afterwards how they are going to do that. They are told what they are supposed to do, but they have to identify the reasons for doing it themselves. They gladly follow in the footsteps of Newton, albeit no one seems to know where he went. The students will just have to wait and see.

The consequence of the feeling of illegitimacy in coping by having found alternative strategies for ensuring understanding leads Bertil to turn the frustration he feels inwards. Confused and disappointed with himself at the end of his first year, he explains:

> Bertil: And I know it comes later. Maybe I'm just the one who is impatient. But the reason I'm so full of self-contradictions, like you say, it's that I'm working on myself. Constantly you work on your own on this ever fleeting enthusiasm you feel for the discipline. Or not fleeting. Because it is there all the time. It's just to get it substantiated in a good way that makes you better at physics. You know, read and do problems. [One of my friends] told me that nor was she in any doubt if it could be anything but physics. It was absolutely what she wanted. But at the same time, she was just so annoyed with herself: "How can you be so certain that this is what you want? And you really want to, so bad. And when it comes

> to show, and you have to deliver, you can't make yourself study. You can't make yourself do the problems. You simply just can't make yourself get yourself together!" It kind of resonated with me.
>
> (Bertil, A12-F-5)

I think the answer to the questions Bertil's friend pose, is that they are all looking in the wrong place, when they are on the lookout for what motivated them in their choice of physics studies. They are motivated to do physics, but what they are asked to do, is to know physics – and at that, only to know certain aspects of physics without any substantial explanation as to why.

Thus, Bertil's aim in his studies is to develop a gaze that is institutionally congruent – by which I mean congruent with a discourse that to Bertil, does not make a distinction between the discourse of physics as a research practice and physics as a learning and teaching practice. Such a discourse would be inherently self-contradictory because the pedagogic device dictates that concerns addressed by the one discourse are radically different from the concerns the other discourse aims to address. It might be true, when Bertil thinks of both discourses primarily as learning endeavours, but there is at least one fundamental difference that Bertil has overlooked: what he needs to learn as a physics student is radically different from what he needs to learn as a physicist. The object of physics learning is known knowledge and established methods. When this is overlooked, physics-as-curriculum will suddenly appear to be an attempt to emulate the discourse of physics-as-research, which is the way Bertil interprets the educational discourse. To ensure better congruence between his take on the educational practice and his take on research practice, he will have to transpose the evaluative rules. But compared to the educational practice, this transposition is illegitimate, while at the same time it ensures a learning outcome that seems more in line with his obligations towards physics as a research discipline. To solve this subjective paradox he turns blame on himself: he is the one who cannot manage to work within the regime that, to him, is physics. A regime that dictates that "it should be possible during this time-span to get an adequate level of understanding," adequate compared to what it takes to interrogate, add to and further develop the research discipline.

Another student who copes by transposing the evaluative rules is Gustav (A09). But he does so in a completely different way compared to Bertil's. He aims to study physics, not as content, but as a cultural practice. This means that he completely accepts the premise of the pedagogic device inherent to this cultural practice, but only to the extent that he participates and involves himself as is prescribed, to become affluent in the discourse of the device. This is different from other students who might accept or challenge the premises of the device in order to ensure access to the store of knowledge that the device operates on. Their concern is not necessarily the device's discourse – since it is assumed. Gustav might not be critical of the discourse; but he is very interested in it as a construct:

Table 6.8 an excerpt from the premise tree constructed from quotes in the final interview with Gustav, student A09

Gratifier pair 14.			
	Need, A09-F-3		Gratifier, A09-F-5
Gustav	If I end up being a researcher I would think it was really interesting. But I don't have any definite aim as such. I would also like to be a teacher, but it needs not necessarily be in physics. I would be happy if it was in physics. Because I think it's exciting and fun and you can do lots of things with physics. Physics can illuminate all sorts of things which, also other stuff than just..	Gustav	Physics is a language open to mistakes. I think I also think this is one of the things I mentioned in the first interview.
I	What kind of teacher?	I	We talked a lot about misunderstandings. And you still insist that physics is open to those misunderstandings?
Gustav	Well, initially I dreamt of opening a school and have the students learn what they..	Gustav	More than compared to my experience when you hear and listen about other people, I often think it seems..
I	Do it properly?	I	Okay, that's your impression? How did you experience this? In relation to your studies and now that you've been confronted with some of your early ideas through studying.
Gustav	Yes, absolutely. Because early on many students learn that it's wrong to make mistakes. It's the other way around. That's what it's all about. Well, not the idea that you need to make as many mistakes	Gustav	When we've done experiments and have discussed the experiments with the lab-teacher, and when we sit together in the hallway and calculate. Suddenly someone is struck by a thought and starts talking about it. That there's a

	as possible, but that it is only through mistakes that we learn what is correct. Yeah, a bit like the scientific approach: the more we discover is wrong with the theory, the better. Because the better we find.. Something like that.		much greater openness towards, well, yes, stupid questions than I would have expected.
		I	So you think it's in the culture? And in the whole of the culture, from the ones who just started to the teachers who herd you around all this?
		Gustav	Yes. I also think that among my fellow students their self-awareness is a large part of their aim in studying - in addition to being interested in physics, they also think that this issue is interesting. Also in relation to the study. Not just reflective as persons, but reflective that physics – I mean, physics is included in their reflections, or perhaps it is at their base for all their reflections.

Gratifier pair 15.

<u>A09-F-13 (the pair is not separated into need and gratifier)</u>

Gustav Is [the recorder] turned back on again? Can I just briefly explain something? Because, I was thinking about the original question, "why physics?" And then I got to thinking: I don't know if it is something general about the entire year, but it certainly is for my group of first years. We're all geeks. We all have a strong relationship with physics, but a lot of the others have a stronger relationship with physics than I have. And the way to explain it, which just came to me out there, it was that in fact a lot of the others are physics geeks. And I started thinking that, actually, I'm not a physics geek, but perhaps more a philosophy geek, or kind of.. Yes. Not philosophy, as in the study, but as in philosophizing. In my case I think I have decided that physics is the best expression for it. The best place for, like, being able to make this interest unfold. In philosophy and such, yes .. the development of existence. So the more precise explanation you were looking for earlier, may be, that in fact, physics is exciting in itself because I like to explore things and figure things out - I'm curious by nature. But more fundamentally, the reason I chose physics is more that physics is – and now it may become too abstract again – it is the best language. There are some things that

> flow easily in Physics [physics now being a metaphor for a certain language]. And there are people to discuss it with at a level you cannot discuss it at, with anyone else. If you take a specific topic a specific physics topic, to discuss in, what do I know, religion or philosophy, it will be an entirely different discussion. Then it's no longer about that specific thing. Instead, if we are talking philosophy, it'll be about something more contrived: what have others thought, and how does it relate to it. And in case of religion it'll perhaps be about how it relates to a biblical understanding or some other culture-specific understanding.

Most of the interviews I had with Gustav was about trying to formulate what he was actually up to; trying to formulate what was his purpose and aim in studying physics. The issue was not that Gustav did not know, but more that he did not know of any good way to explain it to me. He wanted to go somewhere with physics, and in lack of a better word he called this place 'Rome'. An as we all know, all roads lead to Rome, one of which goes through the physics programme. Above, he regrets that he has to explain his reason for choosing physics by drawing on a metaphor of language, because once again his explanation might end up too metaphorically abstract for any of us to figure out what we were talking about. This happened often when we were speaking.

The best way I can describe Gustav's motivation for studying physics is that he perceives life as both an education and as a journey at the same time. Part of his 'education' and 'journey' is his education. His education is likely not to change his life's journey – that is what he means when he emphasizes how 'all roads lead to Rome'. And his education is not supposed to change his life, but it is supposed to influence the quality of his journey. As such, studying physics is a stop on the way, and during his studying he means to pick up on some of the local habits and learn the local language. This stop on his journey is purposeful, because he believes that the local language – Physics – is a language well equipped for describing what he is going to see during the rest of his journey. It is all very spiritually metaphorical, but that is how it is with Gustav. This is how he makes sense of both the world outside and within.

As a result, Gustav has adopted an attitude towards his studies that at the apparent level leaves him impervious to the 'nitty gritty' of making personal physics aspirations congruent with his experience of studying physics. The reason is that any a feeling of incongruence he might still be perceptible to, he perceives and embraces as an inherent attribute and characteristic of the local culture he is visiting. It sets him apart from his peers, as he explains in Gratifier pair 15, but as a visitor he enjoys immensely to learn together with them (Gratifier pair 14). This also means that he does not position himself as an outside observer, but as an active participant. He takes full part in the activities that everyone else does. This means that he is not completely impervious to the kinds of problems others also experience.

Early in his first year Gustav makes a mind-map of his motivation for studying physics based on the themes we had agreed on during the first interview. This he sent me just short of the second interview and below, I have translated a small section of it:

What is Rome?

→ Systematizing the world makes it less self-contradictory ←

Fundamental mistake!

(The world is not self-contradictory, and physics is a tool for realizing the system)

What roads go there?

Soul searching
A wish to understand
Fearlessness, tranquillity
Freedom of mind

My impression of learning

It's been immeasurably interesting starting. Innumerable things have "not been okay", important information was not passed on (about text-books, schedules etc.) or was difficult to access. But in meta-perspective, as a new student, as a teacher(?), all of this is merely a lesson on independence. Not a dead end, but a lesson on how you still make it work despite no solution exists to any problem.

Figure 6.3 An excerpt of the mind-map Gustav(A09) sent to me prior to our second interview.

In his mind-map Gustav mentions that he has experienced some practical problems regarding the information they needed at the beginning of their physics studies, but continue to explain how he perceives this, not as a problem, but as a potential to learn how to be independent, and as a chance to experience how people can make life work despite the problems they experience. Interestingly, the problems he has experienced he perceives to be without any solution. From the other interviews I have had with Gustav I know that what he refers to is not necessarily just practical problems like the ones he mentions in the text, but the much more complex problem that is education. The reason I bring this part of the mind-map is to show how Gustav's strategy for studying is not only a particular mind-set, but also a coping strategy. From his perspective he is still perceptible to the problems other people also experience, and his strategy is a reflection of a conscious effort to cope: any adversity he experiences he turns into an opportunity for learning. As such, his explanation of ‘what roads go to Rome’ can be perceived of as a further explication of his coping strategy: to feel unrestricted and be allowed free passage takes courage, freedom of mind, soul searching and an inherent want to keep on understanding. The destination of his journey is an ordered understanding of a world that at the apparent level can appear self-contradictory, but his life-assumption dictates that, in fact, it is not. The world is an ordered place, and this order can be figured out and understood. For this purpose physics is an ideal tool.

All this might be very well. Gustav still has to pass examinations that are mostly made up of problems that he needs to know how to solve irrespective of what his perspective is of life, learning and physics. The metaphor I used to describe Bertil’s following in the footsteps of Newton without knowing where Newton had gone also applies to Gustav. He explains that at the beginning of every course he never really manages to muster the motivation and drive that is necessary to get all the way through to the other side of the course, having felt properly engaged all along the way. His take on the problem is that at the beginning of every course, the teacher always slow-starts from (what is assumed to be) the beginning (ex. by introducing relevant mathematical constructs), from which the teaching can continue to ease into the actual object of the course. As a student you start the new academic quarter fresh and ready to work hard, but if there is nothing to work hard for to achieve at the start of the course, you settle back into a slow, laid back mode of studying. Suddenly, after a week or two the character of the course-contents has changed and the inherent hardness of learning the contents has increased. More often than not, you find yourself behind in your studies. Gustav’s solution:

I: Why didn’t you manage to study more than half of the textbook?

Gustav: I can’t remember. Back then I know I was wondering about the same thing myself. We were doing the first year project at the same time, so maybe that’s it. You know, time has a tendency to fly. And actually, for the same reason, I signed up for five courses for next academic quarter.

I: [?]

Gustav: A theory I’ve been working on for a while, is that at the beginning of many courses, everything is exceedingly simple for a while. The first two weeks or something like that. And because it is, you simply gear down. But because the pace is also high, you can't keep up. So I've decided to sign up for five courses – or initially three, but then there was this extra course I wanted, and then a prerequisite course for that one. Maybe it's something I know already, and then I'll just skip it. Anyways, I don't intent to sign up for the exam for these extra courses. I intend to follow them and then sign out at the last moment before the exam. Because then, maybe, I'll be able to keep up my pace, and then maybe, I'll make it through more than half the text-book.

I: That's a peculiar logic that: "why didn't you study your text-book?" That's because

Gustav: "there wasn't enough to do" But I mean, there's this saying: "If you want something done, ask someone who's already got too much to do, to do it."

(Gustav, A09-F-11)

To deal with his lack of motivation at the beginning of each course Gustav tells at the final interview, that for the first academic quarter of his second year, he is going to attempt to study five courses during the time others study two. His theory is that if he keeps himself sufficiently busy he will not notice that the introductory weeks of each course do not engage him at all. It might be, as he says, that every new course starts out really simple, but instead of questioning why they do, he figures out a strategy that is sure to complicate as much as possible the beginning of the courses. To this end, I think it safe to presume that his strategy will work.

A reason that a student like Gustav goes out of his way to adapt to the institutional environment, might be that the same belief in hierarchical knowledge structures, the belief that seems to be responsible for the vertical discourse of the pedagogic device of the physics programme in Copenhagen, and source of the need students have for deferring their need for intellectual gratification, is also used to structure the contents of individual courses. Before going anywhere with the core contents of a course, a solid foundation is to be build, from which students will later be able to understand the meaning and purpose of the course. At the beginning of the course – Gustav thinks it is the first two weeks – they will have to work through a simple preamble necessary to begin working with the types of problems that belongs with the core subject of the course. If this interpretation holds true, it means that at the beginning of each course students will have no idea about the gravity of what they are doing. Instead what they are engaged with appears simple, unwarranted and uninspiring, why students tend to reduce their engagement with the course during these initial weeks. Before they know it, the preamble is over and the course has 'begun for real'. But because nothing is made explicit regarding the preamble, nothing is made explicit about the transition from the preamble and into the core contents either. And if the students do not catch this transition by themselves they will end up like Gustav, suddenly realizing that the course is already over.

Summing up

Figure 6.4 expands on Figure 6.2 to illustrate Bertil and Gustav's coping strategies relative to the other students' that have previously been described:

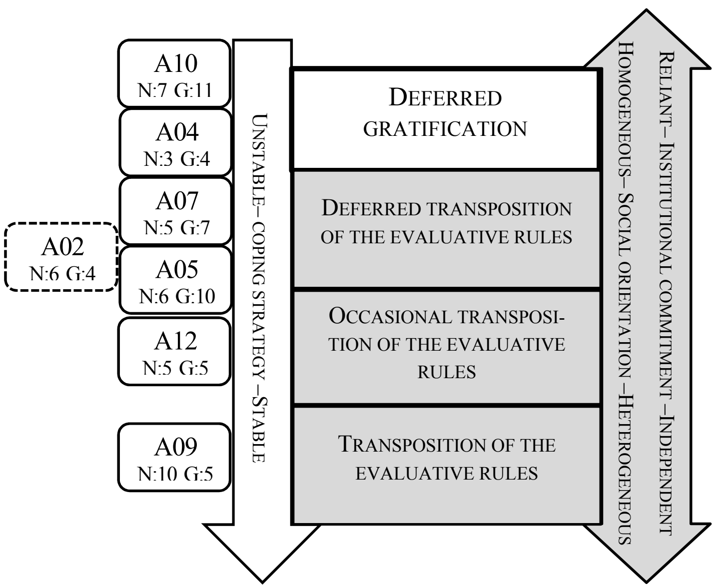

Figure 6.4 A processed illustration of Bertil and Gustav's coping strategies, placed to illustrate relative variety among coping strategies.

I have placed Bertil (A12) next to the box that says 'occasional transposition of the evaluative rules' because Bertil is more outspoken in transposing the evaluative rules compared to Emil (A05). Bertil's strategy for coping is to ensure himself time for engaging deeper with the content than the course otherwise allows. He does not intend to do so, on a regular basis – only occasionally and when needed. The fashion in which he transposes the evaluative rules is different from Emil's, in that he does his evaluation of his outcome of a course while he studies, and not in retrospect as Emil. In this sense one can argue that Bertil is more reliant on the institution and the programme structure compared to Emil. His social orientation however, seems to rely on a more heterogeneous perception of himself in relation to his peers. He does not need to refer to how other students perform and study in order to explain about his strategy. This means that the arrow at the right side that indicates a tendency with regards to both institutional commitment and social orientation is nothing more than an indication. The same might also be true regarding the stability of coping strategies. While Emil seems perfectly at ease with his strategy, Bertil does not think of his strategy as legitimate, and some indications exists that Bertil still have some unresolved issues regarding his strategy relative to his perception of physics as research and curriculum. This difference might be a matter of personality, it may be an indication that developing a coping strategy is done in stages and that Bertil's strategy is not as fully developed as Emil's is, or that the illustration's division between deferred and occasional transposition of the evaluative rules is too fine-grained to also sufficiently indicate the stability of the coping strategy, the strategy's social orientation and institutional commitment.

Gustav's coping strategy, on the other hand, is clearly set apart from the other students' coping strategies. His whole take on the physics programme is different. He is not so much studying physics to learn the contents of the curriculum, as he is studying physics to learn the discourse of physics education. He calls it a 'language' that is particularly apt for describing the aspects of the world he is interested in. Although he was struggling to explain to me clearly what it is he is trying to do, and although it seems like he is also struggling himself to figure out precisely what it is, he seems to be at ease with this situation. It appears as if it is all part of the life that Gustav aspires to. While Gustav enjoys working with his peers tremendously, he is also explicit in stating that their purposes with their studies are different from his own. It seems like Gustav is coping on two levels. At the overt level, his strategy is to transpose the evaluative rules and set the purpose and the intended outcome of studying physics apart from the contents of the curriculum. At an underlying level his strategy still requires that he engages with the curriculum the same way his fellow students do. At this level he also needs to cope, and for the future he has planned taking more courses, which happens to be offered by others than the physics department. Thus, in the future, Gustav is planning to also transpose the distributive rules to go outside of the field of physics education in order to better equip himself to engage in physics learning. At the time of the final interview he had signed up for the courses, but had not yet tested his strategy which is why I have not placed him next to a box that says ‘transposition of the distributive rules’. That is, I do not know if this final aspect of his coping strategy can be termed ‘successful’.

Changing the recontextualising rules

When Isac (A01) was interviewed the first time, before he started in the physics programme, he explained why he had decided to study physics at the University of Copenhagen by contrasting his expectations with his previous educational experience. He had been attending HTX which leads to a higher technical examination and aims to prepare students for studying science or technical sciences (although all university programmes are open to HTX-graduates also). Based on this experience he was confident in saying that he did not want to study at a university where case-based or problem-based learning was prioritized, and he did not want to study at the Danish Technical University since he did not want to work with engineering. He had been working with these types of problems in plenty during his secondary level education. While he enjoyed working with these types of problems, he would like to be sure to retain a more theoretical orientation for his university degree – an orientation he thinks of as ‘more to the point’. He was always amused by working to model problems, but in engineering, he says, you are never done with a problem till you have also found a solution to practical constraints – such as figuring out what kinds of screws and bolts can actually withstand the pressure your model predicts. He never considered any of the humanities or social sciences because he could never get his heart into any of these subjects in school.

During his school years he found ways to keep himself challenged. He was always one of these singular kids in class who could figure everything out long before anyone else. Thus, his biggest challenge in school was to avoid getting bored. His teachers helped him, mostly by allowing him to study ahead – but in primary and upper secondary school he was inevitably faced with not having anything to study unless he found some way of making what the others did, more complicated on his own. And he became good at it. So when we spoke of what he expected his studies in physics to be like, he still expected that, to some extent, he would be faced with a curriculum he had already gone through once. Still, he was confident that he would find ways of avoiding boredom, since, at any rate, university physics ought to offer plenty of resistance – or plenty of what he calls ‘good, complicated problems’ to engage with.

As it turned out, he joined a group of likeminded students, and together they found their own way of engaging with the curriculum. I have interviewed two students from this group, one is Isac and the other is Albert (B25). In this section I use both their final interviews to characterise their strategies for coping.

To illustrate why and how Isac justifies that he stays in the physics programme Table 6.9 brings one gratifier pair, translated from the final interview. In this pair, he reflects on the kind of work that motivates him in his studies. Notice how there is nothing about his characterization of motivating types of problems that makes it necessary for him to study physics. Instead, physics just happens to meet the criteria he defines in order to characterize what motivates him.

Table 6.9 An excerpt of the premise tree constructed from the final interview with Isac, student A01.

Gratifier pair 16.			
	Need, A01-F-17		Gratifier, A01-F-16
I	Where do you find these problems you need?	Isac	This is why I chose it, and this is why I continue – because I don’t think it would be better anywhere else. If I thought: “That place!” and I mean, I would have to be pretty certain about it, if I was to choose something else. Like, I would switch if I really thought that the Danish Technical University was just the thing for me. But I can’t see how I can find it anywhere else. I can’t find it in other disciplines. I can’t find it at other universities. And really, it might be a little sad that you show up at lectures to talk to your friends. But then again, it is nice to study at a place where this is how you feel: there is a reason to show up, right. Basically it’s
Isac	Where do I not: that’s probably a better place to start. I can’t find them in courses that don’t seem to have a purpose or any sensible application. To find them, they need to be useful for something tangible. That’s probably my biggest motivator: Solving a tangible problem. It is likely that it’s wildly abstract, but as long as you can express it in words, it’s a good problem. Like, how long is the line that makes a curve? It’s just a matter of integration, but it’s an example of a tangible problem that I wanted to resolve. They are concrete and make me feel like doing them. Like a		

spring with a mass. That's pretty concrete. But difficult. You might be able to resolve it analytically, but at the end I decided that it would take some mathematics that I don't know about – which is pretty likely. That, or that it's an unresolvable problem. I don't know. So I solved it numerically. 'Cause I can't look at a problem and think "it can't be done." I always start out by thinking: this problem has a solution. Now I just have to learn how to find it. So I think an important criterion for an interesting problem is that I haven't already done it. That's mainly how the problems were in EM. I couldn't be bothered with them since I'd done them before. This must mean that for a problem to amuse me, it has to be something I can't figure out at first glance, and importantly, that I haven't figured it out already or once before. And it must have a certain standard. It can't be an easy problem. I guess this is how I get motivated.

inevitable that some of the lectures, I mean lecturers will be boring. Then you'll just have to find other reasons to show up.

The intention with bringing gratifier premise A01-F-16 is first to give an impression of how the interview with Isac progressed. One of the issues we often returned to in the interview was his reason for studying physics. His characterization of the type of work that motivated him often confused me. At the outset he did explain how he *had* considered engineering and decided against it. Still, to me, he often sounded like he would be better off studying something more akin to engineering. In this quote, however, he explains that although the physics programme might not exactly offer him what he is looking for, he knows of no other place that does. The physics programme in Copenhagen is the closest thing. In the need-premise of Gratifier pair 16 he expands on the reason that he is studying physics by reflecting on what kinds of problems he finds engaging. He brings examples from his experience with physics and mathematics, but when he generalizes on these experiences in order to set up of set of criteria for what a motivating and engaging problem is, he does not explicitly point out anything that would require that he studies physics to encounter these kinds of problems. Together, the two premises leave an impression that his experience of the physics programme is one of a setting that is particularly good (i.e. better than others, but not perfect) at letting him encounter the kinds of problems he finds engaging – and that there are central first year courses that are not good places for him, to go look for these problems. The question then remains where he looks for these problems? Answering this is another reason for bringing Gratifier pair 16.

It is evident from the need-premise in Gratifier pair 16 that Isac works out his characterisation of a set of 'good problem' criteria while he is being interviewed. There is no reason to believe that he recalls criteria he already uses to search for or find engaging problems. Instead, they seem to be derived purely for my benefit from his retrospect reflections. This means that if Gratifier pair 16 is interpreted purely on its own merit, one might be inclined to make the case that Isac's mode of engagement is a perpetual search for instant gratification in his studies: he knows an engaging problem only when he encounters it, and when he does, he engages with it. There might be something to this interpretation, but it is not nearly a complete account of his mode of engagement with his physics studies. As mentioned early in this section, Isac formed a study-group with like-minded students. One of these students is Albert who is part of the B-sample. Albert's way of explaining their group's strategy complements Isac's in a way that leaves an impression of a more complicated and complex relationship between these students and their studies.

As also mentioned in the method Section 5.3, I avoided asking Isac and the other students in the A-sample who were interviewed regularly, about what other students in their year did and did not do. I had promised anonymity to each student and since I was interviewing approximately a quarter of all students in this year, I felt like my ability to keep this promise might be impeded by discussing with one student what another student did. Considering their perspective, I also thought it would help them feel safe, knowing from their own experience of being interviewed by me, that these interviews would not be about their peers, but solely about each participant individually: a way to allow them the power and knowledge about what I came to know and did not get to know. Although this ‘contract’ allowed for sincere and engaging conversations about motivation and experience from a very personal perspective; it might have made it hard for them to explain reasons and experiences of a more situational character. This seem to be the case for Isac, and on contrasting his story with Albert’s, I suspect that this ‘interview contract’ might have made it harder for Isac to characterise and explain his strategy than might otherwise have been.

Albert, on the other hand is part of the B-sample. They were interviewed twice – early in their first academic year and again at the end of this academic year. The first interview was about expectations and the second was, in part, an interview looking back at how these expectations had been met. These interviews thus had a somewhat more contextually rooted quality and importantly they were not open, ongoing conversation like the A-sample interviews had been. For this reason I did not have to be cautious about being able to ensure their anonymity as I had been, doing the A-sample interviews. This may mean that B-sample interviews more clearly reflect the students’ situated experiences – and circumstances regarding these experiences.

Table 6.10, below, brings excerpts from some gratifier pairs from the final interview with Albert where he explains about circumstantial aspects regarding their strategy of alternative engagement with the curriculum.

Table 6.10 an excerpt from the premise tree constructed from quotes in the final interview with Albert, student B25

Gratifier pair 17.			
	Need, B25-F-3,		Gratifier, B25-F-4+6,
Albert	The reason that my experiences of the lectures in TD weren’t good is probably because I like to read the textbook. Having done that, I’ll know what they are going to say at the lectures already. I don’t know if it’s a mistake, but it’s something all lecturers do. They take the textbook and say: “now we are go-	I	Whatever would you have done if you hadn’t been in this study-group of yours?
		Albert	Yeah, I don’t know. I’d probably just turned up at the calculations classes and lectures. But I think it really good that I’m in it, because – that’s something I’ve been thinking about telling you about how you get the very best

	ing to cover these ten pages" and then they do just that. If you've read those ten pages you'll sit thinking "yeah, and in a moment he is going to say.." and that is exactly what he does. Then it stops being exciting. But the guys I've talked to who don't read think he's really good at telling about it.
I	That's how EM was too, right?
Albert	Yes
I	How about the previous courses?
Albert	I didn't turn up much at the first courses. That was when we sat in a group and did some more difficult problems instead of going to the lectures. They were doing stuff we already knew. By and large all lectures follow the textbook.
I	Is it too harsh saying you don't need the lectures because in reality you can just read a book and do the exercises and trust you'll be able to figure out how the exam is going to be?
Albert	Yeah, that's how I've felt all along. MathP was a bit different though. He made a point to avoid following the book too slavishly.
I	How about the calculations classes? Did you go to them?
Albert	Not really. Again, those I've been to, people were just sitting in rows calculating to get the students motivated: we need to realize that we are students. We are not pupils. We do not need to be taught by the teacher. We need to learn the stuff. It's alright if the teacher tells us what the stuff is about and teaches that. But after that it has to be about us figuring out how to understand it. And I definitely think that's what we've realized in this study-group. It is not about going to lectures or being at the calculations classes, or doing the problems that are on the weekly course-notes. It is about understanding what, well, what the subject is all about.
I	What motivates you? It's probably not the exam, because you know how to do that.
Albert	It's because it's fun. It is because for the first time ever, we've met someone who also thinks "yes! This is it!" Earlier we were alone in thinking how interesting it was, and everybody else was just looking at you thinking "no…" Suddenly we can talk about it, in a completely different way. Discuss the things we've been thinking about. That's so nice and it really motivates you to dig up all the stuff you wonder about. To have someone to discuss it with.

lating. The four of us did problems instead of going. I like to do problems together better than to sit calculating. If you go to the university, you might just as well discuss it with someone.

Gratifier pair 18.

<u>Need, B25-F-5+7,</u>

I	Now that you've realized you are students and not pupils, and that the teachers are there to help you when you need help, support or guidance – is that something you make use of?
Albert	We *have* been to a lot of lectures and discussed what the teacher said. When he says: "you can't do this and this" we are like: why can't you? We talk about it for a while and then we get completely side-tracked and start talking about stuff not at all about the lecture. But I think it's useful.
I	That's kind of a one-way thing? You turn up to get a different angle that you can continue to work on?
Albert	Yeah. Sometimes we've also asked them. And even: "I was thinking… can you tell me why the world is like this?" And often they can. That's how we can make use of them. Sometimes they say, "that's a result of hard mathematics" or "that's how it is" – they can tell us, but it would take too

<u>Gratifier, B25-F-12,</u>

I	Tell me, where does he know all this stuff from? It seems like he's the harbinger?
Albert	He is! He's extremely determined. He often goes to Cambridge University's homepage to see what textbooks they use. If they use it for teaching, he says, then it's probably not a bad book. He then researches the book a lot, find out it's probably a decent book, buys it, reads it and figures, wups, it was probably a bit too difficult. But he's determined we need something more to happen here. He drags us along, but we've also started to be able to support him. But most often, he takes the initiative.
I	Is he just a workhorse or does it come to him naturally?
Albert	Both. But I think his dad is a physicist. So he's kind of been getting to know what it means to be a physicist ever since he was little. I think, without him I would probably find the easy way through.

	much time and we wouldn't be able to understand it anyhow. It's not condescending, it's just one of these "it's very complicated"
I	How about the other students?
Albert	We aren't completely isolated. Sometimes we tell the others they are welcome to join us, this is the only right way! That lectures are good for nothing and whatever we can think of telling them.
I	But does it work?
Albert	No. I guess it's a foreign thought to most. For 13 years you've been used to thinking that if you need to learn something, you take a seat and listen. When you get home, you do your homework. What we've started doing is when we want to learn something, we do it together. That's a very different. I think a lot of the others are trained to think that to be a serious student, you go to lectures. If you don't, you're a truant; even if you are just a passive onlooker at the lectures, and when you're not, you actually do something. I think it'd be worthwhile if someone told people: studying is not about looking at the teacher's writing or listening to what he says. Someone forgot to tell us this.
	Think, there's no reason to be better than a D. And I can get a D almost without opening a book. It's all too easy to make that slip.
I	And if a B just means a little more work for you, the question is: what drives you? The answer is: he does?
Albert	Yep.
I	And who drives him?
Albert	He got the rest of us working. So now we drive each other. I don't think he could have kept being our engine forever. Fundamentally we all want the same. We just need somebody to give us that kick, get us going with the right thing. The thing we all know, we truly want.

Essentially, what Albert tells in Gratifier pair 17 is that he and his study-group came into the habit of not going to lectures during the early courses. Instead, they stayed in the hallways to work together on contents they felt were more challenging and appealing compared to the contents covered by the lecturer and text-book. Again, when they started studying the later courses this year they still did not find the lectures crucial to their learning. So they continued their strategy. Nor did they attend calculations classes regularly, because they enjoyed doing text-book problems by engaging in discussions with each other – a type of interactive learning mode that they did not feel was possible during the scheduled problem solving sessions. In the gratifier-premise Albert explains that their strategy of removing themselves from the substantive practices of the other physics students would not have been viable, had they not had each other to work with. Albert explains that it is not merely an issue of practicality – in the sense, you need to be more than one person to be able to discuss a text-book problem – instead, their engagement with each other is deeply gratifying. To explain this, he brings out his own experience of being the only one at school, who wanted to go further in understanding and thinking about the contents covered. Now he is not alone in this 'need', which motivates him more than anything else. They have fun engaging with physics this way, he explains, and one gets the sense, that he has felt constrained engaging this way during earlier stages of his education. In a very real sense what Albert describes is intellectual emancipation. What he and his study group have freed themselves of is the mainstream student practice governed by the recontextualizing rules of the physics programme. On the same line, one might think of their study group as a subculture marked by their particular (or peculiar) engagement with physics compared to the larger mainstream culture of the physics programme.

Gratifier pair 18 expands on how they execute their strategy in an otherwise scheduled regime, surrounded by potentially likeminded students who still adhere to the mainstream practice of this regime. Albert tells that they do attend occasional lectures – but as Isac explains in Gratifier pair 16, they have other reasons for doing so, than to learn from listening to the lectures. Instead they go to get inspiration for the work they do together in their group. Sometimes they even concoct questions to ask the lecturer, and sometimes the lecturer answers these questions. But as I also comment in Need B25-F-5+7, the interaction is somewhat unidirectional. If they have a question, the lecturer might answer it.

During the interview, Albert tells that only twice, have they encountered teachers who truly engaged with them. Both acted as teaching assistants during different courses. One decided to ask the professor responsible for their course if the course might also be made to cater for students like Albert, Isac and the other members in their study group. He did not want to do that, the teaching assistant told Isac afterwards: “Apparently, the answer was: ‘90% need to pass this course. If they can do that easily, congratulations to them.’ So if we can do the problems, there is no reason to spend time on us, right.”

The other teaching assistant extended an open door policy and whenever the group could not figure out the purpose of aspects of courses and modules on their own; they went to him to ask for alternative explanations or justifications. This was also the TA who supplied Isac with the idea to try if he could model a harmonic oscillator with mass (as opposed to the procedure ordinarily used in the introductory classical mechanics course where the harmonic oscillator is described by assuming the spring to be massless).

Gratifier pair 18 also allows information as to whether Albert and his group feel legitimate in their choice of strategy. They clearly do, and are keenly aware that many others do not. The legitimacy they do find, is in their confidence that they have good reason to reject the idea that modes of traditional school-learning also applies to university studies. In part they gain this confidence from the assurances that one of their group members knows from a parent what it means to be a physicist and in part from experiencing how their strategy continues to lead to learning outcomes that they find mutually and personally gratifying.

Interestingly, they do not reject the programme structure. Although they feel they were already proficient in the introductory physics courses and could probably pass these courses merely through cursory studies of old examinations, they still choose to engage with each discipline, but on their own merits, looking for interesting, hard and engaging problems to work with. That is, during their first year they do not challenge the distribution rules, but instead they disregard the recontextualization rules.

The reason they do not challenge the distribution rules might be that in their strategy for coping they did not also aim gain allowance (or endorsement) to set aside certain systemic restrictions. During the final interview Albert explains about what he calls the “prototypical day in the laboratory”: Attendance is compulsory, the task is predefined and scheduled to take three hours, but “there’s not much to do.”

So they found a set of lectures given by the mathematics department to attend half-way through the laboratory exercise. Upon returning to the lab, however, they were scolded by the teacher who threatened with noting them down as absent from the exercise if they did not start being more serious about the exercises. “But it makes me think,” Albert explains, “that it’s pointless. We can make do with one hour of concentration: ‘measure, measure, measure, graph and that looks right.’ To make it matter they need to set higher demands. I mean, this might be something we will need to do a lot in the future, and it might come in handy to have been trained in writing a report and doing this stuff. […] They need to decide what their position is, regarding these labs – instead of just telling us, that we have to do them.” Albert and Isac broke a set of the tacit rules that govern the laboratory exercise environment by deciding to leave it and instead attend a mathematics lecture during the exercise. The teacher in question seems to have perceived of their act as a dismissal of the exercise – which is wrong, one understands: they need to take it seriously. Interestingly this description of Albert and Isac’s wrongdoing shares communality with Hasse’s (2000, 2002a) descriptions of her experience in the laboratory. As an anthropologist she enrolled in the physics programme in Copenhagen to gain access to gendered approaches to physics. The story she tells, involves a bicycle wheel and trying to do a physics experiment which is interrupted by a group of male students who attempt to steal the wheel as part of a game they are playing. The group of female students she is with do not want to engage in play – they are taking the experiment seriously. Another group of males however, do engage and the game starts as one about bicycle-wheel theft-and-chase around the laboratory, and develops into an elaborate ruse involving the bicycle wheel tied to a shaft and a lively discussion about throwing the whole thing off of the Eiffel Tower. Then the teacher gets involved. To the dismay of Hasse and the other members of her all-female group who were interrupted by the male students’ play, he encourages and praises the boys for their ideas and engagement. The feedback the males receive is perceived by the females as also aimed at them. It situates them as the good female studious students who are rarely praised because their behaviour is neither associated with initiative nor innovation and creativity (Hasse, 2002a).

Interestingly Isac and Albert’s behaviour can easily be interpreted as a manifestation of initiative and creativity, but since their initiative is directed outside of the immediate context of the physics exercise in question it is not recognized as legitimate – no matter that their initiative does not even interfere with their ability to finish the problem at hand. Maybe the disappointment that their teacher feels is because Albert and Isac's group do not use their physics abilities to make more of the exercise as did the boys Hasse observed, but instead merely meet the bare requirements. The reason Isac and Albert do not feel inclined to make an extra effort, is because their experience tell them that such an effort will not be appreciated in any substantial manner. Only once, at the end of their first year, did they receive feedback on any of their laboratory reports: they were told to remember to reference their sources. Isac recalls: "That was the first time since I started at university that there's actually been anyone who said: 'you need to put a reference here.' We always did it in high-school. We just had to. But it's just slipped our minds. Not that I think it's less important now. There's just never been anyone who told us: 'it is nice you remembered', or 'you need to remember'".

Another aspect of their coping strategy that they describe during their interviews is that Albert and Isac's group also worked hard at finding alternatives to the physics programme's distribution rules. They never managed to agree on how to do it, however, and at the end of their first academic year they parted on this aspect of their coping strategy. Half of the group spent the summer studying mathematics to prepare for a post-graduate physics course, while the other part decided to adhere to the programme structure and study courses as 'scheduled' in the physics programme. Looking over their transcripts now, it seems they continued their separate ways for the remainder of their studies. One continued as the programme prescribes, another seems to have studied elsewhere for a while, and a third appears to have specialized in mathematics. What a fourth and maybe fifth student in the group did, I do not know.

Summing up

Figure 6.5 expands on Figure 6.4 to illustrate Albert and Isac's coping strategies relative to the other students' that have previously been described:

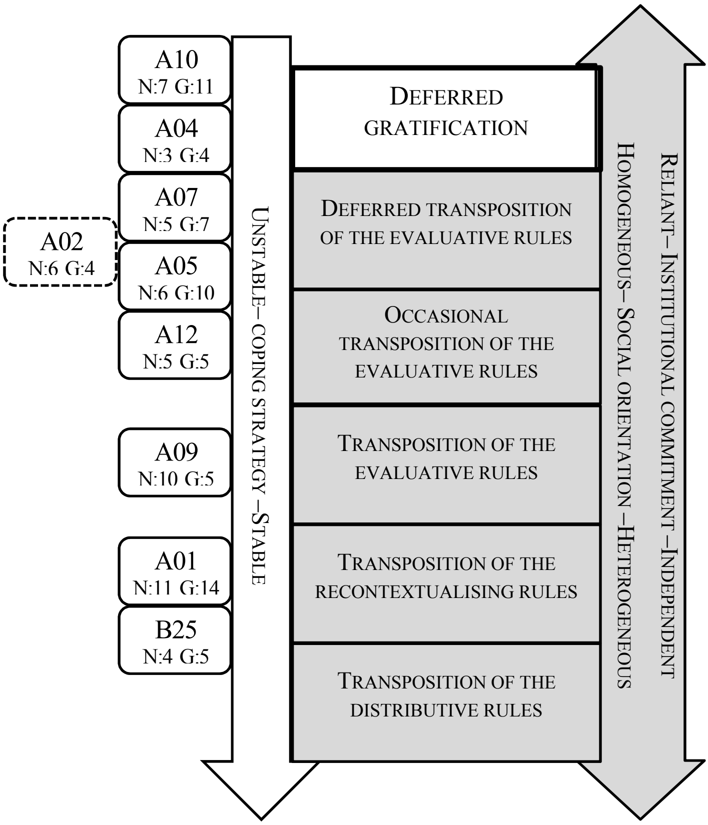

Figure 6.5 A processed illustration of Albert (A01) and Isac's (B25) coping strategies, placed to illustrate relative variety among coping strategies.

As successful strategies for coping with the physics programme at the University of Copenhagen goes, Albert (A01) and Isac's (B25) are definitely the outliers. They study the same subjects as do the other students in the programme, but this might be the only communality their strategy for studying has in common with the other first year students' strategies. They find alternative text-books, seldom do they attend calculations classes, when they go to the laboratory exercises they do so because they have to and only stay as long as is required to finish the task. If they are not sitting in the hallways working out and working on physics problems they attend lectures in courses that they are not taking and that are not offered by the physics department. When they attend lectures in physics they do so mostly to see and talk to other physics students, and to get inspiration for their own work –

not to have the curriculum covered by a lecturer. They might ask the lecturer a question or two, but if there really is something they want to know, they go to the one faculty member who has extended and open door policy to them and seem to have understood what it is they are doing and want to do.

None of the two students believe they would have been able to carry out this strategy of theirs on their own. The main reason they have been able to move so far away from the mainstream practice of the physics programme is because one of the members in the group has a parent who has taught him how to study physics. Now he teaches the rest of the group how to study physics. At the outset they could offer him companionship, but slowly they are getting better at doing what it is he was doing from the beginning, and together they can support each other and drive each other further than anyone could alone. Listening to their story, there is no doubt that what they do is basically just hard work. They keep on pushing themselves to the limit of what they can do, to be able to go even further and do problems that are harder. They do not study one field of physics to be able to engage with another field of physics. They study each field of physics as rigorously and thoroughly as they possibly can and struggle hard to work out applications of each field of physics that bears personal meaning and purpose and allow them to learn more. They take full responsibility for their own learning, and use the institution for only the support it offers. Their purpose is to learn physics, pure and simple, because they like to.

As a group they are isolated. The other students do not engage with them when they study because they perceive of the group's strategy as illegitimate, and would feel uncomfortable and unsafe if they joined them. The group is ignored by the department's senior staff and treated with suspicion by some of the less senior. The reason: they do not abide by any of the rules and make up their own.

The first set of rules they broke were the evaluative rules. They already know how to get top marks on their examinations and have from the beginning not thought of the examinations as anything but a measure of their ability to solve typified problems. To be sure to be engaged with physics contents that would challenge their understanding of physics, they would have to look for alternative literature. Soon they discover that the courses are merely a selection of topics from a much larger knowledge construct, extracted and treated to fit particular institutional constraints. When the lecturer offers the student audience a short-cut through a particularly complicated problem by pointing to theory or methods that will not be covered until courses to come, the group asks to be pointed towards the long way instead, glimpsing a chance to be engaged further with the discipline, to further broaden it and to challenge and transpose the recontextualizing rules: the rules that decides under what conditions, who can teach what to whom. They are radicals who do not believe that learning is about 'listening to the teacher and looking at what he writes on the black-board'. Imagine an environment where this is otherwise the order of the day, a group of four or five students sits in middle of the lecture hall attentively listening. They are not listening so much to what the lecturer says, but instead they are listening hard to hear what he has decided not to say.

When I interviewed Isac at the beginning of his first year, I asked him to remember if he ever experienced something that might enable him to tell me what the institution should do to motivate students like him. A year later he had decided that to motivate the best students, the institution need to realize that they are students, and not pupils. They do not need to be taught, they need to learn. And they need the teachers to help them identify what it is they need to learn.

At the time of the final interview Isac, together with another member of their study group, had spent his summer studying a certain branch of mathematics that they knew would be instrumental to a postgraduate physics course that two of them intended to take at the beginning of their second year. When they did, they discovered that this type of mathematics resolved some major problems in the thermodynamics course that Isac explained he was sure would come in handy for understanding contents of the second-year courses too. Because Isac has not set aside the distribution rules completely, but has only sporadically challenged them, I have placed his strategy as only belonging half-way with the box that says 'transposition of the distribution rules' in Figure 6.5. He has not yet, and probably will not, transpose his physics curriculum completely by studying only the courses he wants and feels he needs. And if he attempted to, he would most likely not be allowed to graduate. Thus transposing the recontextualizing rules and an occasional allowance from the distributive rules, is as institutionally independent successful strategies for coping can become.

6.3. Thriving: Performance, interaction and prior schooling

In the previous two subsections on coping, I have characterized the successful coping strategies that nine students in my sample employ to ensure better congruence between their purpose in studying physics and their interpretation of their institutional experience. In this section I am characterizing the attitudes of seven students who did not have to develop strategies for coping, because their immediate interpretation of their experience of studying physics is well in line with their goals and aims for studying. This attitude I call 'thriving'.

Analyses are not presented separately for each student in this section as is done in the previous two sections because 'strategies for thriving' is outside the scope of this thesis. Instead, I make a case for having decided that overall, these students have not employed strategies in their studies that are rooted in feelings of incongruence between purpose and experience to a degree that warrant a categorization of their strategies as 'coping'. Also, this analysis serves the purpose of contrast: by showing what coping students do relative to what 'thriving' students do, serves to further clarify my characterization of successful coping strategies as well as further point towards some of the underlying reasons that some students need to cope while others apparently do not.

To analyse the students' strategies, I have treated the final interviews with 'thriving' students the same way I did the analysis of interviews with students who cope. I have identified segments of each interview that contained either premises of 'need', 'gratifier' or both and coded them as such. From these coded segments I constructed 'premise trees' for each student. The segments of the tree each consists of a 'need' premise that speaks to a 'gratifier' premise.

In the case of each of these particular 'thriving' students I find that the 'need' premises and the 'gratifier' premises overlap significantly. A significant overlap is when the students' needs, purposes and aims are satisfied and met by educational activities already in place and institutionally provisioned for. When the two premises overlap the 'thriving' students' interpretation of their institutional experiences reinforce their belief that when they decided to study physics, they made the right decision. Consequently they do not develop and apply any coping strategies to any significant degree, simply because they experience no need to do so. Instead they utilize and further develop strategies for studying that are congruent with their interpretation of the provisions and requirements of the institutional setting.

I have identified three dimensions that 'thriving' students draw on to explain how their interpretation of their institutional experience reinforces their feeling of having made the right choice of studies and of employing the right strategies for studying:

1. One dimension is academic performance: the strategies they employ are reinforced and validated by grades.
2. Another dimension is social interaction: the strategies they employ are reinforced and validated by students around them who seem to rely on similar strategies.
3. A third dimension is a sense of congruence between their experience of physics in prior schooling and their experience of physics at university: the strategies they employ are reinforced and validated because they are based on expectations formed from physics learning during prior schooling that also prove valid in university physics learning.

Every one of the three dimensions are normally present in the final interview with 'thriving' students, but are employed by the student to different degrees to explain their satisfaction with the experience of studying physics. Therefore I have decided to represent the students' strategies relative to each other and relative to these dimensions in a triangle. Each corner in the triangle represents one of the dimensions that are used to reinforce their experience of thriving in the physics programme. Thus, a student's strategies placed at the centre indicates that the student draws in equal amounts on all three dimensions. A strategy placed at one corner, indicates that the student primarily draws on one particular dimension to explain how his or her strategies for studying is reinforced through experience:

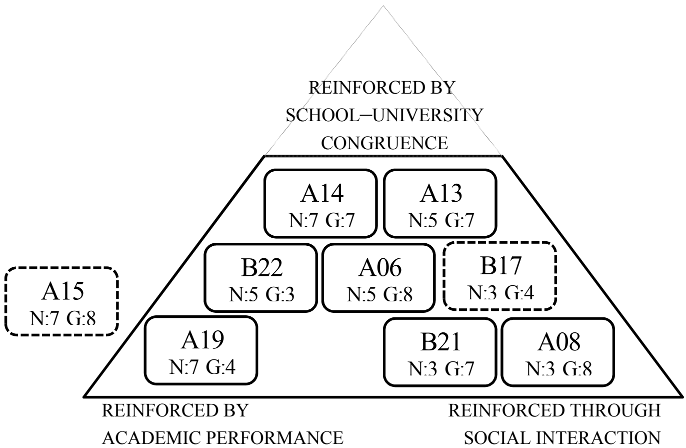

Figure 6.6 Processed relative representation of thriving strategies tendencies. Each box represents a particular student's strategies for studying physics, placed relative to other strategies to illustrate the differences in orientations of strategies. The letter 'A' or 'B' indicates which sample the student belongs to. The number that follows identifies the student. 'N' and 'G' followed by a number indicates the number of 'need' and 'gratifier' premises from the final interviews that were identified and used to decide the position of each student's strategies relative to the other.

To illustrate Figure 6.6 I bring an excerpt from the interview with Julia (A06). Her coping strategies are placed at the centre of the illustration. In this excerpt she draws on all of the three dimensions to explain how she feels that her experience in physics reinforces her strategy for studying. The passages that are underlined are places where it is especially evident that Julia draws on one of the dimensions to justify her strategy:

I: This stuff about: "I pass it, but I don't understand it." And at the same time, we talked about how boring classical mechanics is. But that still, it is absolutely necessary to be able to understand the following courses.

Julia: Yes.

I: How does that work? I mean, then there must be something you do understand?

Julia: Well, for example MathP, when I sat down to read - or not even read. <u>I just practiced problems from old</u>

exams and passed the course fine. But I didn't really understand it. And now with EM, it meant I had to learn it all over again. That I had to keep going back. And milling through it for a practical reason did it for my understanding. But it meant that it took me four or five times as long to make an EM problem because I did not have this simple mathematical background necessary. So it has

I: But what if you hadn't had MathP at all, would that have made a difference?

Julia: Well, I think it would have been almost the same. I didn't learn anything at MathP.

I: Why was it easier to learn EM after you've had classical mechanics and thermodynamics?

Julia: Ehm. only because I've trained reading. You know, that basic: "sit down. Read. And understand it." That was it. Contents-wise I don't think there was anything. It was just kind of a simple training in 2 and 2: to think. I think.

I: I don't know if it's called study technique. Ehm. This might be rude, but it's probably not entirely wrong either: it's good to take classical mechanics while you are still gaffing about?

Julia: Exactly. I can also see that now. They are great warm-up courses. You understand, just as I did in the fourth academic quarter, that it's insanely stupid not to keep up. And that's just a pity for next year. But it also kind of means that now you're motivated. I can see that on my friends too. They are all like, "Okay, we'll have to pull ourselves together, we cannot slag it anymore! And now, now it will have to be." So yes, they're good warm-up courses, and you have to get into studying again.

(Julia, A06-F-6)

At the beginning of Julia's first year in physics she was complaining about classical mechanics, it was too much like physics in secondary school, and she still thinks about the two courses that way at the end of her year. But then she had courses in thermodynamics and electromagnetism and things started to look up. The reason was she was learning something new: "Wow! I understand light!" But mainly, the difference between secondary education physics and university physics is “that now you understand 100% what you once only studied cursorily”, that is, a question of depth rather than modes of engagement. What finally made it for Julia was when her grades picked up, and at the final interview she plans for getting her first top grade and slowly develop into a “star-student” able to compete for a PhD position in physics. Above I mean to illustrate how she continuously draws on all dimensions in Figure 6.6 to justify her strategies for studying: she passed the mathematics course easily, without having engaged deeply with it. She looks to her peers and observes how they too seem to have been slagging during their first year, have suffered from it and used this experience as a source for motivation. And finally she excuses her lack of engagement with the two courses on classical mechanic with reference to the need for ‘getting back into studying again’, implicitly saying that between secondary education and university you get out of the habit to study, and that during the first year at university you need to ‘get back into the habit again’. Had Julia made a distinction between modes of operation inherent to university learning and modes inherent to secondary education learning, she would not have been able to reason thusly.

In the next three subsection I bring examples from the final interviews with students placed at the corners of Figure 6.6 to illustrate each of the dimensions that ‘thriving’ students use to reinforce their strategies for studying.

Thriving reinforced by academic performance

Several students in the ‘thriving’ category have their strategies reinforced by getting good or decent grades. They perceive of the grades as a testimony to what they are doing is right. Below I bring a set of gratifier pairs from the final interview with Bob. Our interviews did not go as well as I had hoped, and when he explains to me that physics is fun because “you can calculate on stuff you wonder about,” I ask him if there is anything in particular he wonders about, which he believes physics can help answer for him. He answers: “Nah, I don’t know of anything like that right now. Not any of the big questions anyway. I don’t much philosophize about much.”

During both the initial and final interview he had explained to me that he thought that a degree in physics would be instrumental to getting a job that could potentially allow him to work at a geographical location he wanted to go to for personal reasons. I can absolutely sympathise with such a reason for getting into a certain profession, but still, I did not understand what motivated him on a daily basis. He seemed to have no troubles finding such motivation, and I wanted to know why. But it did not seem as if he could tell me. Finally my supervisor suggested “that maybe he just likes to get good grades.” And I think this might be true, which I intend to illustrate with the two gratifier pairs brought in Table 6.11:

Table 6.11 An excerpt of the premise tree constructed from the final interview with Bob, student B19. The designator after the student identifier indicates which interview and which coded segment is quoted (ex. F-4 means final interview, fourth coded segment)

	Gratifier pair 19.		
	Need, B19-F-4		Gratifier, B19-F-1
Bob	I think, no matter what I’d started studying I would be absorbed and do all my homework and done the best I could. That’s what I did in all subjects in secondary school.	I:	Did anything surprise you? Was anything more exciting or boring than you’d expected?
		Bob	Nah, not really.
I	And you’d noticed that you could do a little better in physics. You didn’t think chemistry was that fun?		
Bob	Nah. Mathematics and physics was always easier.		
	Gratifier pair 20.		
	Need, B19-F-2+3		Gratifier, B19-F-8
I	How did your exams go?	I	A lot of the people I’ve talked to say it’s strange how they are so interested in physics, while at the same time they have a hard time getting themselves to study the text-book. And I’m thinking, what it is you are able to do, or what is it you are doing right?
Bob	Really well. I was afraid I had to get used to get lower grades after I started university. But they’ve gone up. Mostly I get B’s and A’s.		
I	But you’re also working really hard?		
Bob	Yes. I’d say I’m pretty hard-working. I study before every lecture and do all my homework.	Bob	Well, I don’t know. I found out that I almost have to do my homework before I go to the lectures, otherwise I won’t get much out of them. That always motivates me to read before. It might be dangerous to decide to read afterwards,
	(…)		
I	So that’s what you enjoy the most?		
Bob	Yeah, to do the reports? Yes, but unfortunately, and		

	I think this is a pity, they are not assessed. I mean, practically all lab-exercises we've had, I mean the first two quarters we did log-books on the web and we've had few hand-ins once in a while, but nothing has be assessed. We haven't got any grades or anything. I think that's a real pity. 'Cause that's the part I think is fun about physics, to do some experiment in physics and then write a report. I can't help it, I like to get to know it, because I want to understand it and make a good report. I was like that during secondary school too.
	because then you can keep postponing it. I don't know. It's just, that it feels good to arrive at the calculations classes if you've done all the problems from home.
I	Yeah? What do you do at the calculations class then? Do you have any purpose in being there?
Bob	Sure. Usually we go through all the problems together. Then you see if what you'd done was correct or if someone did it differently.

In Figure 6.6 I have placed Bob (B19) at the far left corner of the triangle to illustrate how his strategies in studying physics are primarily reinforced by his academic achievements. From both 'need' premises in Gratifier pair 19 and Gratifier pair 20 it is evident that there is no way around also pointing out how he draws on his secondary school experiences to explain the strategies he employ for his university studies. However, these experiences are not echoed by the 'gratifier' premises, and therein lies my reason for placing his strategies at the far left corner of Figure 6.6. Instead, what he uses his references to secondary education for, is to explain how his engagement has not changed. He was always a studious student who did the best he could, no matter what the subject. Especially he points out how he liked to do laboratory exercises and how it is a pity that he does not receive grades for his work on laboratory reports at the university as he did in school. He really regrets this, because it is the part of physics he enjoys the most; but without a grade attached to the work he feels like his efforts are invalidated. This is the only bit of complaint or critique that Bob would give up. He likes studying before the lectures, because then he can better follow what happens. I tried to figure out what the purpose of following the lecture was, but did not get very far. He also explains that he likes to prepare before he shows up at calculations classes, because then he can if his solutions to the problems where correct. Everything about what motivates Bob's studious behaviour within the physics programme points towards the examinations and towards receiving perfect grades on them.

I am almost certain that I misrepresent Bob when all I can explain about his motivation is that he likes to get good grades. Instead I think the reason that this is the only thing I know about what motivates Bob's strategies for studying, is that he might not feel a need to be explicit in his reflections about what drives him, as long as he feels driven. But also, his explanation is testament to the legitimacy of justifying ones engagement thusly. It is an explanation for engaging with physics studies that is legitimately available to him as a physics student. It is also an explanation that is legitimately available and used to various extents by most of the other 'thriving' students in my sample.

Thriving reinforced through social engagement

Tinto's (1993) longitudinal model of student departure indicates that social integration is a factor as important to student retention as is academic integration. When I asked students why they study physics the answer I most often received was "because it is fun." I think there is good reason to take this statement literally. Students often do study physics because they have fun when they do.

Hasse (2002b), who enrolled in the physics programme in Copenhagen as an anthropologist to observe physics students in their 'natural' environment, recurrently found herself confronted with a peculiar but characteristic physics-humour that was often enacted through playful behaviour. She wrote a paper about this experience and suggests that on the one hand, playful behaviour is a form of science preparation, necessary for the activity of science (Hasse, 2002a). On the other hand, she also observes that "playful activities connected to science might point to play as a kind of implicit impediment within a physics education for some students who lack the implicitly requested premises for being recognized as a scientist-to-be" (p. 267). If this is the case, the answer 'because physics is fun' is a strong statement that might be translated into: 'because I belong.'

In another paper that addresses humour in physics, a pair of Swedish researchers report that humour is used in group-work by students to position themselves as knowledgeable, but also to pre-emptively deflect any sub-contextual claims to the opposite effect (Berge & Danielsson, 2012). Humour is used by students to open up a safer space where mistakes clouded by humour are easier permitted to the effect of providing "a non-threatening method of introducing new perspectives" (p. 16): "Humour and jokes can unite a group of people but also distinguish them from outsiders" (p. 14).

If we accept the premise that Berge and Danielsson (2012) as well as Hasse (2000, 2002a) suggest, it seems that a sense of 'belonging' together with humour, jokes and 'fun' is a construct tightly linked to perceptions of what constitutes legitimate outcomes of physics education. If so, then clearly when it comes to physics education, social and academic integration start being reflections of one-another why it would only be reasonable to expect that students also draw on social experiences to justify their choice of studies as well as to reinforce their strategies for studying.

As Figure 6.6 is meant to illustrate, all 'thriving' students in my sample does this to various degrees; but none more so, than Tor (A08). Table 6.12 brings a set of gratifier pairs from the premise tree I constructed in order to categorize Tor's strategy for studying physics.

Table 6.12 An excerpt of the premise tree constructed from the final interview with Tor, student A08.

Gratifier pair 21.			
	Need, A08-F-3		Gratifier, A08-F-1
I	Did you just happen to be in the right class? Or?	I	I think the easiest way to do this [start the interview] is to just do as we did the first time: I'll ask you what you think is interesting about physics, but this time, can't you try to explain it relative to where you are now? You've studied physics for a year, and you know more about what it means to study physics.
Tor	I think there was a big difference between the two classes in that course. I'd say, when I went to the first calculations class I might have gone to the wrong one. All the pupils were buried, hunched over their tables and there wasn't a sound in the whole room. Not a single sound. But two weeks later I went to the other class. There was kind of a different atmosphere. It wasn't as dead.	Tor	What I think is interesting about physics is a lot like what we talked about the first time. I still think everything academic is interesting, the science. But also directly, if you look at studying physics. I think we've got a good thing going. It's very socially engaged. And you can really try out a lot of stuff, also
I	Did you change class on purpose.		
Tor	Yes, I did it on purpose. I wanted to try something different because I had been recommended by someone to do it. And I		

	thought, that sounds kind of nice, because I am not always good at making myself read, and then this was a good argument for going there. It works really well.		outside the studies but together with other students. There are a lot of initiatives on behalf of the students – I think is what I'm going to call it. And actually, I think it's very positive that there is so much. It gives you energy to study. If you can experience something together with other students it makes you want to show up and meet them at the study. And it gets you going. You go to lectures and calculations classes because you know that it's interesting all in itself but sometimes it can be pretty boring to go to some place and start to get knowledge in if the way you get knowledge in is pretty boring and monotonous in its expression. But then it helps a lot if you've got some friends you can sit with to discuss: independent of the actual lecture. You can just sit down and discuss the actual discipline.

Gratifier pair 22.

	Need, A08-F-8		Gratifier, A08-F-8(continued)
I	I've tried categorizing your interest for physics from back when you started studying. Then we talked about particles and energy and atoms and antimatter and universe. What they seem to have in common is they are all subjects that easily rouse imagination.	I	So you have no problem accepting that physics education is no workshop for good ideas?
		Tor	No-no, no problem.
		I	And it wasn't something you expected to find?
Tor	Yeah sure, and it's surely something in that line that interests me the most. What rouses imagination. And I	Tor	My reason for starting physics was that I wanted to know more about that universe. And I think I do that now. And I think I've become better at explaining

think it's always been like that. I think I got my interest early on. From all the things you are exposed to when you watch science fiction. If you think it's interesting and you like it, then you'll also become interested in getting to know more about it. Sci-fi never tells you anything about what is happening, because much of what's happening can never happen. But it's really fun to compare the things that are realistic and take a closer look at them.

some of the things you see. And then I also think it's fun to watch some of that stuff and laugh at it 'cause you very well know that it is not at all possible. So I think I got what I came for.

Right from the beginning of the interview Tor goes right into explaining how important social life has become to his studies. One aspect is that meeting his friends has become a reason for him to show up at the university, but more importantly his social relations help him confirm that if he feels bored at a physics lecture, it is not because he is not interested in the subject of the lecture, but because the lecturer is boring. Together they sit after the lecture, or maybe even during the lecture, and help confirm each other that they can locate aspects of the subject they can discuss and make interesting 'independent of the lecture'. Prior to the 'need' premise Gratifier pair 21 Tor and I had been speaking about a particular course that he liked very much. He ascribes the success of this course to the lecturer who also taught the calculations class he switched to a couple of weeks into the course. In connection to this he explains that the main difference, that made this class a good class to be in, was the social engagement and consequent atmosphere this teacher allowed and encouraged which thus became an important reason for Tor's enjoyment with the course, but also for his engagement with it: when he is noticed by others and obliged to engage with others it is easier for him to make sure to make his home-work.

When we speak of his retrospect evaluation of his reasons for starting to study physics compared to his outcome of these studies, he explains how his initial interest was sparked by a curiosity about science-fiction, and has now developed into a sure ability to laugh at the science in these movies. It might not make much sense to an outside observer to hear Tor reinforce his choice of physics studies this way, but to an insider it is a sure sign that he belongs well within the mainstream culture of physics students in Copenhagen and that he is thriving there (cf. Hasse, 2002c).

Thriving reinforced by school–university congruence

A characteristic feature about many of the 'thriving' students' strategies for studying physics is that they do not make a distinction between 'school physics' and 'university physics', and to reinforce their strategies they go back and forth, comparing their experiences of learning physics in secondary school with their experiences of studying physics at university. Often these students explained at the first interview that a major reason for deciding to study physics at university, was that it was among their favourite subjects during prior education and thus wanted to 'know more'. This choice is often reinforced by their experience of physics as university, because it to most extents is very similar to the physics they knew. There are some differences though, but mostly they have to do with the pace and the amount of home-work, and then of course with the extreme amount of physics they are studying compared to secondary school. They also refer to the different pedagogies employed: at university students are expected to be incrementally more self-reliant than they were during prior schooling.

Sometimes they explain about their first year as if it is a transition year. If they cannot see the immediate purpose of certain contents, it might be that the contents is not at all important, but learning to study is – as was the case in the quote with Julia on page 139. In such a case the students imagine that the contents have been chosen because the teachers do not expect that they learn to understand every little detail, but instead that they will have practiced learning to understand. From such a perspective it is possible to find allowance for a strategy that did not immediately lead to understanding, since the strategy allowed the students to gain important insight that can be used onwards to inform, refine or adjust their strategy according to what they have come to know about what it takes to 'understand'.

Other students think of the first year as an expanded version of secondary education physics, and yet others again think of it as the true alternative version to the simplified version of physics they had been exposed to during secondary school. The outcome of such interpretation of the university physics curriculum is that the students have their beliefs about physics and their initial interests confirmed to the effect of being gratified in their choice. Students, like the 'coping' students in my sample, who started studying physics because they wanted to learn something different about physics compared to their time in secondary education have to instate different strategies for studying in order to make their expectations congruent with their experience. This is also the subject of paper II in Section 11.

The student I interviewed most often was Tania (A13). She chose to study physics because of a fundamental curiosity about the answers to fundamental physical questions, like 'what is gravity'? Already at the second interview she has stopped speaking about that aspect of her interest, and instead she talks about her fascination with all the other aspects of physics they are presented with. Below I bring a set of gratifier pairs from the premise tree I have constructed based on her final interview. They are meant to illustrate how her thinking about her interest has changed from being about the very fundamental aspects of nature to be about physics as a 'craft', centred on problem-solving abilities. They are also meant to illustrate that the reason this change makes sense to her, is because she perceives the physics curriculum as the 'true' version of the physics they learned in school, and as such it is inherently gratifying:

Table 6.13 An excerpt of the premise tree constructed from the final interview with Tania, student A13.

Gratifier pair 23.			
	Need, A13-F-4		Gratifier, A13-F-1
Tania	I think it gives me a better fundamental understanding of – you think: "forces, what are forces?" That you get a better sense of how everything is connected. But it's a good question what you need TD for if you are going to be a quantum physicist. But it's just something everybody should have. Period!	I	I was thinking it might be a good idea if we start with what interests you about physics now that you've had physics for a year. Something about what interested you at the beginning and what interests you now. Does it feel like it's changed?
I	I'm thinking about these broad lines in physics. It's something about thinking like a physicist. But they are all very different disciplines. But as a physicist you can for some reason recognize them for what they are anyway. Then you can start talking about	Tania	Yes. I think when I started, I was probably more interested in the more fundamental principles. But now I also think it's fun to geek around with a particular subject or all these mathematical tricks you can use to solve certain problems. But I think it's really cool that we've now got physics as a tool.

phenomena. Heat is one, force is another, electricity a third. I don't know how? Does it just make sense on automatically? Or are you taught that this is how the world is divided?

Tania: Yes.. I think it happens automatically. But maybe it's rooted in secondary school physics. Because here you've also got the beginning of thermodynamics and some mechanics and stuff. So I think it's pretty cool to have it expanded. To get the real version of it.

I: Is it the real version?

Tania: Yes. I guess it has to be. At least back when we discussed what temperature is. I hope it was the true explanation.

It's much about problem solving.

I: Do you recognize any of these problems from real life?

Tania: Yeah, especially now that we've had EM, then there's a lot who is like: "Ohh.." In secondary school we often said that inside magnets there are a lot of tiny magnets, and then you get this neat field. Then you ask, "what does the small magnets contain?", then you get this: "well, you'll learn later." So I think, that's been really cool.

I: What do the small magnets contain?

Tania: That's the small electrons that spin around.

Gratifier pair 24.

<u>Need, A13-F-5</u>

I: This thing about the true explanation, is that real physics?

Tania: Yes. I think so. Of course it is. But I mean, during teaching we don't make much of this: "ah, but we'll just simplify it a bit, to be able to explain it." Then we'll instead work with what we learn and what we are able to. And then we are allowed to sniff a bit of this other stuff.

<u>Gratifier, A13-F-5(continued)</u>

I: It has been simplified for you to be able to work with it?

Tania: No I mean, the part where it's simplified, we don't work with that part. Instead they choose that we go into the areas that we *can* work with, a 100% as it is supposed to be. That's how it seems to me at least.

I: And then there are some areas you can't work with, and then you are given a simplified explanation?

Tania: You have the principle explained to you, but if you are to calculate it you have to wait until you get

	QM1 for example.
I	And to calculate it is the ultimate..?
Tania	Yes, I think that's how it's become. You know, start thinking problem-oriented. You need to have an understanding for what's happening.
I	And by problem-oriented you mean?
Tania	Solution-oriented. You can get a problem and then you need to be able to think creatively about how to solve it.

Scandinavian as well as German secondary education is constructed around the notion of 'almendannelse' (Danish) or 'Allgemeinbildung' (German) which, depending on perspective and pedagogical ideology, is a notion used to argue that young people of today will need to learn about Roman and Greek civilization, physics, poetry, art, mathematics, history etcetera, to become properly and generally 'well-assembled' human beings ready to take part in the complex life of democracy where it is imperative that everyone are be able to make informed decisions about mostly everything all the time (cf. Elmose & Roth, 2005 for an argument along those lines). It is also a notion that is used to explain away the need to justify the contents of a curriculum (cf. Midtsundstad & Werler, 2011, p. 78ff), simply by referring to tradition and the elusive nature of the concept, the main components of which are aesthetics and morality. Knowledge that lead to 'Allgemeinbildung' is the knowledge of the powerful which by no mean guarantees that it is also powerful knowledge (see page 19).

The sentiment of 'Allgemeinbildung' is precisely what Tania draws on, when she justifies the course in thermodynamic: it belongs among the store of knowledge that any a decent physicist will have acquired during his or her training. Knowing about thermodynamics is what makes one physicist recognize another physicist. "Period!" However, implicit in this line of reasoning is the idea that it is the 'right' version of thermodynamics that they are taught – otherwise the whole course would defy its purpose: if once again, the students are subjected to a simplified version (what I have so far called a transposition) of thermodynamics it means that someone else, probably more senior physicists have access to a version that is 'more right'; and since the teaching does not hint at this being the case – except in the cases where the lecturer points towards the course in quantum mechanics – the version they are presented with is the 'right one': "I guess it has to be."

When Tania imagines how the curriculum is constructed, it seems like she imagines a number of knowledge elements that have been chosen based on how difficult they are to work with. Those elements that are too hard are not included in the curriculum (maybe they are left for later or put into the quantum mechanics curriculum), while those that are of a befitting difficulty are included. Thus, what they learn during the course is true physics, and not simplified physics. During the interview I try to confront Tania with the transposed nature of the curriculum she is studying – for example by asking her to relate what they learn to the real world, to see if she feels the course content has any application outside of the course. She does not quite follow me, but she definitely recognizes the feeling of having come to understand something about reality that she had been wondering about: the small magnets inside the big ones are in fact electron with a certain spin property (in a part of the interview not included in Gratifier pair 23 we continue to talk about what magnets are, and soon she needs to refer to the quantum mechanics course she is going to take next year to finish her explanation). My interpretation of this part of the interview is that 'the fundamental issues' she is so curious about are the fundamental issues that had been left unexplained in the secondary school physics curriculum. In this light, studying physics at university is inherently satisfying because step by step it takes her further towards the truth by introducing more and more advanced models that explain the less advanced models she had previously been wondering about:

I: Where did you put it [your curiosity about what gravity is], by the way?

Tania: It's still smouldering in the back of my mind. But after we've started to: like the first lecture in EM – it was really good by the way – she listed the four natural forces, and told us that people are trying to construct these complete theories, like string theory and so on, how all these forces fits into them. And now they are just assembling all these small puzzles. When I understand what gravity is at some point,

> and the strong and weak forces, then I hope to get a complete understanding of gravity. Or that someone else got it.

My interpretation of Tania's perspective on physics is that she believes in curricular simplifications of an objective physical truth that are made for teaching purposes. Gradually as she moves through the physics programme she will be sufficiently skilled to work with knowledge that is even closer to the truth. A comparison of her experience between secondary school and university physics confirm and reinforces this belief and consequent strategies for studying: to keep on solving problems.

An altogether different way to employ experiences from secondary school to justify and reinforce strategies for studying physics at university level, are utilized by Niels (A14). He is slightly troubled by his own difficulties. In part these difficulties are about mustering sufficient motivation due to a lack of insight into purpose and aim, and in part about attaining better grades due to his difficulties with mathematics. But to explain his difficulties he draws on his only other experience of his strategizing education, namely his secondary school experiences:

Gratifier pair 25.

<u>Need, A14-F-10+13</u>

I	Do you think you can make do without MathP2?
Niels	I don't know. I'll have to wait and see. I always think that when you go at a university or secondary school then what you know grows automatically. So, in a year I hope that I've become better at mathematical calculations and, well, physics way of thinking and stuff like that.
	(…)
Niels	That stuff about understanding what happens during the process where the universe becomes transparent, I can understand stuff like that. But then when you need to start

<u>Gratifier, A14-F-10(continued)</u>

I	Do you have a sense of what you need to do, to become better at that? Is it just to do what you are told to do?
Niels	I think that I just need to keep on trying. I remember that I wasn't that engaged back in secondary school about anything the whole first year. But then during third year I began to see that now it starts getting fun. Now I can see some meaning with it. And yes, think it was interesting and fascinating. Suddenly understanding started following, and the grades started to follow. Right away. Something just.. I think that in reality I liked

	calculating it, it starts getting difficult. Then you need to find the right equations and put them together in the right way. Then there's something with the sign [plus or minus] that signifies something important that you just can't figure out how to spot. Then everything suddenly gets a lot harder.
I	Yeah, and that's the stuff it takes to get the good grades
Niels	Yes. I am absolutely convinced about that, believe you me!
	it secretly during first and second year, but couldn't really be bothered. But suddenly something made me want to again. It's probably been something pubescent.
I	But you half expect that it's the same again, and until further you just hold on?
Niels	I wouldn't say I'm just holding on. Most of the courses have been interesting.

The reason that I have categorized Niels as a 'thriving' student is that he insists this is so. Where Gratifier-A14-10 ends, he continues to list all the courses that he has enjoyed, and even find reasons that he has enjoyed important aspects of the boring ones. The main source of his frustration is that he feels like there is something he has overlooked, something important that he can almost spot, but just do not know how to spot, which will obviously be a source of frustration to him. He does not turn this frustration into a critique of the teaching and learning environment, however, because his experience with education predicts that such troubles have a tendency to sort themselves out by themselves over time. One might argue that this is an expression of deferred gratification, which it might be, but it does not lead Niels to a feeling of incongruence. He feels "he just need to keep on trying", which means that he perceives of nothing he does, wants or feels as substantially at odds with the institution.

Dappled student strategies

In Figure 6.6 there are also two 'dappled' boxes that represent the strategies of student A15 and B17. They are not 'thriving' students as such, nor are they 'successfully coping' with their studies in a way that can be captured by the framework I am utilizing in this study. Still, aspects of their strategies draw on the three dimensions in each their way, why I have placed them as I have. The 'dabbling' indicates that only to a small degree, do their strategies belong within this figure.

In the case of B17 the issue is that he does not feel any apparent joy in studying. He does so because of a strong sense of duty:

I: Where did you get that from?

B17: I don't know. I've just always got this feeling that I could never dream of not showing up. I will always be able to make it. Even if I am very, very unprepared, I'll show up anyway. I don't know where this feeling comes from, but when I get up in the morning I might not want to, but still I get here. It's a completely different thing with reading. That one causes me some troubles. I don't know why, but that's how it's been through my entire schooling. But I've often been sitting in the lecture hall thinking, "man, this is boring." I've also thought that maybe I should skip the next one. But still, the next Thursday at 8 o clock, I sit here once again, thinking: 'ah well'

At the first interview B17 told me that he would much rather have started working in a supermarket, but felt like it would be easier to graduate in physics than to convince his parents that working in a supermarket would be a good idea. It seems to me that B17 possesses a natural ability to defer gratification which he has utilized during a large part of his life.

A15, I cannot place either. His reasons for studying physics are exceedingly intermingled with religion, which is an oddity in the otherwise secular Danish society. He constantly needs to justify himself. His choice of physics he needs to justify to his religious affiliation and his choice of religion *and* physics, he constantly needs to justify to his friends in physics. And then of course, four times to me when I interviewed him during his first year. His story is inspiring, insightful and thought-provoking, but also personal in ways that make me worry that every way I might try to tell his story or about his strategies, I might also end up disabusing his confidence in my ability to ensure him anonymity. It is not that he necessarily needs anonymity, but merely that I do not know how to ensure it. All I can say is that his strategies for studying physics are neither captured by Figure 6.6 nor by my characterization of successful strategies for coping that rely on an ability to defer the need for intellectual gratification by transposing various aspects of the pedagogic device.

Summing up

6.4. Quality of learning

In Paper III (Johannsen & Rump, 2011), *Evolution of approaches to proactive engagement* which accompanies this thesis as Section 10 as a manuscript, we illustrate how deferring intellectual gratification as a coping strategy can be observed as a gradual change in the students' potential for engaging with their studies in a proactive manner. In Table 3 in this paper we estimate the overall distribution of students' characterisation of their engagement with learning. We compare these distributions in early interviews with distributions in later interviews, and claim that our estimate is that during early interviews approximately half of the students predominantly use expressions reminiscent of proactive engagement when they describe what they do to learn, and that the approximate other half of the students in my sample use expressions reminiscent of a certain subset of surface learning approaches, when they describe activities related to their learning in the physics programme. We then compare this estimation from the early interviews with the same estimate from later interviews, and find that the numbers have changed to a 1/4 – 3/4 ratio, or that approximately half of the students who seemed to be proactively engaged with their studies at the beginning of their first year, have stopped being so at the end. Instead they have adopted strategies for learning that are not proactive strategies or strategies reminiscent of surface approaches to learning.

The reason we give this quantitative estimate in Paper III is to motivate a qualitative exploration of the effects of deferred gratification relative to types of engagement in learning that are consistently linked to the quality of learning outcomes (cf. Case & Marshall, 2009 for a review of approaches to learning research). This is important because traditionally the ability to defer ones need for gratification is considered an academic virtue associated with academic achievement. For example, a 1967 sociological paper written in concern for the adolescent behaviour of London schoolboys says:

> As [society's] members go through [adolescence], the survival of the society requires that most of them should gain a certain basis of knowledge and social values, as well as certain intellectual and social skills. Yet at this phase of their lives, it seems that the young are undergoing considerable psychic strains (partly determined by the structure of their society) and are exposed to the temptations of a youth culture that encourages at the least a considerable diversion of time and energy from these educational pursuits and at the most an inversion of the related values of deferred gratifica-

> tion, academic achievement and conformity to rules. (…) These [London schoolboys] are on the whole rebelling against the norms imposed by the school and performing academically below expectations; they have unfavourable attitudes towards school and score low on deferred gratification. (Sugarman, 1967, p. 151 & 160)

In Paper III, we implicitly challenge this traditional claim that deferred gratification should be considered an academic virtue. In the context of this thesis my suggestion is that deferred gratification is an important strategy for coping with an institutional environment that is powerful in fostering surface approaches and suppressing other attempts at approaches that are consistently associated with quality learning outcomes. As such, deferred gratification is a symptom of an institutional defect, which is what Table 3 in Paper III suggests.

In this section I offer the background, for the estimate that motivates Paper III and answer research question 2: *what might the consequences of these successful strategies for coping be for the quality of their approaches to learning?*

Coding and coding result

When utilizing the concept of approaches to learning, it is important to stress that an approach to learning is *not* a personal disposition, but instead a manifestation of the student's interpretation of the learning setting and of the requirements posed by this setting. How the student makes and act on this interpretation is in part a product of the student's previous experience with learning (cf. Trigwell & Prosser, 1997). This relationship is illustrated with a quote from one of my interviews at the beginning of the next section.

Another important aspect to realize is that students' approaches to learning are concepts that have been developed based on phenomenographic methodologies that focus on unmasking the phenomenon as an 'experience of learning' that exist within a group of people, and not with people individually. As such, the phenomenographic research-aim is to characterize the qualitatively *different* ways a particular phenomenon is experienced within a group (Ashwin, 2009, p. 32). The outcomes of this type of research are rich hierarchical categorizations that illustrate how groups of people engage with a particular phenomenon. One categorization that has especially gained ground is a distinction between deep and surface approaches to learning. One is associated with engagement for understanding, the other with rote memorization.

Here I also make use of a deep-surface distinction to evaluate the students' predominant modes of engagement over time, but by way of a more recent distinction that insists that relations between the phenomena that are the object of the learning approach must also be taken into account. The distinction is named sifting and building, the latter I refer to as *proactive*. In sifting, the student will typically be focused on acquiring an outcome in line with what the system demands. The student's intention with being engaged with learning this way is to have learning verified. Learning and understanding in itself is associated with 'taking in' knowledge that is made accessible by text-books and teachers (Fyrenius, Wirell, & Silén, 2007). Characteristic of the proactive approach is that the student focuses on acquiring the ability to apply knowledge in new situations, that the student is engaged with learning to refine his or her understanding in an open-ended process, while learning and understanding in itself is associated with a strive for variation and use of multiple learning modalities and inquiry techniques (*ibid*). I find it interesting that the description of the latter approach seem to contest the idea that deep learning is necessarily "founded in intrinsic interest" (Biggs, 1993, p. 7). One can easily imagine how the proactive use of a certain knowledge construct can be instrumentally or extrinsically motivated within a more complex open-ended process of variation and use of multiple learning modalities, why an intrinsic interest will not be required. This means, that when I code for 'proactive' engagement, intrinsic interest is not necessarily an aspect I look for. Similarly I do not associate intrinsically motivated learning with a sifting approach since I emphasize the aspect of the sifting approach that is primarily motivated by a concern for meeting institutional requirements.

McCune and Entwistle (2011) associates proactive engagement with the disposition to understand in 21st century university education. I agree with them, and this is why I have decided to use Fyrenius, Wirell and Silén's (2007) distinctions between learning approaches as way to evaluate the evolution of coping students' engagement with their learning in the physics programme in Copenhagen.

To inform this evaluation, I have coded the interviews as described in Section 5.6. However, it is necessary to stress that what is coded is sections of interview discourse in which the student who is interviewed reveals his or her approach to studying by telling about what he or she *has done* to learn in activities the student find related to his or her experience as a student in physics. Thus, I have characterized instances where the student speaks of learning in the programme in general, of learning by doing physics or mathematics problems, learning in the laboratory, during calculations classes, in groups, at lectures and during extracurricular activities like public lectures given by visiting scholars or physicists working at the institution. I have also sought to characterize instances as either proactive or sifting when students speak of their engagement with text-books, of choices of elective courses, of reasons for having chosen to study physics and for having decided to do a particular first year project. Similarly, I have coded instances where students speak of how they engaged with doing the first year project, both practically and conceptually, how they worked together to finish the project and what they did with the evaluation they received on their final report. I have also coded instances where they speak of how they prepare for examinations and tests, and how they use their grades to inform their on-going studies. In short, I have coded each and every phenomena related to their engagement with studying physics, that the students bring out when they explained how their experience with studying physics spoke to their intentions and purposes regarding their physics studies. For this reason, I have even coded one instant where a student speaks of his preparation for the interview, because he said it was important to think of these things when you are a physics student.

For each interview I have only coded each aspect of a phenomenon once. For example: the first year project was a dominant theme in interviews performed during academic quarter three and four. Thus, a returning issue during one interview could be that of making a choice of a project. The choice was only coded once, but based on an evaluation of the whole description that was offered during the entire interview. Several aspects inform such a choice however, and sometimes I have judged these aspects to be expressions of different phenomena. Thus, I have not kept to a dogmatic regime, but attempted to make a reasonable distinction between repetitions and complex elaboration: the choice of a first year project can be made with consideration of both professional or personal aspirations at the general level, or with reference to courses, to maintaining social relations or to be ensure that institutional requirement are met in certain ways. Thus, the point is that I have worked to avoid inflation of the 'approaches to learning counts' by evaluating repetitions as one expression of what a student has done to learn in a particular situation.

This means that the number of times I have recorded 'speak about learning' dramatically varies from interview to interview. Some interviews were focused on certain aspects of the educational experience, whereas in others, the students sought to cover many aspects. This, because the students themselves where in charge of deciding the theme of the interview based on a set of themes that the student and I had decided on, during the first interview.

There are also a number of instances where students spoke of types of engagement that could not be captured by making a distinction between sifting and proactive approaches. These instances are coded as ‘neither or’. If the numbers from each interview are added together, they make the number of distinct phenomena that involved ‘doing something’ to learn ‘something’ that the student in his or her interpretation thought of as related to and relevant for his or her experience of studying physics. Added, these ‘counts’ are and expression of the students’ engagement with the multiple faceted and complex phenomenon that is physics learning at the University of Copenhagen – but must only be considered *an aspect* of this experience, namely the aspect that was brought up during the interview.

All in all, there is a considerable amount of considerations that must be taken into account when the result of this ‘count’ of instances where approaches to learning are revealed during the interview. In Table 6.14 I present the results of my classification of students’ reflections on their engagement and experience with studying during the first four academic quarters of their physics studies. The next section addresses how the results might be interpreted.

Table 6.14 Raw and normalized representation of approaches to learning counts. S=Sifting, n/o=neither or, P=Proactive. Shaded: no interview.

	AQ1			AQ2			AQ3			AQ4		
	S	n/o	P	S	n/o	P	S	n/o	P	S	n/o	P
A10	6	6	7							7	18	7
A04				11	7	2				10	6	0
A07	5	5	1				1	4	3	3	4	6
A05	5	4	1				7	3	3	2	4	1
A12	8	8	12							10	3	9
A09	1	3	9	4	7	9	4	6	3	1	4	0
A01	14	1	5	4	3	8	4	1	4			
B25												
A10	31%	32%	37%							22%	56%	22%
A04				55%	35%	10%				62%	38%	0%
A07	45%	46%	9%				12%	50%	38%	23%	31%	46%
A05	50%	40%	10%				54%	23%	23%	29%	57%	14%
A12	28%	29%	43%							45%	14%	41%
A09	8%	23%	69%	20%	35%	45%	31%	46%	23%	20%	80%	0%
A01	70%	5%	25%	27%	20%	53%	44%	12%	44%			
B25												

Above, the table offers both the actual (raw) counts and the relative (normalized) appearance of expressions of learning approaches during the interviews. For example, this means that in the interview we did during the first academic quarter, student A05 spoke about learning in a way that I interpreted as an expression of a surface approach five times. In four other distinct instances he spoke about learning in a way which can be described as neither a sifting nor a proactive approach. But one time, he spoke about learning in a specific context that I interpreted as an expression of a proactive approach to learning. In total he described what he had done to learn in ten different situations. This means that of these ten situations I interpret 50% of the situations as expressions of a sifting approach, 10% of the situations as expressions of approaches that are neither sifting nor proactive, and 40% of the times he talked about what he did to learn, in ways I interpreted as proactive.

Interpreting 'approaches to learning counts'

To give an idea of what the numbers in Table 6.14 are an expression of, I start by offering a transcript from the third interview with Conrad (A07). Prior to enrolling in physics, Conrad had been studying mathematics, and he brings this experience with him to interpret his experience in the physics programme. The quote neatly illustrates how his prior experiences with learning, together with his experience of the context of the physics and of the mathematics lectures respectively influence two very different ways of interpreting the requirements that these settings make of him – and thus result in two very different strategies for engaging with the lectures offered in the two courses. One course is Mathematics for Physicists (MathP) the other is Thermodynamics (TD).

> Conrad: It's almost impossible to have time to copy down what he writes on the blackboard. And while he is writing he is also explaining and you need to have an ear for that too. And I remember I figured out how to do it when I studied mathematics, it's a little nag you develop. And now that I'm getting more used to it I'm feeling more at ease. I can see that really, it isn't that difficult the stuff he comes with compared to what we had when I studied mathematics. So I say to myself: 'okay fine, ease down, easy, you'll get there, don't doubt it.' I can see the others panic because of that way of teaching, it goes

incredibly fast. But I still think that it's something you can take care of during the calculations classes.

I: Is it different in physics? The pace?

Conrad: Yes. They keep an incredible pace in MathP

I: Is it the same pace in other mathematics courses?

Conrad: Yes

I: Funny, this difference

Conrad: Uhm. Yes. Well, I've got a feeling that he's a mathematician, the guy who tries to teach us. You kind of sense that. I've got this feeling that their heads run at an uneven speed.

I: Do you think mathematicians are smarter than physicists?

Conrad: Ehm, smarter like in 'quicker'? That depends, I think. They are quick on their home turf. No doubt about that. Then it's at a furious pace you can hardly keep up with. Because they know all the stuff and they know what to do and they are at home with it. They can make these sudden jumps where they say: "from which one clearly sees" – like from the textbooks – where you think: "one doesn't see, no. It isn't clear." They can do a couple of lines on, like a piece of paper, and then it's just like, alright fine, onwards: in a pace you can't follow.

I: But why isn't the same thing true for physics teachers who teach classical mechanics?

Conrad: They are teaching something different. I've got this feeling that most mathematicians, when they give a lecture the things they must say are already decided and systematised. Then it's just a quick jabber to get it out. And then they say 'just stop me if there're any questions'. But that doesn't ensure that we manage to do it if you had a question, because it's so fast and you also have to pay attention. So you don't have any actual thought-process. It's just 'receive, receive, receive'. You don't have time to actually reflect, and then you might not be able to form a question. Then you just end up sitting there. Physicists, on the other hand they are like: "Do you follow?" "Do you understand?" "Ah, you seem a bit tired. Fair enough, let's take a round of questions: if

> I do this, and this, and this, then what will this do? 1, is this. 2, is this. 3 and 4. And now I'd like to see your indicate which with your hands or with the paper" – that's what the guy we have now does. He has made piece of paper with 1, 2, 3, 4 that we show. And then you answer what the solution to the questions is by showing the paper or your hands,
>
> I: That's your lecturer in thermodynamics?
>
> Conrad: Yes. I've also heard talk in the corners that [a professor] does the same thing. He's just got these clickers. We didn't have stuff like that in classical mechanics. But there were open questions asked to the lecture hall. To get people along and to understand the concepts and why it is like it is. Because that not something that is immediately clear. You need to gain an intuitive understanding for it. That's mostly what it rests on. In mathematics I've got a feeling they just assume everybody have an intuitive understanding – although it's not necessarily so. (Conrad, A07, Interview III, minutes 25-27, AQ3)

What Conrad is explaining, is that his experience during the mathematics lectures tell him that his learning in mathematics must take place during the calculations classes. For this reason I have coded Conrad's approach to learning in the mathematics lecture environment of the MathP course as Sifting. He copies down everything written on the blackboard in an attempt to 'receive' or 'take in' knowledge just from being present. He harbours no illusions regarding his understanding, but still, this is what he does at during mathematics lectures. He then explains that his learning will have to take during the calculations classes, but does not give any indication as to how this learning takes place – why this part of the quote is not coded. Because he compares and equates this experience to similar experiences when he was studying mathematics, I ask him if his experience is any different during the physics courses he is also taking. He answers that it seems to him like mathematicians think in a manner that is different from physicists, and I ask him if they are smarter; a question that serves as a cue for Conrad to elaborate in this distinction he made. In this elaboration he does not carry his sentiment regarding mathematicians and how their brains work further, but instead he explains about his impression of the pedagogy they utilize. According to Conrad, it seems like the structure of the mathematics curriculum is precisely structured and not at all difficult to the lecturer. Because the contents is easy to the lecturer and because it is precisely structured, he might not be able to help himself, when he paces through the contents too quickly for the students to follow. I then ask him why the same notion might not hold true for a physicist who teaches a first year course in physics. Conrad explains that it is because the nature of the contents is different, and that the difference lies in physics being a conceptually dependent discipline. For its practitioners to be engaged with it, it takes a conceptual understanding, an almost intuitive feeling for the phenomena that are the objects of the discipline. To explain what he means he draws on examples where his lecturers make use of peer-instruction, which is a pedagogical technology that has been developed as a means to get students engaged in lectures. This technology was initially developed to improve a physics learning environment (Crouch & Mazur, 2001) but a growing body of evidence shows the technology effective irrespective of the discipline (cf. Michael, 2006). For this reason I do not think it reasonable to think of the technology as a practical expression of the physics discipline, but as an expression of the pedagogy that is used to teach physics with. Still, Conrad compares his consistent experience with mathematics pedagogies with his consistent experience of physics pedagogies and interprets this difference as an indication that the two disciplines are inherently different. In turn, this influences his interpretation of the disciplinary requirements, and makes him engage for conceptual understanding when he is at the physics lecture. This segment of the interview I have coded as an expression of an approach to learning that is neither sifting nor proactive.

Besides serving the purpose of illustrating how I code, and how both prior educational experience as well as the student's interpretation of the learning environment influences a student's approach to learning, I think the quote is important in another respect. It illustrates that Conrad is not particularly disposed to employ any particular learning approach separately from his experience of the learning environment. Students are not by nature surface learners, nor are they inherently proactive. To evaluate the learning approaches students employ, it is necessary to take into consideration their experience of studying as well as their previous experiences of learning – since this previous experience is the lens they use in an almost customary manner to interpret and act on later experiences (Johannsen & Jacobsen, 2010).

Consequently, the transcript of minutes 25-27 from the interview with Conrad performed during his third academic quarter adds to Table 6.14 (A07, AQ3) with one 'sifting count' and one 'neither or count'. In normalized terms, this means that the quote above signifies the 12% sifting and a quarter of the 50% 'neither or' counts of approaches to learning. The three 'proactive' counts are about his engagement with the first year project.

If one compares these counts with the other counts that I made based on the three interviews I did with Conrad during his first academic year in physics, it appears that Conrad was predominantly engaged in learning in ways that are different from the proactive approach, split equally between sifting approaches and other approaches. During the interview in the third and fourth academic quarter he utilizes proactive approaches to his studies more. These counts are based on his explanations about the various ways he was engaged with doing the first year project in physics. In general the first year project is often the subject of conversation in which the students explain about their modes of learning in ways I code as evidence of proactive engagement. Thus, there is no doubt that the choice of first year project is a splendid initiative for allowing students to be proactively engaged in their physics learning. Also, during these projects some students, like A01 and B25 form groups they utilize in their coping strategies. The first year project is cause of much that is good, but there is however not much further evidence of that students 'learn' how to be proactively engaged with other forms of in-course learning. To some extent, interview-discourse on the first year project obscures the overall impression of the evolution of students' engagement with their learning. Thus, in

Table 6.15 I have removed 'counts' that are directly related to what students did to learn while doing their first year project. Instead, the table offers a representation of the distribution of 'approaches to learning counts' from interviews I did with coping students during their first academic year, on everything but their first year project. To make the representation more discernible I have also removed counts that I could not categorize as either sifting or proactive and resorted the order of the students, to emphasize the general tendency.

Table 6.15 A normalized representation of approaches to learning counts. S=Sifting, P=Proactive. Shaded: no interview.

	AQ1		AQ2		AQ3		AQ4	
	S	P	S	P	S	P	S	P
A09	8%	69%	20%	45%	36%	18%	0%	0%
A12	29%	43%					50%	39%
A10	32%	37%					24%	14%
A01	70%	25%	31%	46%	100%	0%		
A04			55%	10%			67%	0
A05	50%	10%			56%	33%	29%	14%
A07	45%	9%			50%	0%	43%	26%
B25								

Student identifiers that are typed in bold-italics show a shift from being predominantly proactively engaged to predominantly approaching their studies in a 'sifting' manner. These are A10, A09 and A12. Two students are typed in bold because, although they are predominantly approaching their studies through sifting, their pro-active engagement does also decline as time goes. These are A01 and A04. Three coping students does not exhibit such a tendency. They are A07, A05 and B25. B25 belong to the group of students I did not interview in an on-going fashion during their first year in physics, why he his interviews do not add to this analysis.

Now, again, it is important to remember that students' approaches to learning are reflections of their interpretation of their learning environment informed by their experience of previous education. This means that when we see A01 exhibiting a 70% sifting behaviour, it does not mean that he is sifting by nature, but that his interpretation of his learning environment makes him approach his studies in a sifting manner.

All in all, my interpretation of

Table 6.15, is that it supports my impression that at least half of the coping students evolve from being initially proactively engaged with their learning to approaching their studies in a sifting manner. The 'approaches to learning counts' alone, is not a convincing argument, but as a background for a qualitative interpretation of the interviews it is based on, it serves its purpose well.

In the following three sections I will offer more information about the findings from the interviews that were utilized for this analysis of engagement in learning, to further support my impression of this shift. As an outset, the premise I am working from is that gradually the students' experience in their physics studies become dominant in informing their interpretation of learning experiences, why, as time goes by, the idea that proactive learning strategies might be employed to different situations, become more distant – and that this, is the reason we can see this slow decline of employment of proactive engagement.

A05 and A07

Emil (A05) is predominantly sifting during AQ1. At this stage he is trying to find his feet as a physics student, and does exactly as the institution requires. One aspect of this quest is to figure out how he compares to other physics students, why he works hard to get good grades. During AQ3 he has found out that he compares well with the other students, and he is about to decide that the physics programme is a place where he feels he belongs, why he is 'experimenting' with his commitment to the studies. He reflects on the relationship between his perspective on life, and how studying physics adds to that:

> Emil: It's very focused on the discipline: why does it do like this. That's what a lot of physics is about: why do things move like this, if you do like this? So it's almost only in this regard I can use it.
>
> I: Are you satisfied with this limitation?
>
> Emil: It can seem a little so-so sometimes, when it's this specific. There're no humans in it. There's no spirit if you can say it like that. And that's a pity, except I don't know if you can even say that. That's how it is in this programme. And I can settle for that. There's a lot of other stuff out there in the world, and as long as I can still see the other stuff in the world, then it's just a cool bonus to be able to analyse that stuff. (Emil, A05, Interview III, minutes 12-13, AQ3)

At this point in time, Emil is settling for what he perceives to be the institutional conditions. The scope of physics is focused, limited to certain inanimate objects. Emil can explain what the objects do, if he does certain things to the them, and he can settle for that, because to him life is a lot of other things than physics. To me the quote is suggestive of his need to cope, but also to his learning strategy. It is not necessarily a sifting strategy nor is it proactive; but he would have liked to include more parts of what life is, in his studies. Unfortunately, that's not what physics is, at the University of Copenhagen.

When I speak to Emil again during AQ4, he has come a bit further in his experimentation regarding his commitment and his institutional identity. He knows how he wants to develop as a physics student:

> Emil: That's the next step. To take my circumstances seriously. The conditions that are given from the side of the institution. I don't think I'm quite there yet. I've just come over that part about deciding that it's alright what I'm doing. And then I can start thinking about what could be better on the institution's part.
>
> I: I can understand that you need to root yourself, make roots before you can start making a decision about the fundament you are standing in.

Emil: Yeah, I don't think you can be specific about it until you know what specific is. I have to react on my feeling. And I can't say more about that until I can take a look at it retrospectively.

I: Alright, let's tie a knot: We started by talking about your motivation which rests on you having a bad conscience and on the demands you make of yourself. And at the beginning some of these demands was about figuring out if this [physics] was the right thing. And then you've figured out that deciding if it's the right thing or not it's not as simple as that. Because 'right' is relative to what. And then you decide that it's relative to yourself, because the thing about a royal road doesn't make sense. And that's the next phase in your life.

Emil: At least in my studies

I: Yes, I guess that's an important distinction to make. But it's the next phase to get you convinces that it feels right, now. But at some point

Emil: At some point I have to make a decision that this is what I am going to do. And then the choice is made. No turning back. I have to decide that now, I'm studying physics and then that's what I do, and then I am going to finish it. Then something must go awfully wrong for me to decide otherwise.

I: What do you imagine could influence that?

Emil: Bad grades for a long while. Feelings of inadequacy all the time. As if I'm not good enough no matter what I do in my studies. I guess these are the big ones. (…)

I: But this has still got something to do with you. Because I thought that we'd just decided that at some point you are going to make demands of the institution too?

Emil: Yes.

I: I mean, that feeling of inadequacy, could it be turned around? Could you instead say "How can you do that to me?"

Emil: yes, it's the institution that is supposed to support us if we feel inadequate and feel like we are dumb no matter what we do.

I: But it seems like there's some way to go before you can start thinking like that?

Emil: Yes

I: Do you know why it is like that? It's like you think of the institution as a given.

Emil: Yeah, you just accept its basic conditions, and then the rest is about yourself.

I: And then you have to adapt?

Emil: Yes

I: Why is it like that? Is it good?

Emil: No, it isn't. Because then you force yourself to accept. I don't want to do that, but I can't find the energy to demonstrate or throw paint around for that matter. And I kind of feel like it, and I think you ought to. But I just can't find the energy for it.

I: No, why not?

Emil: It's as if you make other priorities. I arrive at the point where I just about want to untangle; like metaphorically again: All the institution's ailments are as if a lot of seaweed is put on top of you. All your movements are laboured. And then you get just about enough, God dammit I'm going to untangle myself of this bloody seaweed, and 'argh', 'uff', 'ay', I guess this weed kind of looks nice on me. It's too much trouble getting rid of it, I'll just continue covered in this stuff. You settle for it. (Emil, A05, Interview IV, minutes 5-13, AQ3)

This quote is a splendid example of how coping by deferred gratification can also look like. Emil knows that there are circumstances regarding his education that he should not accept, and the next phase of his institutional life ought to entail making demands of the institution too. He is still not there, though, and when he imagines what might make him leave the programme, he fails to think of this decision in terms that are institutionally rooted. As he says, he is not yet ready to think of his engagement with his studies as the result of an interaction. When he explains why it is like this, he explains that it takes a lot of energy to do something different from settling with the institution and doing what is required by it, whether it makes sense or if it hinders him in his learning endeavour. The first part of the quote I have coded as neither a sifting nor a proactive strategy. The last part I coded as a sifting way of approaching the studies in general.

Based on this interpretation I would argue that a student like Emil is a late starter. During AQ1 he was sifting, because he wanted to find his place at the institution. Then somewhere during AQ2 and AQ3 he starts thinking of his studies in terms of himself and in terms of what he wants to do with his learning in an open-ended way. This is what gives rise to his proactive engagement during this period. Then, somewhere during AQ3 and AQ4 he gives up on his proactive behaviour, because the next step would be 'to take his circumstances in the institution seriously'. This, however, is a task that defeats him. Instead he relies on his ability to transpose the evaluative rules, to make sure that his engagement with his studies makes sense to him, as a whole person who might very well study physics, but who is mostly gratified by all the other aspects that are to life.

As a late starter he is predominantly proactively engaged with his studies. As the year draws to an end, he is defers his ambition of continue to be proactively engaged with his studies, and settles for sifting.

The development of Conrad's (A07) engagement is a different and shorter story. He is not doing well with his studies. When he engaged in the first year project he was hugely engaged with his studies, but the outcome of the project and the way the product was received turned out to be a disappointment. The group he was proactively engaged with dispersed (maybe just for a period of time) and during AQ4 Conrad started to look outside of the institution to find something that could help him keep motivated in his physics studies. This latter part is what gives rise to an increase in Conrad's proactive engagement. Regarding the in-course studies, he is sifting through the course contents with bad results while he is deferring his need for intellectual gratification. First he needs to find a good reason for engaging with his studies – which he does in a proactive manner. I have categorized Conrad as a student who develops his ability to engage proactively, because this is precisely what he attempts to do, the best he can. I do it hesitantly though because the proactive component of his overall approach to learning physics is directed away from the institution (this is what the parenthesis indicate in Table 6.1).

A01 and A04

Isac (A01) is the student who formed a study-group together with Albert (B25). At the beginning they are just sitting together working on end-of-chapter problems, doing their homework in "just a couple of hours". It is not until they do the first year project together with two other students that they develop their strategy for coping to the point where they start transposing the recontextualizing rules. But during the first three academic quarters Isac cannot see much point in the studies. He feels he knows everything already, and explains to me during AQ1 that he is just following the course in classical mechanics to see if they do it differently than he is used to. This reason is reason enough for a ‘proactive’ count in Table 6.14 and

Table 6.15). He does everything he is required to do, but cannot see any point to much of it. He knows how to solve all the problems, and he feels that he is not learning anything. This is the reason why his ‘sifting’ count is so high during AQ1. Then during AQ2 he meets a teacher who engages with him and helps him identify types of problems that are more engaging. This is why the ‘proactive’ count is higher during AQ2, plus he has started engaging with the literature in a critical manner: complaining that the hints in the book practically solve the problem for them, but still the solution at the end of the book is wrong. Also he works to understand what the relevance of the mathematics courses are, compared to the physics courses, and he is starting to have thoughts on what his first year project is going to be about. At the interview during AQ3 we mostly talk about his first year project, and very little about his other strategies for studying. What we do talk about however, is that he sees no reason for being part of study-group because everything need is provided for by the calculations-classes; which in turn entail preparation for the examination. This is the reason he seems to be a 100% sifting, if his engagement with the first year project is not taken into account. I think this is a misleading result, because in all actuality he is slowly developing his ability to engage proactively parallel to other institutional activities.

Asta (A04) is sifting through her studies through and through. She came to study high-energy physics, and none of the courses she is required to take during her first year seems to her, to add to this aspiration in any other way than to allow her the degree she needs to take high-energy physics courses. All she does is to defer her need for intellectual gratification. The only two instances that I count as proactive, is when she explains that it is more important to her that she develops a social network in the programme than to make sure to pass all the courses, and when she explains that she would never work as an engineer, because she does not study physics to make money (or bridges) but to understand the world, fully and completely. Asta is not a disengaged student. Quite the contrary. Her whole identity is constructed around the ambition to one day become a high-energy physicist. No-one, however, manages to convince her that any of the courses during the first year, serves a purpose in this regard. At the beginning of her first year she was looking forward to the course in electrodynamics, but to her great frustration, the course unfortunately did not live up to her expectations. Much of the frustration she experiences related to not encountering the type of physics she was expecting to encounter when she started studying physics, she turns into contempt, not directed at physics as a discipline, but at the ones who teach physics during AQ3 and AQ4. The result is that she perceives the pedagogy of the reformed course-design of the thermodynamics course to be an expression that the lecturer is either unable or unwilling to take care to make his teaching as rigorous and orderly as she came to be accustomed to while listening to the lectures in classical mechanics. As a result she completely misses this opportunity to do anything but sift through this course too. Also, she did not manage to find a group of people who were willing to do a high-energy first year physics project, and settles for what she can find. She is not impressed with their shared work, and partly sifts through this experience too. That is why she is categorized as one of the students who change their strategy from one of being proactively engaged to sifting. She just did so, right from the outset. While Asta's strategy for engaging with her studies shares many characteristics with the 'thriving' students, the main difference between them and her is that she is not intrinsically motivated by sifting through the programme the way they are. Like the thriving students, she does not make a distinction between physics-as-curriculum and physics-as-research. Because of this, she is not able to see that any viable alternatives to her strategy exist. Electrodynamics is just electrodynamics, and if she is not motivated by it the way she thought she would be, the only viable explanation is, that the lecturer manages to take the life out of a subject, that she is sure is otherwise inherently interesting. Since this is often the case, she can only wait it out.

A10, A12 and A09

Jon (A10) is insecure about his abilities in physics, and actually was right from the beginning. He had never experienced the joy of attending school, and only finished secondary education because he needed to, to enter university and become an academic. His interest in physics is genuine, though, and his overall experience studying physics is a one filled with joy at finally experiencing happiness in education. At the beginning of his studies has a well-developed sense of what is entailed in learning, and readily applies his own version of constructivism to his own learning. The quote starts at the beginning of the interview, where I ask Jon if he has chosen any of the themes we had decided on during the first interview:

I: Did you choose one already?

Jon: Yeah, I was trying to decide between the two first ones, because we have simply not come sufficiently far for me to say anything about the third theme. But we are getting there, but then again. And then I thought that, all things considered, 'learning to learn' was more interesting compared to 'participation'. (…) This first quarter is really making allowance for the fact that we are fresh out of secondary school and at that, that some of us weren't necessarily that good at studying. Something which is really good is the continuing evaluation we get on both physics and mathematics hand-inns, as opposed to just a free run and then an exam at the end. (…) At the same time it is still very open compared to secondary school, which means that it's a kind of mixture between what it is going to be later, when it becomes less framed, and then secondary school that was far too framed. It suits me well, this way.

I: Alright, so you expect that it will loosen up later?

Jon: Yes

I: Why? Why couldn't this keep on being the format?

Jon: It could, that would suit me just fine. But I think that at some point we need to switch to a more independent format. And I have to prepare for that. Then I'll need to keep a firmer grasp on myself. When we do this thing with a lot of hand-inns it makes you read also when you do the problems. At some point or other you arrive at a problem and then you discover, man, I haven't read that yet. Then you need to look up that chapter to solve it. You are forced to take in the curriculum to do the problems.

I: Don't you risk, well okay that depends on the type of problems, but don't you risk that your study-strategy is about solving problems?

Jon: Yes, certainly! And I think it becomes better when we do lab-exercises where it's more free: I mean, figure out your own way to solve this. I mean, you don't have a solid square with a certain mass, acceleration, etcetera. That would be very schematic. You just follow this 'bam-bam-bam-done', right. But we have to think for ourselves in the lab. We've had these fantastic exercises and I think that we are going to work with these types of problems a lot more. That's just super, I think.

I: Can you give an example of a lab-exercise that's been like that?

Jon: Sure. We got a toy: a lane that a matchbox-car could run through. Then we had to construct a loop. We could do that as we chose and then we had to figure out theoretically what height to let the car go from, to make sure that it just barely came through the loop. And then we had to evaluate how many non-conservative forces works on the car. And how far we came from the theoretical value in practice, and from how much higher we needed to let the car go. That was a super nice problem. Of course not a high level problem. But cool to do it this way. You were allowed to think for yourself. It was really cool that, really, you can figure out the loss of mechanical energy in such a simple manner. (..) Otherwise we've done a lot of modelling and simulations in the lab. We've worked with v-python to simulate relativity theory. Included the Lorentz-effect, for example the twin paradox. Although based on hand-outs because not everybody has done programming before. But I think it's a great way to do it. It's extremely illustrative compared to what we're otherwise doing. Because it's kind of hard to go to the lab and make relativistic experiments in general. Then it's good to do it this way. Then at least, we have it visualized instead of just sitting about, thinking about it all the time. (Jon, A10, Interview II, minutes 0-5, AQ1)

I have coded the first part of the quote from Jon's second interview as sifting. In part because he does what he does to make sure to arrive prepared when time comes for the examination, and in part because he does not associate much understanding with the practice of problem solving. It just 'forces him to 'take in' the curriculum' – a precise characterization of the sifting approach. But Jon acknowledges the dangers associated with this learning strategy and tells about his experiences in the laboratory, a part of the interview I have coded as pro-active. He expects that the exercises he find himself proactively engaged with are of a type that he will increasingly encounter during his studies. Unfortunately it is the other way around: undergraduate physics education reform usually starts where it appears needed the most (Hilborn & Howes, 2003): with the introductory courses, gradually, and in sustainable situations spreading cumulatively to the later more advanced or specialized courses (Tobias, 1992).

When I interview Jon a third time during AQ4 he seems to have lost sight of his initial proactive engagement with his studies. First of all he has troubles finding motivation to read. He is still extremely motivated to be in the programme, but for some reason it is just difficult for him to muster the motivation anyway:

> Jon: I love being here. It is a bit stressful to be on at the edge of being thrown out. That wasn't my plan when I started. But again, I can only blame myself and my missing motivation. And it's terribly annoying. How can you think it's super interesting and still do far too little? I mean, it's strange. But it just tells something about me: I'm far too lazy really. And I think I can get into a rhythm where I do a lot more. (Jon, A10, Interview III, minute 55, AQ4)

To Jon, studying at this point is only about survival. Still he insists on also studying for understanding the best he can, but this is something he can only do in parallel with the content of the programme and invents his own ways of doing so. One way is to never use a calculator that can do symbolic manipulation, but always calculate by hand. Another is to find web-based lectures on mathematics offered by US Universities, and by studying alternative text-books during the summer (an expression of deferred gratification). Generally his take on the outcome of his approach is that "although I won't be able to recall it later, I have learnt how to learn the discipline." He has hopes that he is going to make it, but has stopped talking about the programme activities as some that can add to his understanding. At this point, all he can do is to make sure to pass examinations. The quote above is coded as neither sifting nor proactive.

The first interview I did with Gustav (A09) and Bertil (A12) after they had started, I did as a group interview. The appointments I had made with these two happened to be on the same day, and they showed up at the same time, suggesting that we did the interview together. This was not planned, but since they wanted to, I thought it was interesting to try it out. This means that at one instant it is possible to compare their interpretation of the educational environment directly. The quote starts at the middle of a discussion, where Gustav attempts to explain to me what he perceives is the relevance of the laboratory exercises in classical mechanics. At the beginning I am making a stab at an interpretation of what he has just said:

I: alright, so it doesn't need more purpose to it, than that you calculate the inclination of a race-car track, because some people do this?

Bertil: I think, now at the beginning it doesn't need more, no. Later there probably needs to be more to it. Like direct application. But at the beginning I think it's sufficient with a couple of examples from everyday life. How you use the different things.

I: What is direct application?

Bertil: That's just if you take a physical law and make it into a mathematically simplified model of a real thing and then solve a problem. And then you need to keep in mind how much it is simplified and how well your result represents the expected result from reality.

I: Alright, so that's kind of a generalization of what physics is, that is 'direct application', while that stuff about calculating a racetrack is kind of a cute thing to start with as long as you aren't better? Is this what you are saying?

Bertil: Yes. I think if you can find some good fun examples to start with, where in reality you've got both friction and air-resistance and so forth, but if just for a starters you can find some fun – nah, not fun – just examples that doesn't just say that a particle must follow this path, but says that there is a car or a can on an inclination, and then you need to figure out where the centre of mass is, at what point it is going to tip and at what angle it will do it. Just that kind of stuff. It just needs to be something that is related to reality in some way. (…) At some point later, we can arrive at something that is closer to reality. Like: "well, what do we really use this for?"

Gustav: I think our lab-exercises are super good at that. We had battle of the orcs the very first time. [The professor] had cut out small catapults that we had to launch and calculate how far they could shoot and what was relevant to how everything happened. And

> we had loop-de-loop with toy cars (…) And I think this makes it interesting and super relevant. This type of absolutely everyday things. Out in the big daily life I guess it's not so daily, but I mean 97% of us have played with this kind of stuff earlier on. It's been part of your everyday life, and now you can see how physics has a role in what you have experienced yourself. In secondary education I was enormously fascinated by the advanced experiments we could do and still get decent results. That was the stuff that was exciting back in high-school. What is exciting now is that it doesn't have to be advanced for us to still be able to figure it out! We have all kinds of uncertainties and it's no issue at all. We can still do measurements and get something useful from them. That's what makes it relevant for everyday life. (Bertil & Gustav, A12 & A09, Interview II, minute 40-44, AQ1)

I have coded Bertil's interpretation of the laboratory exercises as a sifting strategy because he does not seem to appreciate that the context that has been added to the exercise is supposed to help him acquire physics modelling abilities. Instead he perceives of the context as one that makes the example more fun or engaging compared to the completely idealized or decontextualized physics problems that also exist. In essence, Bertil thinks of the two as expressions of the same type of problem: one that just needs to be solved, and one that does not have much in common with 'direct physics application' or doing physics for real. It is an expression of deferred gratification.

Gustav on the other hand sees it completely different. He is aware that the toy car serves the purpose of bringing back childhood experience and knowledge that can, in cognitive terms, be incorporated with physics knowledge and experience. Also, he is aware that context-rich laboratory exercises are much more difficult compared the types of advanced laboratory exercises done during secondary education that relies on elaborate algorithms to ensure that the students arrive at the expected result without being excessively challenged (Johannsen & Jacobsen, 2010). For these reasons I have coded Gustav's approach to the laboratory exercises as proactive.

During AQ2 and AQ3 Gustav gets behind in his studies, and he has to engage in a way he call superficial to keep up. During AQ2 he still enjoys the laboratory exercises "because we got to calculate ourselves". He has decided not to go to calculations classes, because he gains nothing from seeing others do the problems, and if he must do the problems himself he can just as well do it outside of these classes. Others thought that this was a good idea and joined him, but too much time was spent on regular talk. To learn mathematics he relies on webcasts from US universities and in general his social engagement with learning at the institution seems to be declining. During AQ3 he is crazy about the thermodynamics course which has been reformed to include a set of different learning technologies such as peer instruction, but also quick shifts between lecture-type-instruction and laboratory exercises to ensure greater congruence between theoretical and practical elements of the course. This means that he sifts through mathematics courses while he is proactively engaged with the physics course. But at this point he has been engaged with surface learning for so long, that he does not seem to be able to distinguish it from deeper forms of learning:

> I: How is MathP?
>
> Gustav: I think it's interesting.
>
> I: Is it better than linear algebra?
>
> Gustav: Ehm, I would say it's the opposite of linear algebra. Last time we talked about how it was difficult to get a grip on what linear algebra was about. It seemed like it was mathematics for the sake of mathematics and not mathematics because it's useful in any way. And this stuff [MathP] is very, very useful for things we don't know about yet. I mean, we don't know the physics. And it makes it super relevant and you can feel that it is about something practical. You have a closer relationship to it, in some ways. On the other hand you can also feel that it's Math-P and P is for physics. So even if there are proofs, we don't start at the beginning and then you end up there. You start at the beginning and suddenly you are there. It's tough reading, but it is interesting. This actually reminds me of a thing I seem to have noticed lately, especially in relation to learning, that in some ways it seems like what we learn the most, by far, here – sorry this is a sidetrack, but I think it is important – what we learn the most is actually not so much to understand something concrete, but actually to find the ways to arrive at understanding something or other as quickly as possible. I think there is a pattern in how you kind of

read and perceive some contents, like you have problem in front of you: if you study it too hard, you become tired and get nowhere, you simply don't understand what it is about if you concentrate on the problem too hard. If you concentrate too little on the problem nothing happens. It's like finding this balance where you concentrate with the exact right amount of concentration, then suddenly, when you are there, then "wups" you get through the whole. And then at the other side you stand there thinking "how on earth did I get this far?" In some way I think that MathP is a good example of this. You have something that is very complicated because first of all it's physics you don't quite know what is, and we have some formulas that work in one way or another on this stuff. And their relationship, we don't know yet. We neither know what the formulae are supposed to describe, because they are brand new, and we have no relationship to the physics either. So it's becomes a mix-of-new. And when you mix them just right then the solution-path is suddenly incredibly simple. Even though if you just look at it, you have no idea what either one or the other is about.

I: There's this principle for learning called constructivism (…) And now that you tell this about MathP, you tell that you don't know the physics and you don't know the mathematics then there is a problem about constructing on top of nothing. So my guess is that this process can be something like "alright, but if I just don't pay attention to the fact that I don't have any basis to anchor it to, but instead just start using it, then suddenly everything glides." But I guess that's something like allowing it to exist without being anchored anywhere.

Gustav: Yes exactly

I: Cool that you can do that. But also inappropriate. (…) Because there is also something called rote-learning right? (…) And you can kind of learn everything by rote. (…) And I half expect that maybe this was the handiest strategy in when you don't have anything to construct on top of. I mean learning a line of algorithms that you can always look up on the text-book, and you know how to solve typical problems, but in reality you don't have any idea about what you are actually doing. That's kind of how I felt with MathP when I took the course.

Gustav: Yes, I imagine it a lot like that. Also because you skip what at the face of it seems to be the essential mathematics and physics. You don't see why it is like this. Just that it is. In principle everything could be cheating, to get through that whole. (Gustav, A09, Interview IV, minute 40-49, AQ3)

What is interesting here, is that Gustav also seems to be toying with the idea that what they do, during this later courses is to learn how to gain knowledge fast. It is the same sentiment that Jon uses when he explains that he will not be able to recall anything later, but he is certain he will be able to re-learn faster. To Gustav the idea has taken on an entirely bigger dimension: maybe this is what physics learning is. When I explain to him about how I think of learning, and explain to him that what he describes seems to be rote-learning, he agrees with me. But still his experience seems to be that rote-learning can also be a profound experience. The contents of the mathematics course is so hard and difficult to understand, and completely separate from anything he has intimate experience with, that just the act of learning it takes enough concentration and hard work, to make it seem like he is working to gain real understanding. He might be, but the outcome is not. He recognizes the potential application of the contents, but does not engage with understanding the application. He leaves it 'out there', 'untethered', 'ready for later use'. To me this change between the first interview and this latter interview appears profound. Initially Gustav was a skilled proactive learner, but in the fourth interview in AQ3 he can hardly distinguish between rote-learning and other forms of learning. The fifth interview during AQ4 is mostly about their first year project and the outcome of it. For this reason I do not know much about his approaches to learning. He does tell, however, that he did not manage to finish the text-book on thermodynamics and thus could not answer the questions on the final examination. This is cause for him to revise what he as this point thinks of as his earlier strategy of trying to make sure to study at a pace that was suitable to him, and him alone: "no one else got upset, so I thought there was no reason that I did. But my new strategy is to finish stuff before it is necessary that I do it." To me this is a sign, that he is changing his strategy to be more congruous with institutional demands. Bertil (A12) is the same way, though more explicit:

Bertil: My problem is probably that I don't see any easy quick-fix solution. Like if we just made a small adjustment everything would be much better. I can only see that a radical change is necessary. But I can't imagine that they want to do that any time soon (…) I know that you can't allow students to do whatever they want, and expect that they are probably done in a couple of year. Of course we need a red threat, some guidance, supervision, something that guides us through. But sometimes I wish.. What was the university a hundred years ago?! Didn't people just sit here and cultivated knowledge as their primary objective, and not this need to meet a schedule, this pre-set, determinate, scheduled, absolutely inflexible frozen schedule you have to follow just for the sake of the schedule that ensures that you meet some goal someone have set for some reason, instead of focusing on the fact that this guy seems to be great, so he will probably make it in less time, this guy is not so good, so he needs some more time. And this guy is good too, but he's got a lot of crazy ideas that he needs to vent off, so maybe he needs time for that too. Yes, I guess that's it. How do you make room for the individual in an education that needs to fit everyone? (…)

I: How do you intend to deal with this frustration you feel?

Bertil: I intend to attempt at changing myself because I don't think the university is ready to change according to the ways we do things. Then you just have to adapt. So that's what I'm going to try next year, to do everything I can do to do all the things they tell me to do every single day. Live under that time pressure and that schedule. See if I can't do that. There's not much else to do. (Bertil, student A12, interview III, minute 32-38, AQ4)

Apparently it takes an effort to drown the ideals of an idealist. But at the time of our final interview during the summer, Bertil's frustration with the programme structure and strict regime has died down to a self-directed surprise at his own lack of motivation.

Summing up

This section aimed at providing the necessary background for answering research question 2:

> *Compared to the successful strategies physics students employ to cope, (2) what might the consequences of these successful strategies for coping be for the quality of their approaches to learning?*

This is in part the subject of the next section. The section also served the purpose to justify the estimate used to motivate Paper III, in which we state that approximately half of the students who employ strategies for coping evolve from being proactive learners, to predominantly sifting through their education. To make this claim, it was necessary in part, to disregard students' experience while doing the first year project in physics, because this experience was a very obvious activity fit for proactive engagement. But in doing so, the estimate becomes more reasonable. For the purpose of ease, I have included a copy of Table 6.15 from page 164.

Table 6.15 from page 164

	AQ1		AQ2		AQ3		AQ4	
	S	P	S	P	S	P	S	P
A09	8%	69%	20%	45%	36%	18%	0%	0%
A12	29%	43%					50%	39%
A10	32%	37%					24%	14%
A01	70%	25%	31%	46%	100%	0%		
A04			55%	10%			67%	0
A05	50%	10%			56%	33%	29%	14%
A07	45%	9%			50%	0%	43%	26%
B25								

I find no reason to doubt the claim that based on their experience with studying physics students A09, A12 and A10 change their strategies for studying during their first academic year from being students who are predominantly looking for ways to be proactively engaged, to students who sift through their courses.

The 'approaches to learning counts' for students A01 and A04 suggests that although they are not students who are engaged proactively much, their proactive engagement does go down during their first year. In case of A01 this is a misrepresentation. At the end of AQ3 he settles with a study group together with B25, and as the final interviews with these students show, they find ways to become proactively engaged by transposing the recontextualizing rules. My impression of A04 during the first interview is that she intends to engage deeply with the sort of physics she was looking for when she started studying physics. But because this type of physics is not offered until she starts studying for a Master's degree she is deferring her need for gratification. The way she reinforces this strategy is by sifting through her studies, in an effort to arrive on the other side of graduation as fast as possible. In this light I think it reasonable that her rapid change of strategy in studying supports the estimate that half of the coping students evolve into students who predominantly sift.

A05, I characterize as a slow starter, in that he sifts a lot during AQ1 in order to figure out how he compares to the other students of his year. He slowly has to find a reason to decide that physics is actually his study, and when we arrive at AQ3 he is starting to seriously employ proactive strategies for learning, where he can. At the time of AQ4 he is overwhelmed by the task he set himself, and has eased down considerably on his proactive engagement, by way of which I think in part, his engagement with his studies support the estimate regarding the evolution of coping students' strategies for learning.

A07 is different. In an attempt to survive in his studies, he employs proactive engagement to find motivation for engaging with his studies, but his engagement is directed away from the institution. While he is waiting for discovering something that motivates him, he sifts through the courses. For this reason, I am hesitant to count him among the students whose strategies support my estimate. One argument against this, is that what is most interesting, is what students do, during their course learning, and not in life, in general.

Of eight students who have found successful ways for coping, 2-3 students do so by becoming more proactively engaged, while five other students tend to sift more than they did at the outset of their studies. The ninth coping student, A02 was not included, because his strategy for coping was by way of engaging socially. But as I quote him saying on page 100: "I think I'm just sitting here and realizing that I've done virtually no physics," I think there can be no doubt that he also sifted through his first year.

All in all, I do not hesitate to claim that among the students who employed successful strategies for coping, approximately half of these students start out studying physics being proactively engaged with their studies, but end out by sifting through their courses. This leaves the question of what happened with the 'thriving' students. I think the answer to this question is already evident from the what the students make use of in reinforcing their strategies for studying: grades and the fact that the physics education programme is congruous with their experience of secondary school physics: they are reinforced in their strategies by striving for an outcome that matches what the system demands. And they are intrinsically motivated by doing so, which is basically the gist of my interpretation of what is entailed by the sifting strategy. There are seven students in my sample who ‘thrive’, and two students whose strategies for studying I cannot capture using the methodologies I have used. However, given student B17 general tendency for deferred gratification and apparent lack of motivation overall, I think it safe to presume that he also sifts. A17, I am still hesitant to categorize in any way. Thus, the result of the analysis of the students’ quality of learning is as depicted below:

Table 6.17 End of year approaches to learning tendencies.

	Total	Thriving	Coping	Outside category
Total	18	7 (39%)	8 (44%)	3 (17%)
Sifting	14 (78%)	7 (39%)	5 (28%)	2 (11%)
Proactive	<4 (22%)	0 (0%)	3 (15%)	<1 (10%)

In the next section I will use the results of this section to answer my two research questions.

7. Findings

Something Asta (A04) said during her final interview nicely sums up the gist of my findings:

> I think it depends on what kind of expectations you have. If you start by expecting something like: "well, I guess this is pretty fun", then you won't get disappointed. But if you start studying having expectations like: "I don't really know what I am going to use this for, but I just want to understand nature and the universe," then you'll be disappointed – during the first year. (Asta, A04, Final Interview)

Like Asta, I have divided the students in my sample into two types: those who thrive, and those who cope. Those who thrive with studying physics at the University of Copenhagen are typically students who started studying because they liked physics during secondary education. Students like Asta, who need to cope in order to attain better congruence between their expectations and their perception of first year institutional life, liked physics during secondary education too, but had expected that upon entering into university physics, something new and profound was going to happen to their understanding and perception of the natural world. But nothing does, and they turn to deferring their need for intellectual gratification; exactly as Asta does in the quote above, when she adds to her statement the qualifier: "during first year." One gets the sense that, implicitly, Asta expects that university physics life will be different after the first year.

Asta, together with Jon (A10) are the only students in my sample that rely solely on deferred gratification as a way to cope with their frustration at the disappointment they feel with their physics studies. The remaining six successfully coping students in my sample have found secondary strategies that assist them in deferring their need for intellectual gratification. They found a way to experience gratification by transposing the rules of the rules of the pedagogic device (Bernstein, 2000) that otherwise governs the physics programme.

If perceived as a phenomenon rather than as a set of distinct individual student strategies, it appears as if coping by transposed gratification is a strategy that can develop in stages. The first 'easy' stage is to transpose the evaluative rules, thereby ascribing a different and individually relevant purpose to activities in the programme. One such way is to disregard the idea that examinations measure understanding, and thus that activities directly related to preparation for the examination, is not an opportunity for engagement in acquiring understanding. Another way to disregard the evaluative rules, is by surrendering to the regime of problem solving, while knowing that valuable physics experience is gained elsewhere, for instance by using the time that the summer vacation allows to engage with the type of physics that offers insight that is perceived to be subjectively valuable. It also entails being constantly ready to jump at any chance offered for deep engagement. To be engaged in a steadier manner it is necessary for the strategy to develop into the second stage: transposition of the recontextualising rules. In practice this means learning by other modes than those suggested and encouraged by the institution. This would entail not attending lectures and calculation classes to instead spend the time working with likeminded, and seeking out a physicist who is willing to guide students towards more engaging and subjectively relevant tasks. It also entails searching out alternative literature. The final stage entails transposing the distributive rules, which equates to, as a first step, taking courses in a different order compared to what is prescribed by the programme. A final step would be to completely reinvent the physics programme. No student did that, most likely because powerful forces work to prevent these stages of successful coping.

The more students engage in transposing the pedagogic device of the physics curriculum, the more they distance themselves from the institution and from their peers. They become a sub-culture of physics learners among a mainstream culture of physics students. Still, there are some rules they have to abide to. They must take the examinations, and to do so, they must spent time solving problems that offer virtually no potential for learning anything but solving problems. And they have to spend a lot of time doing this. At the end, not much energy remains for transposing any rules; the result being that motivation to do so slowly dies away; and more and more they conform to the regime of the pedagogic device of the physics programme. What started as a disappointment at the contents of the physics programme turns into a disappointment at their own inability to feel motivated by the activities associated with mainstream physics teaching.

My impression of these successfully coping students is that they arrived at the institution disposed to engage proactively in their physics learning. Since the institution does not readily offer opportunities for this kind of engagement, their disposition is gradually subdued and replaced by their cumulative experience of learning in the physics programme.

Besides pointing out the fields of physics and the order in which the students need to study them, as well as occasional opportunities for proactive engagement, it seems from this perspective that all the institution offers, is an obstacle to students' attempts at engaging with physics in ways that are typically associated with quality learning outcomes – which is also what my investigation of the evolution of engagement for proactive engagement suggests.

The other students, the thriving students, are deeply imbedded in the mainstream physics culture. When they learn, they learn what they are supposed to, and are gratified to see that their grades reflect their engagement in this endeavour. They compare themselves to the other students in the mainstream culture, and feel reassured in what they are doing since everybody else does so too. The programme structure and contents also reinforces them in their choice since it offers no real surprises. It was more of what they liked to do during secondary education. It might very well be like starting all over again, right from the beginning of where physics seems to start, but they expect and assume that this time around they are being offered the real explanations to those phenomena that were only cursorily treated during secondary school education – at least those of the phenomena they can handle. In essence, what they seem to be doing, is to re-learn what they were not quite offered to learn during their previous education.

The hierarchical structure of the curriculum contents, reinforced by a chronological logic, offers a refugee for most doubts concerning the purpose and aim of the programme. Everybody can see where it is leading, but not many can point out exactly how it leads there. Learning to do problems particular to each of the great disciplines of physics, one by one, is something any physicist will have to do, in order to become a physicist, characterized by the abilities that characterizes a physicist. One of the most concrete examples of the abilities thriving students feel they have acquired in one physics course and used in another is the ability to quickly start learning the next physics course. In itself, this might not be so unfortunate at that, unless one remembers that the purpose of the physics programme should not be to educate people to take physics courses. The purpose should always be to educate people to do physics. But this is very hard to remember, especially for the students who have no real idea about what is entailed by doing physics. To them, physics-as-curriculum equates to physics-as-research, most of the time.

From this perspective there is something to be said about the character of the physics programme that is important. Very few students in my sample experience any significant difficulties figuring out what is required of them, to be considered legitimately engaged in physics learning. This means that as a programme, it appears to be open to a diverse student population, also counting those, whose families do not have an academic background. Also, concerning those students who cope by distancing themselves from the academic student life, do not seem to become less socially integrated. Although they do not go to lectures to learn, they still go to the lectures to see their friends. Likewise with the thriving students, they use each other to reinforce their belief that what they do is right. Generally students speak extremely well of the social environment at the institution especially when they talk about each other, but also when they speak of their reception by faculty. All are friendly, considerate and concerned for each other; and if one does not dig too deep, almost every student involved in this study are happy, almost euphoric about being part of the community that is encompassed by the Niels Bohr Institute.

A subject that I feel I have neglected in this study, is the signs that are present everywhere, there and again, that the efforts some of the faculty have made to reform their teaching, are duly noted by the students. They might not understand or know exactly, that what they are subjected to is different from what students were subjected to 10 years ago; but as an interviewer on the side-line, one who knows what physics education reform is, and as one who studied in the programme 10 years ago, there is absolutely no doubt in my mind, that these reforms have been worthwhile. Notable mentions are the laboratory exercises in Introduction to Classical Mechanics (and not the least the people who taught them), Electromagnetism and Cosmology. And then there is the first year physics project. But that is an altogether different, happy story.

8. Discussion

If for a minute we pretend that my findings are indicative of a phenomenon inherent to physics or even science education, the figure I have developed to illustrate distinct individual coping strategies, might be perceived of as an empirical model of successful student coping – or a model for directing efforts at increasing congruence:

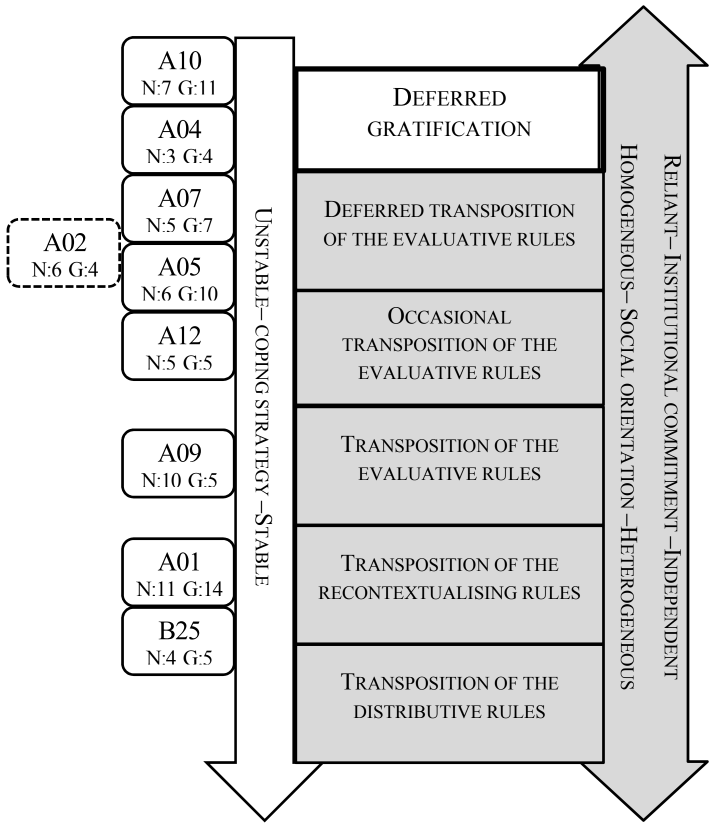

Figure 8.1 An empirical model for directing efforts at increasing congruence?

Since each step towards coping by transposing the distributive rules, are prerequisite parts of that strategy, it seems that if the evaluative rules were changed to be more congruous with coping students' expectations, it would affect all of the students who cope by transposed gratification. If, on the other hand, one was to change the distributive rules without changing the distributive rules, it would only be felt by few of the coping students. If this is a perspective we can generalize to inform educational reform, then the figure above is a clear suggestion of where such efforts would be best spent: in changing the evaluative rules, since this would speak to more students' feelings of incongruity.

At Rutgers University in the United States, for example, this is precisely what was done when the Investigative Science Learning Environment (ISLE) was introduced. Besides offering relatively authentic problems for the students to engage with, the students are not evaluated based on their ability to reproduce knowledge or find the solution to typical problems. Instead they are evaluated by their ability to represent physical processes in multiple way, devise and test qualitative explanations or quantitative relationships, design experimental investigations, collect and analyse data, evaluate experimental predictions and outcomes, conceptual claims, problem solutions and models, and the ability to communicate (Etkina et al., 2006).

For good reason, it is hard to imagine that the evaluation rules of the curriculum can be changed without also changing the recontextualizing rules (this is what Bernstein's model of the pedagogic device also dictates), but still, it seems like a more feasible place to begin, than to begin by uprooting the whole curriculum to begin from scratch. Also, changing the evaluation rules seems more precisely aimed at where the problem resides compared to the reform of the recontextualising rules – which is what I perceive initiatives such as peer-instruction to be an attempt at doing.

Instead, focusing on the evaluative rules by making evaluation, not only about measuring skills and competences, but about letting students know that they are evaluated based on their ability to demonstrate competencies would give grounds for students to get more proactively engaged with their studies. If at that, these competences were the ones that have now been included in the ministerial order regarding the Danish secondary education curriculum, they might be recognized by those of the students who enter university physics to do more of what they did during their previous experience. These competences are:

To build and analyse models. To plan, execute and describe physical experiments. To work with different representations of physical phenomena. To put physics into perspective relative to the discipline itself, to other disciplines, other ways of knowing, to historical development and itself (Dolin, 2006; Dolin, Krogh, & Troelsen, 2003, p. 108). Now, considering the extreme likeness between Dolin's description of science competencies and Etkina's scientific abilities that have been developed independently of each other; might we not be safe in assuming that they are both on to something important and true? Something that is relevant to physics learning? Something that by far would be more relevant to the students than the current curriculum structure, focused at imparting qualifications on students instead of allowing them to develop the abilities they so desire?

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10. Paper I: A critical attrition analysis

The first paper of this thesis explores the direct approach to understanding attrition: the interview with students who have decided to leave.

The paper is a critical analysis of interviews I have performed with seven Swedes who had opted to leave the physics programme at Uppsala University. With respect to this thesis, the paper serves in part as a general literature review of studies on early departure and in part as explanation for the longitudinal research design that is employed in the thesis and in the studies that Paper II and Paper III reports on.

Although the interviews that are utilized in this paper were performed during my studies in Uppsala, they were revisited and reinterpreted for the purpose of writing this paper during my PhD studies.

The paper is included in this thesis as an author created preprint.

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Penetrating a wall of introspection: a critical attrition analysis

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Keywords: attrition and retention · higher education · interview analysis · ability · physics

Executive Summary in Danish

Gennem tiderne har mangen et studie og undersøgelse bekræftet professorer såvel som studerende i deres mistanke om, at de studerende der droppede ud, var dem der havde valgt det forkerte studie. Det er ganske rigtigt, at dette er den mest nærliggende begrundelse man kan give, hvis man som studerende begyndte på et studie man endte med at beslutte sig for at forlade. Det vil dog være en fejltagelse at slutte, at årsagen til beslutningen er den samme som begrundelsen for beslutningen. Ikke desto mindre er det, det der sker, når en mere målrettet vejledning af nye studerendes studievalg anbefales på baggrund af frafaldsundersøgelser der konkluderer at problemet skyldes forkerte eller misinformerede studievalg. Sådanne konklusioner misser pointen: givet, at en studerende opdager at han eller hun har valgt det forkerte studie, findes der en oplagt mulighed for at undersøge hvilke oplevelser der havde indflydelse på beslutningsprocessen undervejs i uddannelsesforløbet. Den mulighed forpasses, hvis begrundelse og årsag forveksles.

I denne artikel tager vi udgangspunkt i en række studier af frafald, vedholdenhed og læring på videregående uddannelser, og begrunder at hvis man vil forstå den proces der leder frem til en beslutning om at droppe ud af et studie, må man tage højde for at det at *være* og *blive* studerende er et komplekst samspil mellem ét individ og en institution, som i sin tur udgøres af en række individer (herunder de studerende der måtte falde fra), kulturer (herunder fagkulturer) samt en lang række dybt forankrede vaner og traditioner. Inden for rammen af sådan et perspektiv vil det være forkert at sige at uddannelsen var forkert til den studerende, ligesom det ville være forkert at sige at den studerende var forkert til uddannelsen. Hvis noget var forkert, så var det *situationen*. Dette perspektiv udnytter vi til at foretage en grundig analyse af syv interviews med tidligere fysikstuderende, der havde valgt at forlade fysikstudiet ved Uppsala Universitet i Sverige.

I interviewene bedes de studerende begrunde deres frafald. Men analysen såvel som interviewet tager sit omdrejningspunkt i, at de begrundelser der gives også har en baggrund. Det vi finder ud af er, at dette omdrejningspunkt har et forskelligt fokus afhængigt af perspektiv. Interviewerens fokus tager udgangspunkt i et ønske om at forstå de strukturelle betingelser omkring fysikstudiet der danner baggrund for frafaldets begrundelse. De studerende selv, tager udgangspunkt i sig selv. For at illustrere dette forhold benytter vi Aristoteles årsagsbegreb i analysen, og viser at de årsager de studerende bruger som baggrund til at forklare deres beslutning om at forlade studiet, har en væsentlig anden karakter, end årsager der kan knyttes til strukturelle betingelser omkring fysikstudiet.

Konklusionen er, at hvis ikke man gør sig det klart, når man undersøger årsager til frafald, så er udbyttet i bedste fald en for simpel forståelse for de årsager, strukturelle såvel som individuelle, der måtte kunne knyttes til frafald fra videregående uddannelser.

Abstract

This paper presents a critical analysis of student discourse on attrition as it unfolds in interviews on early departure from higher education. A synthesis of relevant studies and modelling done in the field shows that essential aspects affecting attrition and retention can be effectively conceptualized and acted upon in terms of the interplay between student and institution. These aspects were used in combination with James Gee's notion of Discourse models to design a unique framing for interpretation of interviews aimed at bringing out new causal dynamics that lie in this interplay. To illustrate this interpretation Aristotle's notion of four causes is used. The analysis presented is a study of interviews with seven former physics students about their early departure. This framing of the analysis was necessary because the students' description of how they understood their actions did not explicitly reveal interplay between student and institution. These details lay behind a 'wall of introspection' that otherwise posed a serious challenge to the use of student testimony as direct means to identify and address issues of early departure. The results are used to discuss research implications.

Although research on attrition and retention has convincingly pointed out the issues that are at stake, decades of research has yet to sufficiently expose the specific and actual mechanisms in relation to content, curriculum and modes of teaching that drive early student departure in ways that can be used to effectively implement measures to approach the problem at the institutional and departmental level.

Generally little is known about international attrition or drop-out rates as they pertain to the number of students who opt to leave different fields of study at different universities. The Organisation for Economic Co-operation and Development (OECD) reports an overall 31 per cent rate of non-completion among students who enrol at tertiary level education for their first degree across all universities in the OECD countries (OECD 2010). The organization also remarks that Science and Technology are among the disciplines with the highest attrition rates (OECD 2008). Concerning all levels of science education, primary through tertiary, an independent expert group set up by the European Commission deems attrition rates in the science and technology disciplines "unacceptably high" (European Commission 2004, p. 181). The expert group goes on to describe how tertiary science and technology education in most universities characteristically adheres to a prevailing paradigm that "is poorly suited to the needs of a knowledge-based economy, where original thinking and creative work are expected of the many rather than the few" (*ibid,* p. 104).

This same concern regarding the quality of education is also raised by physics education research. When B.H. Briggs (1976) devised and carried out a small scale survey at the University of Adelaide in Australia, he found that students who chose physics do so because they are interested in the subject. Students who do not find physics interesting, do not ascribe this lack of interest to the subject itself, but to the way it is taught. Nearly thirty years later in North America, this same relationship between a decline in students' interest and students' experience of physics instruction prevails (Perkins, Gratny, Adams, Finkelstein, and Wieman 2005). One might interject that if groups of students systematically loose interest in physics after they have taken part of a physics course, their expectations of these physics courses might have been naïve at the outset. And indeed such a link between students' interest in physics and their attitudes towards what physics learning entails (i.e. novice-like through expert-like) exists. But since a negative shift in these attitudes is commonly observed as a general result of physics instruction, one would expect it reasonable to link students' attitudes with their choice to continue in physics. Although such a correlation is found, the effect size is small (Kost-Smith, Pollock, and Finkelstein 2010). In fact, Lauren E. Kost-Smith, Steven J. Pollock and Noah D. Finkelstein who worked to find and characterize a pattern in gender differences related to physics retention, performance and attitudes find this to be true for all these factors. They conclude that "this pattern of disadvantage [towards female students] suggests a systematic culture in which males are privileged over females. […] Understanding that retention, performance, and attitudes and beliefs are some of the mechanisms by which a cultural bias is maintained and reinforced is a first step towards alleviating the gender disparities in physics" (*ibid,* p. 15).

Gender disparity is just one expression of how cultural biases impede the participation of any particular group. In any endeavour of original thought and creative work, such as physics, cultural heterogeneity is much to prefer over homogeneity (Hazari, Tai, and Sadler 2007). And it all points back to students' experience of physics instruction: their experience of content, curriculum and modes of teaching.

Guide for reading this paper

This paper has two parts. One part consists of a critical overview of relevant literature, a theory section and a methods section. The other part consists of an analysis of interviews and a concluding discussion.

In the first part of this paper we characterise an appropriate framework for conceptualizing the dynamic linkage between students' experience of their physics instruction and their choice of leaving. To do so we briefly outline the general field of higher education research into student retention and attrition and argue in favour of a research perspective that focuses on interactions between student and institution. In the next section of this part, this research perspective is tied to a discourse analysis framework suitable for assisting the interpretation of seven qualitative interviews that were carried out to gain knowledge of how students' experience of their participation in university physics education led them to decide to leave the physics programme early. We also describe how the interviews were carried out.

In the second part we analyse and discuss this analysis of interviews we performed with seven former physics students who had decided to leave the physics programme at a traditional Swedish research university. The analysis and discussion is aimed at illustrating how the causal dynamics regarding the interplay between student, content, curriculum and modes of teaching are embedded in the interview discourse instead of explicitly present in conversation as one would have hoped for. We show how the embedded dynamics manifest as a type of ‘introspective discourse’, but illustrate how this discourse can be interpretatively perceived as an issue of the premises of the interviewers’ questions and the premises of the respondents’ replies. To assist in illustrating these premises and their difference, we draw on Aristotle’s four causes.

The reasons we do this, is first, that we find it important to point out that students in interviews might make use of introspective discourse, and we want to show that this particular discourse can be perceived of as mirroring an existing institutional discourse on attrition and learning in general. That is, when students say that they were ‘unable’ (to meet disciplinary demands) for instance, it might actually be so, but it might also be that the particular make-up of the institutional setting allows for, or even encourages this type of discourse. If so, it would be a discourse that is focused on the individual as a stable configuration to be tested rather than on the individual as a developing learner. Such a discourse is not unheard of. In fact, US medical schools for example have a long tradition of using introductory chemistry, biology and physics courses (Barr 2010) to identify the students “who are apparently intellectually or emotionally unable” (Mullin 1948, p. 164, also cited in Barr 2010). The interviews we analyse here reveal that the same sentiment saturates the interviewed students’ justifications for leaving their physics studies.

Second, by explicitly and rigorously probing discourse on attrition for subtle hints that give evidence to certain aspects of interaction between student and institution it is possible to gain a nuanced and contextually rooted understanding of attrition. We find it important to illustrate how such a rigorous analysis can be performed, and why this type of analysis yields results that are not possible in student interview analysis that does not take such measures.

The third reason for bringing out and emphasizing the causal dynamics that resides in ‘introspective discourse’ is to argue that if substantial emphasis is put on the unmasking of implicit relational aspects with regards to student and institution that are also part of student discourse on attrition, then we gain a better, more nuanced outcome of student interview interpretations compared to what resides at the apparent, explicit level of student testimony.

We end the paper by discussing research implications for the general field of higher education research on attrition and retention and consider how the results add to the field of physics education research.

The need for linking attrition to student-institution interactions

The following is a brief overview which serves as an argument for a strand of research into attrition and retention that is informed through a focus on students' interactions with the praxis and content of teaching and learning. For a recent and more complete review of theoretical and empirical trends in research on attrition in higher education with special emphasis on Science, Technology and Mathematics we refer to Lars Ulriksen, Lene Møller Madsen and Henriette Tolstrup Holmegaard's review (2010).

We take as the outset of this overview an on-going discussion about the issue of remedying early departure through better integration of students and especially how to interpret the notion of better integration. The source of this discussion is Vincent Tinto's longitudinal model of institutional departure (Tinto 1975, 1993) sometimes called Tinto's interactionalist model (cf. Braxton, Vesper, and Hossler 1995). Here, Tinto emphasises the importance of academic and social integration to student success in higher education. The model has been paramount to most research carried out within the field (Braxton, Sullivan, and Johnson Jr. 1997) but has also been subject to both critique and numerous modifications, most of which addresses aspects related to the non-traditional student (cf. Bean and Metzner 1985).

The critiques often seem to depart in a reading of Tinto's emphasis on the need for strengthening students' involvement with their own education through integration into the institution in ways that equates to enforcing academic and social assimilation. We find, however, that there is hardly basis for assuming that enforced assimilation is an integrated part of Tinto's interactionalist model. To this end Ulriksen, Madsen and Holmegaard (2010) point out that "what permeates the model is that attending university is a process of socialisation, and as such it is to be regarded as an interactional process between what the students bring with them and the culture they meet." (p. 215).

Very much in line with this sentiment, Jill Lawrence (2005) brings together her interpretation of strands of research into attrition and retention and adds to this a perspective on student transition, which she calls 'the student perspective'. Together, these perspectives equates to a type of re-conceptualization that "challenges universities to identify the (often less explicit) discourses and institutional practices involved in transition and retention" (*ibid,* p. 30).

Below, we briefly present results from a selection of studies on attrition and retention. We find the threefold categorization, introduced by Lawrence (2005) useful and refer to these as 'the assimilation strand', 'the institutional services strand' and 'the interactions strand'.

The assimilation strand

Lawrence (2005) refers to this strand of research as a strand that aims to bring information to light that will allow researchers and institutional planners to better assimilate all students into the (definitive) institutional setting. The focus tends to be on identifying student traits such as attitude, ethnic background, social status, sex etc. that predict retention or attrition.

Often the studies are large scale statistics surveys that aim to uncover attitudes and/or abilities that correlate with student retention (cf. Cabrera, Nora, and Casteñeda 1993). Results reveal that ethnicity, socioeconomic standing, and education generational status (i.e. the level of parental education) are important factors related to student attrition and retention (Pascarella and Terenzini 2005). Evidence also suggests that these factors together with income, physiological gender, academic access (e.g., outcome and quality of primary and secondary education) are severely entangled and not readily separable into distinct groups (Tinto 2006-2007). Specifically, physiological gender has received considerable attention, but appears not to be a convincing predictor of dropout in literature. Instead the possibility of gender-specific *attraction* to certain programmes (i.e. the pull-out rather than push-off) may have some explanatory power in the landscape of attrition (Mastekaasa and Smeby 2008). In other cases, local ways of *negotiating* gender appear to substantially influence non-completion (cf. Hasse 2002).

Partly as a reaction to these types of studies, Elaine Seymour and Nancy M. Hewitt (1997) interviewed nearly 500 students, leavers and non-leavers alike, across science, mathematics and engineering majors in both private and public colleges in the US, who all earned good mathematics results on their Scholastic Assessment Test. They conclude that it is not possible to distinguish leavers from non-leavers with respect to "individual attributes of performance, attitude, or behaviour, to any degree sufficient to explain why one group left, and the other group stayed" (*ibid,* p. 30). Instead Seymour and Hewitt point at individual coping strategies as key to persistence. Similar to Tinto's conclusion above, the authors find that leavers and non-leavers are not different types of people. Thus, the general sentiment is that "students persist in their studies if the learning they experience is meaningful, deeply engaging, and relevant to their lives" (Lardner and Malnarich 2008, p. 32).

Essentially this strand of research tells us that among students who have the formal qualifications to succeed in higher education, no generic student-type exists with respect to socioeconomic status, gender, academic access, performance, attitude, or behaviour that is more prone to leave than others. Thus, the assimilation strand does not point out an unmistaken group of students that are especially susceptible to any mechanisms inherent to the institution that exclude them. Instead studies like Seymour and Hewitt's point toward a conceptualization of retention and attrition in terms of coping. One way forward is to seek knowledge that can help us better anticipate and react to students' difficulties. This is the institutional services strand.

The institutional services strand

Integral to this strand is the assertion that students increasingly exhibit different motivational strategies in studying. Accordingly a realization is emerging that institutions must be equipped to cater learning strategies that are appropriate to the students individually (cf. Zepke and Leach 2005). One might say that the institution needs to find ways to accommodate the students.

In the previous section, we saw that it was not possible for Seymour and Hewitt (1997) to identify one distinct group of students who have the formal qualifications to succeed, that are more prone to leave than others. This does not mean that a distinct group of students that is more prone to leave than another does not exist. It does, but is already classified as different to the main group: as non-traditional students. Depending on context these classifications might involve notions of underprivileged students, adult learners, Hispanic, women, etc., of whom, for various reasons, it is expected that they will be in need of special considerations (Haggis 2006). This is where institutional services come into the picture. Traditionally, such services take the form of, for example, financial aid, child-care services or academic counselling (cf. Nora, Cabrera, Hagedorn, and Pascarella 1996).

As such, the strand is not as much focused on attrition, as it is on retention. Mantz Yorke and Bernard Longden (2004), for instance, point towards a student-interest perspective (that is, a perspective that focuses on what students need, rather than on what abilities they might lack) for providing information that can be employed to support students to stay in higher education. Later they used this perspective in devising and interpreting a UK questionnaire survey with a free response option (Yorke and Longden 2008). Students' reasons for leaving turned out to be poor quality learning experiences (e.g., large lecture halls, lack of contact with academic staff, feelings of indoctrination), difficulties coping with academic demands (some perceived of them as too hard, others too easy in terms of structure, apparent level of difficulty, etc.), and realizing that the choice of field of study was wrong (motivating their initial 'hasty' choice with external pressure or based on their secondary education interest and performance, and also misinformation). Such results are, as mentioned in the introduction, echoed in the interview discourse that we analyse in this paper but also internationally. For example, the results of both Monika Appel (2007) in Sweden and Elizabeth Godfrey, Tim Aubrey and Robin King (2010) in Australia are remarkably similar to Yorke and Longden's findings listed above.

The problem is that issues pertaining to attrition or retention are not penetrated sufficiently in ways that allow for an understanding of interacting causes that link attrition to teaching and learning, or even university and student. If we focus on the question of wrong choice, for instance, which a UK-government report identifies as the most prominent of reasons for attrition (Davies and Elias 2003), the authors link this reason to being unaware of the advice- and support-mechanisms that were already in place. Similarly, a small scale Danish questionnaire survey that focuses on students' interests concludes that "the departments cannot do anything to address a number of the causes for early departure. The results suggest that a number of students enrol in a trial-like fashion, but either they do not have the interest or they are more interested in another area." (Andersen and Laursen 2003, p. 65 own translation).

Generally the decision of leaving is presented as an issue of different manifestations of (or perspective on) students' inabilities to adapt to the immediate educational circumstances. Zepke and Leach (2005) review more than one hundred research studies on retention and achievement in higher education and provide a comprehensive list of initiatives that prove to vent students' difficulties adapting, through institutional adaptation to an increasingly diverse student population. Among these, they mention induction programmes and supplemental instruction specifically targeted at risk students and risk subjects (i.e., specific courses) respectively and the provision of accurate and comprehensive pre-enrolment advice. They recommend offering peer mentoring services, the establishing of academic learning communities (as do for instance Catherine Engstrom and Tinto 2007) and a general focus on quality of teaching. Especially this last recommendation must be emphasized. Otherwise a closed circle seems to form between the assimilation strand and the institutional services strand: in realizing the needs of the students, the institution can accommodate these needs by successfully supporting students assimilating to institutional requirements.

The interactions strand

We note that a salient characteristic of both the assimilation strand and the institutional services strand is that the specific teaching and learning environment and the educational programmes in general seem to be 'black-boxed'. They are taken for granted and considered invariable. The only variable left is the students (who need to be assimilated if they do not assimilate naturally), or the sets of institutional services that supplement invariable teaching activities to provide the extra support some students need in order to assimilate.

What we miss in these research strands is a focus on the aspects of academic integration that relates to students-institution interactions – including curriculum content and structure, and teaching and learning. In line with Tinto's interactionalist model, Lawrence (2005) aims for inclusion and argues that the purpose of a focus on academic integration would be to link transition, attrition and retention with "engagement and mastery of mainstream university discourse/literacies" (p. 30). Tamsin Haggis (2006) extends this sentiment, and reminds us to integrate in this focus a perspective that aims to sustain and avoid corrosion of the positive aspects of mainstream university discourse.

Tierney (2000) suggests that one way to improve the university's fit to the environment is to define, affirm and incorporate practices for negotiating academic identity within the institutional culture. But this is significantly easier said than done, as Wolff-Michael Roth and Yew-Jin Lee (2006) make abundantly clear in their case study analyses of learning communities.

At an initial stage, another of many approaches, is to linger at mapping the constraints already experienced in contemporary higher education and work at (re)clarifying how attrition and retention (and learning in general) link to the negotiation of an academic identity and the experience of teaching and learning. An illustration of how this link might be envisioned with respect to university physics education is suggested by figure 1 below:

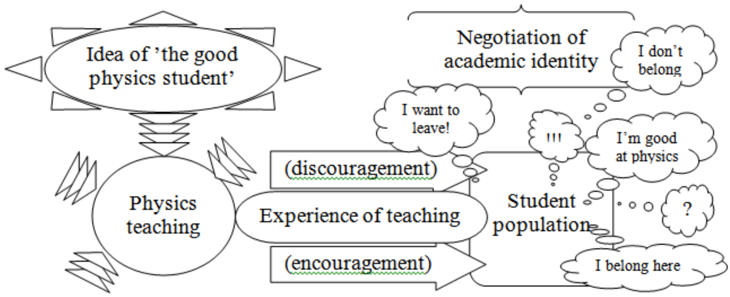

Figure 1: an illustration of how the idea of 'the good physics student' influences physics teaching. Students experience this teaching, and part of this experience is encouragement and discouragement. Students use such experiences when they negotiate their academic identity. Part of this negotiation is to negotiate feelings of belonging and of being 'a good physics students'.

An aspect of the culture of any educational practice is ideas about what is implied, when we talk about good, bad, mediocre, etc. students (Ulriksen 2009). In the introduction to this paper we describe how researchers in North America have found evidence that the culture of physics education at their institution is systematically biased against women in various ways. Such a bias is of course unintentional, why it seems safe to presume that other kinds of unintentional cultural bias exist which target student types who are not necessarily all female. Seymour and Hewitt (1997) confirm this presumption.

To decide which bias is unintentional and what bias is preferable, one needs to know what biases exist and what the effect of such biases might be. With regards to science and technology education, we already know the effect to be "unacceptably high drop-out rates in many European countries" (European Commission 2004, p. 181). It is an empirical question to investigate what kind of bias that causes these attrition rates, and for the physics community to decide, what aspects of this cultural bias are acceptable and may even be considered intentional. In figure 1 above, such a decision could thus add to or constitute an intentional explication of a clarifying link between students' 'Negotiation of academic identity' and 'What a good physics student is'. Such a link may help address unintentional bias and ultimately alleviate unintentional attrition. Initially, however, important knowledge can be gained from asking how the students themselves make meaning of the link between their negotiation of an academic identity and their participation in university teaching and learning activities. This is what we do in this paper.

We analyse a set of interviews with students who opted to leave the physics programme at a Swedish university with the purpose of clarifying how these students' experiences of studying physics relate to what they tell about the reasons for their decision to leave. This approach differs from the integration strand as delineated here, in this overview, in that we take the students' motivational strategies as they relate to their perceived experiences of learning into consideration. It also differs from the institutional services strand in that this perspective does not assume a complete correspondence between reasons for leaving and educational experience. Instead we approach student interviews about leaving, as a source for clarifying how the educational experience *links* to the reason for leaving. The aim is thus to identify issues which can be addressed at the institutional level by, for example, modifying the curriculum and/or the teaching and learning environment in order to give future students a different, and hopefully better, educational experience.

In the next section, we tie this overview to a discourse analysis framework and thus describe an interpretative perspective that allows for approaching such a clarifying linkage.

A discourse analysis framework for interpreting attrition linked to student-institution interaction

Tinto (2006-2007) remarks in one of his later papers and also in his book (1993) that attrition is not the complementary opposite of retention. One cannot assume what might be the impact of learning and teaching practices on stayers from research into the impact of experiences on leavers. To move forward in our effort to increase retention, it is necessary to assume a perspective that "delineate[s] the organizational context within which effective practices and programs arise and endure" (2006-2007, p. 7). If Tinto is right in pointing out that we cannot assume the impact on stayers from the impact of experiences on leavers, is this an impasse? Do we have to be pragmatic and leave research on attrition behind and instead focus research on 'what seems to work?'

Not necessarily, but it does mean that we need to be careful not to draw hasty conclusions and expect to be able to render practices effective by scrutinizing 'what did not work.' We thus briefly look at how perspectives on teaching and learning (i.e. research into the organizational context of practices at institutions of higher educations) have developed.

Haggis (2009a, 2009b) reviewed four decades of student learning research in a selection of UK and US based higher education journals. She concludes that cognitive psychological learning theory (focusing on the individual) "has developed at the expense of […] other approaches" (2009a, p. 34). For this reason, we need to look beyond the enculturation of our field and "step into the unknown" (Haggis 2009b, p. 388). In an earlier paper on "Pedagogies for diversity", Haggis (2006) distinguishes between forms of such dominant research in a way that is very similar to the distinctions made by Zepke and Leach (2005) and Lawrence (2005), which was used in the previous section. Here, Haggis identifies research on teaching and learning that either locates the problem "within the student" or as an indication of a "need to improve conventional teaching methods" (Haggis 2006, p. 523). But also, she identifies a third branch that draws on results from research on adult learning that argues for a move away from individuals focused research to allow for a broader perspective that takes into consideration, not only the discourse and power relations, but the process of discourse and power relations specific to the disciplinary contexts (*ibid*). An example of such an approach to delineating teaching/learning situations is John Biggs and Catherine Tang's (2007) conception of outcomes-based teaching and learning designs.

It appears, that no matter how we turn and twist the issue, whether we look at the issue of attrition emphasizing the perspective of those who leave or are in danger of leaving (as was done at the beginning of this paper), or we look at the issue of learning emphasizing the perspective of those who stay, we hear a call for a focus on the interaction between student and institution. A focus that is contextually and disciplinarily rooted – or situated. Maintaining such a focus on attrition thus holds promise for gaining knowledge that is also valuable for informing and supporting retention.

To recapitulate the previous overview: to move forward in researching attrition it is necessary to consider the interplay between student and the specific disciplinary context that this student decided to leave. In the next subsection "Interactions", we identify an analytical framework suitable for analysing interviews with such considerations in mind and in the subsection that follows we introduce Aristotle's four variations of cause in order to illustrate how students' experiences link with causes for leaving.

Interactions: Discourse models

James Gee (2005, 2011) has developed a framework that is specifically intended for analysing and understanding interactions between individuals and the structural, as constituted by for instance culture or institutions of education. In this framework, one creates oneself and is created in discourse. Gee (2005) explains: "We continually and actively build and rebuild our worlds not just through language but through language used in tandem with action, interactions, non-linguistic symbol systems, objects, tools, technologies and distinctive ways of thinking, valuing, feeling, and believing. […] We use language to get recognized as taking on a certain identity or role, that is to build an identity here-and-now." (p. 10-11).

If a student is interviewed about his or her choice of leaving, we might thus think of the way causes are ascribed to choice as part of an identity created for the occasion. Characteristic of this identity creation, among many other things, are ways in which the account of such a choice is made meaningful. At the same time, these ways also reveal characteristics of the culture in which such discourse is meaningful: "discourse (and language in general) is a part of culture: because culture is a framework for acting, believing, and understanding, culture is the framework in which communication (and the use of utterances) becomes meaningful." (Schiffrin 1994, p. 408). Since the interview situation is not culturally self-contained or isolated, the creation of identity for the occasion does to some extent link back to the culture of reference, to the topic of conversation. What makes Gee's sociolinguistic framework interesting in this respect is that it is especially well suited for getting at this reciprocity of meaning, identity and culture that is sketched in Deborah Schiffrin's quote above, and that which binds it together. In an earlier edition of his book, Gee (2005) referred to this reciprocity as "Discourse models". He now calls this reciprocity "figured worlds" to stress that we are talking about "ways in which people construe aspects of the world in their heads" (Gee 2011, p. 76); but also he does so to better retain his discourse analysis toolkit's kinship with the wider field of discourse-research that Dorothy Holland and her colleagues' work represent (cf. Holland, Skinner, Lachicotte Jr, and Cain 2001). Here, we still use the term 'Discourse models' because we want to emphasize our analytical approach to interviews: the stories that students relate in interviews are subjectively meaningful to each student individually, but to us they represent a conglomerate of situational experiences that students link to make meaning of the experiences. This way of linking, resembles modelling, and to approach this coherence- and meaning-making as a type of modelling, allows us to 'get at' the situational experience – which first and foremost is the purpose of this paper. Gee characterize the Discourse models in this way:

> "Discourse models" are "theories" (storylines, images, explanatory frameworks) that people hold, often unconsciously, and use to make sense of the world and their experience in it. They are always oversimplified, an attempt to capture some main elements and background subtleties, in order to allow us to act in the world without having to think overtly about everything all at once. In this sense they are like stereotypes, though we should keep in mind that all theories, even overt theories in science, are simplifications of reality that are meant to help us understand complicated realities by focusing on important things and leaving out some of the details. (Gee 2005, p.61)

The analytical lens that we employ here by making use of Gee's notion of Discourse models (the capital 'D' is meant to signify that language-in-use-discourse, is 'melded integrally' with the ad-hoc creation of identity), allows us a conscious explication of these 'background subtleties' and theories that make attrition meaningful to those students who leave. But not to those alone. These theories, as previously argued, per the reciprocity of meaning, identity and culture, are also *indicators* of the culture they refer to. Even the aspects that are left out to form these theories are important referential indicators. This in turn means that one cannot infer cause directly from interviews on early departure, as appears to be the approach in many studies in 'the institutional services strand'. An extra analytical layer is needed to manage and characterise both the referential indicators that are explicitly present in interviews and those that are made apparent in their absence. The focus of the analysis in this paper is to link students' characteristic modes of Discursive modelling of causal relations regarding their choice of leaving to the interplay between student and institution. To thus specify and characterise modes of reasoning that are present or evidently absent we turn to Aristotle's characterization of causal relations because it explicitly deals with this schism. Consequently it is an appealing characterization for illustrating students' characteristic modes of Discursive modelling.

Aristotle's four causes

When we speak of intentions and causes (e.g. as when we speak of choice and of changing one's mind) we tend to rationalize subjectively although intention and cause is usually manifested externally in action and interaction (Hineline 2003). Each of us, individually, are all socially intertwined in motivation, and as to what is which, there is a natural basis for confusion: "for each individual 'sees the *other* do the same as it does; each does itself what it demands of the other, and therefore also does what it does only in so far as the other does the same' (Hegel 1807/1977, p.112)" (Roth and Lee 2006, p. 28). For this reason it can be necessary to have a framework to compare against, when attempting to sort out the mangled logic of causality that is more often than not our stories. To this end we have chosen Aristotle's four causes, as gathered from Thomas Aquinas' commentary on Aristotle's Metaphysics (1272/1961). They are:

1 causa materialis, which concerns the cause of a thing, without which it would not be. That is, a goblet of silver, for instance, is not at all a goblet of silver, without the silver. Conversely silver is not destroyed by being moulded into a cup. That is, silver (among other things) is the material cause of the silver cup, and also that which makes a silver cup a subset of cups. Aquinas emphasises that the material cause is an intrinsic quality pertaining to the thing we want to explain the cause of. According to Peter R. Killeen (2001), who is a psychologist, material causes are what neuroscientists are concerned with when they explain cognition of various kinds by pointing out how physical components of the brain interact.

2 causa formalis, which concerns the cause of a thing that makes us recognize it as just such a thing. It is the characteristics of the thing pertaining to its likeness to the exemplary or ideal version of the thing. In terms of the silver cup, we might talk of its metallic gleam, its shape or maybe a certain pattern around the edge that we have come to identify with fine metal cups. As such, the formal cause is very much connected to ideas extrinsic to the thing itself. Killeen (2001) suggests that Newton's laws are perfect examples of how the formal cause is emphasized in explanation of terrestrial movements.

Devoid of any apparent material causes, such as hooks and eyes, Newton described the reason for the planets' apparent behaviour with a mathematical 'model of gravity' – and here, gravity is the formal cause of the planets' movements, neatly formalised as a mathematical model, a theoretical description of interaction that does not have a material designation.

3 causa efficiens, which concerns the cause of a thing that makes it begin being or do, come to rest or move. Most often the efficient cause lies in the activity that is associated with the thing. With respect to the silver cup, the need for a place to pour wine might be its efficient cause. But also the silver smith who made it or the chieftain who supplied the silver for the making of the cup might be associated with its efficient cause. "Efficient causes identify the early parts of a sequence that are essential for the later parts," says Killeen (2001, p 137), and interprets this as "the contemporary meaning of *cause"* (ibid, p. 136).

4 causa finalis, which concerns the cause of a thing pertaining to its purpose, that for the sake of which it exists or 'does.' As with the efficient cause, the final cause is strongly associated with activity. Different though, is an insistence that a final cause is meaningful, to some extent intentional. The final cause of a silver cup might be that it completes the idea of a good bottle of wine. Much of the causality that natural science deals with traditionally assumes to avoid issue of inherent purpose. If explaining the purpose of gravity, for instance, one soon wanders into domains assumedly irrelevant to science and not at all in line with the process of thinking scientifically – for we do no longer think that the stone is falling because it is *supposed* to rest on the ground, nor that the planets want to go anywhere in particular. However, one often turn to final causes in practical explanation of science: for instance when working with circuitry utilizing the principle of the path of least resistance (implicitly assuming that electricity wants to, or is supposed to 'run' as easily as possible), or pointing out that a giraffe has a long neck so it can reach high foliage (Killeen 2001).

In the context of this paper, we use Aristotle's four causes as a form of analogy: as an illustration that assists understanding a characterisation of what conversation-paths are accessible with respect to explorations of what went ahead of the events that interview participants offer as reasons for leaving their studies. We acknowledge that it can be problematic to talk about causes in relation to human action, because hopefully we are all individuals who are able to act in the world, individuals who can always rationalize and give reason for our actions. It surely is different to give reason for one's action compared to saying that someone or something caused our actions. Using Aristotle's four causes to contrast students' explanations for leaving, however, allows for a coherent way of illustrating the analyses of student Discourse, which in turn allows a different understanding of the interviews. Thus, Aristotle's causes are utilized to illustrate, contrast, link and characterise Discourse on attrition.

Below we make *our* Discourse model explicit through an analogy. Often "the acorn and oak tree" paralleled with "the boy and the man" is used to illustrate causa finalis (cf. Cohen 2009). We relate the notion of the two to all four causes. But instead of using the latter notion in terms of 'boy becomes man', we think 'physics student become physicist' (no gendered connotation intended) by metaphorically retaining an implicit notion of personal development, here limited to the scope of physics education. Thus, we introduce the metaphor used in this analysis.

Aristotle's causes		**The causes that an acorn realizes its potential to become an oak tree**	**The causes that a student realizes his or her potential to become a physicist**
1	Causa materialis the material cause *matter*	The acorn, within which a seed is constituted in ways that can allow for it to mature	The student, constituted in certain ways that align with that which is needed to study physics. Abilities, capacities
2	Causa Formalis the formal cause *form*	The tree (as an idea or concept). The biological imperative: acorns develop into trees	Physics as an educational discipline (as an idea or concept). The disciplinary imperative: through education you become a physicist
3	Causa Efficiens	The right conditions for growth (sunlight,	Good teaching and learning conditions.

	The efficient cause *moving*	rain, nutritious soil, etc.)	Programme structure, teaching and learning environment
4	Causa Finalis The final cause *end purpose*	Becoming a mature oak tree	Becoming a physicist

Table 1: an illustration of our use of cause, exemplified by the analogy of an acorn that grows into an oak-tree and a physics student that grows into becoming a physicist.

If a man plants an acorn, but an oak does not grow, the frame above will be a useful way to approach ascribing causality to the failure. Some aspects of cause will be more interesting to the man than others, however. If the acorn was just a bad acorn (material cause), he will get a new one and see what happens. But if the conditions in front of his house prove unsuitable for oak-growth (efficient cause), this will be of special concern to him, since such a realization is of consequence to all his attempts to grow oaks in his front yard.

The same goes for research into attrition. Naturally – and especially from the interactions perspective on attrition – we recognize that all causes in one way or another apply when a student leaves a university programme without graduating. But as educators and researchers into education, the efficient cause is the one that is most interesting simply because it is the aspect of cause that is concerned with conditions that we can best control. Also, efficient causes concern aspects of cause that most readily inform issues of academic and social integration, which according to Tinto (1993) are all-important factors in attrition and retention. Note, however, that the research strands of 'assimilation' and 'institutional services' seem to focus mainly on material causes: who, how, and what the students are.

In the next section, we describe how interviews where performed, and with whom.

The interview as a critical on-going investigation of the interview itself

The students who participated in the interviews we analyse here all studied in a physics programme at a traditional Swedish research university where attrition rates exceeded fifty per cent. Parts of the interview study that are reported on elsewhere (see Johannsen 2007), entailed rigorous analysis of individual students' test results throughout a rather big spread of cohorts.

To allow the possibility for comparing narratives across situated experiences, the first criterion for selecting interview participants was that they started at different years and had performed differently while they were in the programme. In total, seven students were interviewed separately. Based on their grades and time in the programme three of these were students that we had loosely categorized as 'low achievers' (they had stayed in the programme for ½ a year, 1 year and 1½ years respectively), one was a student that we had categorized 'average achiever' (who had stayed in the programme for 1 year), two were students categorized as 'high achievers' (who both stayed in the programme for 1 year) and one student had switched just short of study-start immediately after the preliminary activities, and had thus not 'achieved' at all.

As the purpose of the interviews was to get more detailed knowledge about the story behind our statistical analysis, the learned experience from one interview was intentionally carried into the next. In praxis, this meant that the interview participants were effectively invited into a room for reflection on retention and attrition. In this room each interviewee was treated as an expert-informer on the subject, but still reflectively confronted with the cumulative understanding of the phenomenon that the interviewer had attained during other interviews.

To some extent the interview-form can be likened to what Steinar Kvale (2006) has termed a "one way dialogue" (p. 484) in the sense that the interviewer had a set agenda, questioned the interview participant and expected of the participant to answer these questions elaborately. But given our analytical frame, attempts were made to depart from this one-way dialogue and instead actively confront the interview participants with assumptions that were made during the interview – implicitly and explicitly by both interviewer and interview participant. To some effect this is a very different approach to interviewing than is commonly used in standard 'life-world' interviews (cf. Kvale 1983). Here, the interviewer will prompt the interviewee to *describe* and continue to describe his or her experiences in depth. The interviewer will never explicitly ask of the participant to reflect interpretatively upon such descriptions because interpretation, parallel to a medical doctor's diagnosis, is something that is carried out at the researcher's sole discretion outside of the interview-space, possibly in collaboration with peers (*ibid*).

During our interviews, participants *were* asked to engage interpretatively with any assumption caught by the interviewer in order to co-construct with the interviewed a “logical space of reasons, of justifying and being able to justify what one says.” (Sellars, et al. 1997, p. 76). To such an end this one-sided request for deeper reflection gives the interview a character of a critical investigation of the on-going interview. The interviewer validates tentative analyses together with the interviewee. At the same time this validation serves to sharpen attention on certain areas of interest which the interviewer and interviewee can duly react to, thus allowing conversation of a quality that is both important to later analysis, but also important to help empower the interviewee as informant. As Svend Brinkmann (2007, pp. 1123-1124) argues in this respect: “We come into being as reflexive human participants when we are prompted by others to give accounts, account that are given meaning by reference to a social dimension or normativity [out of which] a knowing subject emerges”. To this end, the interview protocol was designed to ensure that a broad spectrum of themes were discussed (ranging from background – place of birth, school and interests, choice of physics and possible alternatives to studying physics, to themes of developing an identity as a physics student – feelings of belonging, being a student, perceptions of other students and of physicists in general). On average, the interviews were performed in 1 hour 10 minutes (ranging from 30 minutes to 1 hour 45 minutes).

All interviews were conducted in English because the interviewer was Danish and the participants Swedish. This choice ensured that both interviewer and interviewee were almost equally conversationally proficient. Thus, the citations used here are not translations, but verbatim transcripts of the conversations. As will be evident in the text a peculiar type of English develops between Scandinavians who speak English with each other. Instead of a distraction, it should be considered characteristic of the interview Discourse that is utilized for this study. All names used are pseudonyms.

The interview data have been analysed in various ways and for different purposes several times. For this paper, the interviews were analysed thematically (see Braun and Clarke 2006) – at certain stages using ATLAS.ti, which is a computer software designed to assist qualitative analysis. This process of thematic analysis began already while interviews were conducted. The interviewer expected that the interviews would revolve around aspects of teaching and learning experiences related to the informants’ decisions of leaving. Instead students typically seemed to reason introspectively when they explained their decision. Consequently, the first round of coding the transcribed interview-data was about identifying introspective reasoning. The next step in the analysis entailed sorting this introspective reasoning into particular ‘types’ of reasoning. One ‘pile of typical reasoning’ grew surprisingly large, and on discussing the nature of this type of introspective reasoning we realized that the type of causation used here, was characteristically similar to Aristotle’s description of the material cause. Consequently the whole dataset was revisited using ATLAS.ti to code for all of Aristotle’s four causes.

In the next section, we utilize the outcome of the last stage of the thematic analysis of the interviews to bring out some of the other possible interpretations these interviews offer by introducing the extra layer of illustrative interpretation that Aristotle’s four causes offer, and contrast these to the interpretations that are overtly accessible in the interviews. The purpose of bringing out this contrast is to show how the ‘integration’ and ‘institutional services’ strands in research on attrition and retention fall short in relation to finding reasons and cause for attrition.

Introspective Discourse on reasons and causes for choosing to leave

The interviews that are analysed here were planed based on the premise that students’ decision of leaving the physics programme is a decision based on experiences of participating in physics courses and on interaction with peers and teachers in the programme. During the interviews the interviewer soon felt that students resisted talking about such external conditions that might pertain to their interaction with the institutional setting of the physics programme. Instead they crafted their arguments introspectively on aspects of their selves – mostly pertaining to what they were personally lacking relative to physics learning. In terms Aristotle’s four causes, this means that only one type of cause was applied by the students to describe their choice of leaving the physics programme: the material cause. Continually the students somehow managed to waylay the conversation to make it about themselves, their own lack of interest or lack of hard-headed endurance instead of allowing conversation to run along the lines of, for example, the ways teaching was performed or ways in which physics-problems were or were not presented in engaging ways. As mentioned in the previous section we soon realized that this was a particular phenomenon, characteristic of the way these students position themselves in relation to their decision to leave. A phenomenon, which to the interviewer would resemble a discursively impenetrable wall of introspection. The students would readily talk about how and why they could not meet institutional requirements, but resisted speaking about ways in which the institution did not meet their needs.

This situation is perceived as evidence of a certain kind of sense-making or logic that is evidently infused with the Discourse particular to these interviews. This logic is one that we will penetrate in the next subsections. First, it is identified. Second and third, two central particulars of the Discourse are presented and analysed.

It is important to note that when we penetrate the logic and challenge the students' reasoning, we do not do so claiming that the causes the students give are 'wrong' nor that suggestions of other possible (e.g. efficient) causes are more 'valid' or that there is such a thing as one 'objective' causal explanation. On the contrary. We believe that the *purpose* of the explanation is very important, and that it determines which types of causes are meaningfully emphasized. For the students, it is important to construct an explanatory framework that supports their identity building and meaning-making – which becomes the premise of their replies. For us it is important to construct an explanatory framework that can support quality development of educational programmes and other types of institutional support in order to better facilitate academic integration – which in turn was the premise of the type of interview-questions that were posed.

Material cause: destiny

Characteristic of all the interviews is that students kept to an explanation for their departure that was contained within their self-story – i.e., a story contained through introspection. Underneath is an example of this introspective theme that was approached by the interviewer from a variety of angles placed externally to the student, trying to look for different types of causes, during the interviews, but which inevitably led to the same family of conclusions, namely those that has to do with something internal, something within the self:

I:	was there like an incident or something that happened?	(5.1.1)
Susan:	I just realized I wasn't interested in that. I was beginning to be more and more interest-	

ed in languages, and less and less interested in physics.

In Susan's case, her final conclusion is that while she found herself gradually becoming more attracted to studies in the humanities, she also found her interest for physics diminishing. This explanation is very much in line with Arne Mastekaasa and Jens-Christian Smeby's (2008) find, from which they posit that instead of focusing on explanations for female students' drop-out from male-dominated programmes, one would instead benefit from asking "why they are so strongly attracted to the female-dominated ones" (*ibid.* p. 200). So let us briefly revisit Susan's story.

Susan's story is one of solitude. She started studying physics, forming a tight group with a few people she knew from home. But they were quick to leave the programme and the city, and she was left to her own devices. These did not suffice. She did not look for new friends in the programme, and on her own she soon had difficulties finding meaning and purpose in her studies. This left her wondering, and as she remembers, she started studying physics because of a deep philosophical interest.

When Susan ascribes cause to her decision of leaving (transcript line 5.1.1) she does it with reference to some type of interests-alchemy that transforms one kind of interest into an entirely different interest. Contrary to Mastekaasa and Smeby's suspicion, Susan's argument is not crafted around an experience of neither push nor pull. It is crafted around a perceived change within herself.

Left to her own devices, and to some extent isolated, it does not seem unreasonable that Susan looks within to find cause. Yet, a different student who was deeply involved with a great number of students in his year ascribes cause in much the same way. He also emphasizes that the students individually will have to come to terms with themselves if they want to succeed in the physics programme. Below the interviewer is attempting at introducing the notion that maybe the structural is also a cause for attrition, i.e. prompting an exploration of causes other than the ones pertaining to the students' themselves:

I:	but there's just the difference between physics here and a lot of other educations. I mean every second student don't make it. And that's really high, and I mean, that's peculiar.	(5.1.2)
Clas:	I guess so. I don't think it's. I'm not a, I	

don't… I think it – every second did you say?

I: mhm. Yeah fifty per cent.

Clas: Fifty. That's good I think, hehe

I: Yeah?

Clas: yeah… if fifty per cent of the people I studied with make it, then I… I must say I think that is good.

I: okay?

Clas: You have to try if you are interested and they want to try it, but then, you can't… I feel that you can't just say that something is wrong with the education because you can't manage it. Then you are just meant to do something else. Because it is hard…

[…]

Clas: … I don't think that fifty per cent, I mean a lot of people have to… try it to just come to the conclusion that you are not meant to study it, so…

Here, Clas gives three reasons for attrition. One is personal interest, another is the inherent 'hardness' of the programme, and a third is something that resembles destiny, but which is obviously connected to his notion of how personal interest can be explored in interaction with the field to see "if you are interested". According to Clas, trying to see if you are interested is a permissible behaviour characteristic of learning physics at university. We are reminded of the "trial like fashion" of enrolment that Niels O. Andersen and Kjeld Bagger Laursen (2003, p. 65) identify as a central cause for attrition. Clas expands this notion and explains that since the field of physics is inherently harder than other fields, high attrition rates are inevitable when interest is explored in interaction with such a difficult field. But contrary to Andersen and Laursen, who believe that only some students do so, Clas is of the opinion that this sort of exploration is a type of behaviour characteristic of all students in his year, necessary for all to find out if they are "meant to study" physics.

The exact same concluding figure, although somewhat condensed, appeared in the interview with Anita, a third participant:

Anita: the next autumn I decided to drop out. I didn't know what to study, but I understood that physics wasn't something I was meant to study – at least at that point. (5.1.3)

It is important to the interpretation of this quote that Anita hesitates at the end, adding "at least at that point." It is a strong cue to indicate that her outlook was different at a different time – a cue that speaks straight back to Clas' sentiment (transcript line 5.1.2) that whether you are 'meant to' study physics or not, is a conclusion you reach by confronting the discipline, and sensing your own reaction.

In an attempt to avoid introspection, by suggesting a new premise for the conversation, the interviewer attempted at approaching the problem of attrition by invoking a third person perspective in the interview with a fourth participant. Below, Joanna was asked to reflect on experiences of a particular friend who also opted to leave physics early:

I: Do you remember why he stopped studying physics?

Joanna: I don't think we ever discussed it actually. We just… it just wasn't for him. (5.1.4)

Interestingly the resulting answer is that "it" did not suit Joanna's friend, which could be considered an opening for discussing what aspects of "it" did not suit her friend. Notice however, how Joanna contains the finality of her explanation with the word "just". The interviewer's attempt at qualifying statements like these, most often resulted in exasperation on the student's part. This exasperation is particularly obvious in this next quote, with which Clas finalized his interview:

I: do you think that there's anything we missed? Something that I should know?

Clas: No, I don't think so… Guess you asked the questions that you need. But… I don't think, ehm… Oh, it's so individual. Some people make it, some don't. It's just… You can't say that there's something wrong with the courses or with the pace, because some people make it. Maybe you are not meant to study that. (5.1.5)

> Maybe they are… So I wasn't angry because the pace was too high. Or because I didn't understand it. Maybe… then you just. Yeah, think that maybe I should study something else. It's not… someone else's fault. Because some make it.

As he indicates, and as was also illustrated by transcript line 5.1.2 previously, the interviewer has been introducing a variety of alternative causes to the ones Clas had been utilizing in explaining his decision to leave. Here, Clas uses this last chance to explain himself properly and emphasize the finality of his experience: some make it, some do not. If you do not make it, you are not meant to. If you are not meant to make it, you will not. This might be a sufficient explanation to both the students who stay, and those who leave; and also to Rhys Davies and Peter Elias (2003) who list "mistaken choice" among the most prominent of causes for attrition. But to an interviewer who attempts at penetrating the process and the interactions that lead students to reach such conclusions, insistence on this limited application of cause is unsatisfactory. If we compares with Aristotle's four causes we understand why. It is because the students limit their explanation of cause to emphasizing the material cause.

Material cause: ability – to estimate one's capability

Characteristic of the way students model their Discourse on leaving is their use of a notion of 'ability', which is another cause, but also a material cause. In this section, we will show some examples of the ways this notion is used by the interviewed students to construct causal relations between 'ability' and the decision of leaving. The examples are not chosen to further emphasize this find, but because they serve to represent various ways in which students talk about ability in relation to their experience.

We start with Thomas who had changed from studying in the physics programme to studying in the mathematics programme. As the two programmes overlap it is arguable whether such a slight shift actually constitutes attrition or if it is more an act of specialization. But listening to Thomas' story it appears to be a matter of the former in that the shift is more an issue of having misinterpreted formal requirements than a question of a conscious choice.

Thomas started studying physics because he wanted to work with theoretical physics. He knew that he thus needed to also become an expert mathematician and opted for a strand of more advanced mathematics than the standard offered during the introductory years. In this strand, two introductory and compulsory mathematics courses had been merged into one (i.e. algebra 1+2), and a series of extra lectures were offered instead of problem-solving sessions. But Thomas had difficulties with this merged course, and gathered from his impressions of the physics course that he could prioritize mathematics without seriously jeopardizing his chances of passing physics. As it turned out, he could not, and at the end of the year he decided to take a regular mathematics examination (i.e. algebra 1) instead of the merged exam. He passed the mathematics, but failed physics – and suddenly, instead of having passed more courses than required, as he had planned, he was now behind in his studies. To remedy the situation he tried to pass the algebra 2 course on his own. This did not go too well either. Thomas explains his take on the situation:

Thomas: pff, well, I, maybe I was just too self-confident. Like I thought I had an idea [a plan], so I just studied this book, I had no teacher. And at one end, well, I just thought I knew more than I actually did. (5.2.1)

Here, Thomas uses 'having no teacher' to characterise his situation. To explain the cause of deciding to take the examination without following the course a second time, he explains that (1): he made his decision because he was too self-confident, and (2): that this self-confidence arose from 'thinking he knew more than he actually did.'

We turn to another quote in the interview to get a better sense of what gave Thomas his "idea". Below Thomas expands on it in relation to his decision to prioritize mathematics over physics and to continue applying himself to pass these mathematics courses:

Thomas: well, I thought I had an idea after all. I had attended the lectures and everything, and I knew that they didn't think that mechanics was that terribly difficult. So, well, I still had the idea that I could take the physics. But I think the main reason that I didn't, was that there seemed to be some interesting math courses that I wanted to take. (5.2.2)

At the beginning of our treatment of Thomas' experience in the physics programme we argued that Thomas' shift from physics to mathematics was more a result of misinterpreting institutional requirements (and thus a case of attrition) than an act of specialization. Above however, Thomas seems to be of the opinion that the latter is the case, that 'the main reason was that he wanted to take interesting math courses' (where his interest in mathematics is considered a material cause).

Holmegaard, Ulriksen and Madsen (2011) give convincing evidence that the process of choice – for instance the shift between one programme to another – is an on-going negotiation of intersecting spheres of interest, which work harmoniously at the subjectively present but might appear as if conflicting when viewed over time. In praxis, this means that we, as humans, remember and emphasize what interests us in an ad hoc manner in which we make meaning of the past based on our knowledge of the present. This ensures that we feel in control of our lives (cf. Bruner 1990). In accordance, we acknowledge that at the time of the interview with Thomas, his choice of studying mathematics is perceived by him as an act of specialization. But, as Thomas also indicates in the quote above, it was not always an act of specialization, since he initially intended to catch up with his aspirations regarding mathematics before he continued his studies towards becoming a theoretical physicist.

For Thomas, this way of constructing causality is fully functional and probably also very satisfying to him. But from the perspective of someone who wishes to gain insight into the interactions between students, institution and content, we will need to turn our focus back to the cause of Thomas' "idea" or 'plan'. Above we are led to know that this idea has its origin in Thomas' interpretation of the lecturers' perception of the content – 'they said mechanics was not difficult.'

Thus, a researcher who is interested in understanding causes of attrition in an interactions-perspective could use Thomas' story as a cue for turning attention to the aspects of introductory physics that downplays the importance of physics content – "I knew that they didn't think that mechanics was that terribly difficult" – compared to, in this case, the mathematics content. It seems that such aspects confirm students like Thomas in emphasizing other aspects of their difficulties in such a course, than what has to do with the course itself. In the case of Thomas, we see that he turns to emphasizing that his main interest was in mathematics, and that the main reason for not passing his physics and mathematics courses was his inability to properly judge his own capacity as a physics and mathematics student. This capacity or ‘ability’ of his is essentially utilized by Thomas as a material cause for explaining the unfortunate events that, contrary to his original beliefs when he chose to study physics, allowed Thomas to experience that mathematics “was more abstract and interesting than I had thought it would be. That it was what I was searching for in some sense. [That] I liked it very much,” as he says at an early stage of the interview. Of course, we need not be anything but happy for Thomas, but we still need to be suspicious of aspects of physics teaching that downplays the importance of the physics contents; because as we see, when students are involuntarily confronted by systemic contradictions (as is a physics lecturer who tells his students that physics is easy) they tend to interpret the situation in terms of personal ability or endurance (see next subsection).

We find the same kind of basic pattern in the interview with Joanna who decided to attempt passing the mathematics examination by studying on her own. Joanna started studying physics because of an interest in astronomy. But she is struggling - on the motivational level but also on the very apparent level. She cannot pass her mathematics course, and she takes this as a sign that she, as a student, is incapable, and not as a sign that her learning needs to be facilitated through instruction. Instead of attempting to reinforce her motivation by moving on to the astronomy course, she lingers with the mathematics course and is of the impression that she needs to pass this course before anything else can happen:

I: …then you decided ‘now I’m gonna go for the exam’?

Joanna: yeah, because I really liked algebra, I just

I: you did?

Joanna: Yeah! I really liked it! And I wanted to pass. But apparently I didn’t. So maybe it was too difficult for me. (5.2.3)

I: well… if you only studied the two first months…

Joanna: But I had the book. So I expected to pass on the book.

I: But why…? Why didn’t you do anything? Or sorry, but I mean why? You had a chance to take some astronomy courses I bet, after autumn, or after Christmas.

Joanna: But I have to pass the math first as well. Or anyway, so…

Although Joanna had not opted for the more advanced mathematics strand as Thomas did, Joanna was also of the impression that she should be able to learn mathematics alone. Unlike Thomas she did not realize that she might have chosen an unwise alternative strategy. Instead she uses the experience to explain how she realized that she did not have sufficient ability. The interviewer even suggests that given her lack of effort ("you only studied the two first months") other aspects than 'ability' could be a cause for failing. But Joanna maintains that since she had the book, she expected to pass. Penetrating the logic of this statement we see that Joanna and a book, is what it should take, for Joanna to pass an examination. If she does not, there is only the book or Joanna to blame.

The interviewer then goes on to suggest that gaining a broader perspective on the programme by taking an astronomy course would also be a viable attempt for regaining the motivation she needed to study in the programme. Joanna denies this: "I have to pass the math first". To Joanna passing mathematics is a structural requirement she has to abide to, and nothing but the book mediates her learning of mathematics. Hence, as a reason for failing, there is nothing or no-one left, but Joanna herself.

True, it is a requirement in the programme that the students pass the mathematics course before they move forward and take new courses, but although the sentiment might seem reasonable from an administrative point of view, failure at an examination, whatever examination, does not have to be cause for leaving. Students do however interpret these experiences differently, and those students who are able to perceive of failure as an invitation to attempt different forms of participation fare better than students who focus on the aspects of these experiences that constitute a formally designated exclusion (Hasse 2007). Joanna's sole interpretation of her failure is that it constitutes a formal designation of lack of ability and she decides that she will have to leave without ever taking any of the courses she originally enrolled in the programme to take.

Compared, Thomas' and Joanna's stories are markedly different. Thomas moved on in a way that to him resembles specialization, while Joanna left the institution entirely. Thomas was not put off by failing his examinations, but moved on to other courses that he thought were interesting, expecting to return to the failed courses later. Joanna took the rules and regulations at face value and was stopped by her immediate inability to pass the mathematics course. By comparing the two stories, it would be possible to gain further insight into how structural boundaries specific to the institution are perceived and dealt with by different students.

We return to Anita who found out that 'she was not meant to study physics' (transcript line 5.1.3). She also failed an examination. But in retrospect, she figures that at that point she was in a state of denial:

Anita:	I didn't want to accept the fact that I was going to fail. So I tried not to think about that, which meant that I didn't actually handle it as I perhaps should have.	(5.2.4)

We get the sense that Anita, just as Joanna, could see no viable alternative to passing the examination. Had she been able to see one, she might have been better equipped to "accept" that she was going to fail, and thus try different ways of approaching her impediment. As it was, she was unable to, did not and concluded that she would have to leave the programme.

In this section, we have seen how students use the notion of 'ability' with respect to the content of the discipline and to formal requirements. By approaching their stories as Discourse models that can be analysed to penetrate the implied and taken for granted truths, one is allowed a glimpse through the wall of introspection, into how their interactions with the institution might also add to the cause for their experience in the physics programme. Generally we see that the students feel like they had decided on an unsuccessful approach to their studies, because they overestimated their own abilities. It is important to add that the extra interpretational layer reveals how efficient causes, with respect to students' (misplaced) interactions with the institution, are also important factors that add to explaining this estimation at a level that can be addressed at the institutional level.

Material cause: ability – to pull through

Sometimes 'ability' in terms of ability to understand or learn, turned out to be insufficient to explain early departure. This was especially the case when the interviewer asked the participants to compare and contrast different experiences that came up during the interview. In some of these instances, the interviewed would extend the notion of lack of ability to also include lack of ability to ‘pull through’: an inherent lack of ability to commit, be motivated or desire. In this section, we will explore this aspect of ‘ability’, but also explore how ‘ability to learn’ relates to the ‘ability to pull through’.

We begin by demonstrating that the ‘ability to pull through’ also has a causal-efficient dimension, much the same way ‘ability to learn’ has.

During the start of the interview Marie explains that she decided to leave the physics programme when she realized that she would not be able to compete with the other students in her year. To finish would thus be pointless, she explained, since she would have difficulties getting the job she wanted. As the interview continued, and Marie’s experiences as a student in other programmes were explored, Marie realizes that her initial thoughts on leaving were probably premature:

Marie:	if I had wanted to do it, I would probably have gone for it anyways, right? I mean, I wasn’t the best person in my class in English class. I wasn’t, I’m not the best person in my health and sports-science class, for sure. But…	(5.3.1)

Marie’s initial way of constructing an explanation was very much in line with the other students’ we interviewed. It was about ability to understand and learn. But what Marie realizes above, is that had she asserted herself differently, she might have been able to learn physics. But during the interview, she explains that she was not sufficiently interested to ‘want’ to make the effort necessary. Here, ‘inherent ability’ is turned into ‘inherent ability to will a result’ or to ‘desire it’ – but given the inherent quality of her desire, she still applies cause to her argument in the form of material cause. This is also the case when David Allen (1999) links desire to academic performance and persistence by conceptualizing the notion as an innate ability, a precollege variable along with academic ability, which to Allen translates into an issue of knowing “why am I really going to college?” (p. 467).

With the following three quotes from the interview with Clas, we exemplify how this relationship can be interpreted in different ways. The first quote starts where Clas explains that his decision to take a break away from the programme was due to his perception of the pace in the programme. Instead of allowing this perception to be the basis for a critique of the programme, Clas insists that his experience was purely subjective, and thus cannot be used to characterize the physics programme:

Clas:	[…] I think the speed was too high, too much.	
I:	But what kept you from getting angry and saying ‘what are you doing? It doesn’t make sense!’ for instance?	
Clas:	No I th…. well… yeah because some students did manage the speed, so I guess it wasn’t me that just ehm… You know people, people can do. Some have it very easy to learn, and some have it harder. I don’t think I have it hard to learn, but I… .. well I don’t know.	(5.3.2)
I:	But you are not among the best or the fastest learners?	
Clas	no	

Just previous to the beginning of this quote (transcript line 5.3.2), Clas was explaining how he had a feeling that he needed more time to really understand, that he needed to slow down a bit. The interviewer then asks about the particulars of the situation, asks why he did not complain about not having enough time; i.e., why Clas did not attempt at finding explanations external to himself. Clas replies that people are different, saying that understanding is about ability to learn, and that some people learn more readily than others. In effect, Clas refuses the viability of the notion that the pace was generally too high. It was merely too high for him.

We know from the literature (cf. Ramsden 2003) that subject matter abundance and the experience of a fast pace, like Clas describes it, are factors that encourage students to use surface learning approaches. The learning environment thus presents itself as a viable alternative cause, an efficient cause, for Clas’ experiences: the high pace characteristic of the learning environment did not allow Clas room nor opportunity to engage the way he values. But Clas will not accept this alternative cause:

I: […] Why should they [the students who cope with the pace] set the standard?

Clas: Well… ehm, yeah you are absolutely right, and I don't… But at the same time you have to get, there has to be meaning with the course. If it's said you are gonna learn this, you can't say 'No, because I can't'. Then there is no point in…

I: Exactly, and that's what I mean. What goes into the consideration of deciding the pace? I mean, I don't think they just look at the best and say 'OK, they are hanging on, so we can continue.' There must be something that decides what, something that makes you think that it is reasonable to have that pace (5.3.3.)

Clas: OK. I think maybe if I had kept to the studies, maybe then I had understood what they did six months ago, after working with it. Working with things besides and so on.

Like Joanna in transcript line 5.2.3, Clas constructs an argument based on the necessity for accepting his notion of what is entailed in the structural constitution of the discipline. One aspect of the way the discipline is constituted is apparently the pace. But when he is asked to attempt at explaining what considerations might have gone into deciding that pace, he changes the subject. The reason for this change might very well be that Clas does not accept the question's premise, that pace is somehow decided upon. For Clas' Discourse model to be consistent, it is necessary that pace is an inherent aspect of the discipline, the structural: unquestionable and inadaptable. The interviewer in turn suggests that the discipline and the way it is taught is a construction based on student-institution negotiations, and that the discipline thus might have been adapted to certain kinds of students, who are either faster learners or willing to adopt surface learning strategies. Instead Clas changes the focus of the conversation and states that his lack of ability to cope in this particular environment was due to his lack of commitment. Following this line of argumentation, the interviewer tries to track the source of this waning commitment:

I: You said that the pace was too fast for you, and that sounds like you decided that you couldn't keep up with that speed, so you had to slow down a bit?

Clas: Yeah, exactly. I think it was during the summer, when I started working, I decided to take a year off and… let things fall in a bit… but then, ehm…

I: Okay, how did you expect things to fall in? Did you… (5.3.4)

Clas: No, maybe I just… no maybe not like that… that I will wake up and understand what I have been doing. Not in that way, just that ehm… I don't know really… … … maybe I just thought that I needed new, ehm… Just rest a bit to get more strength to come back and continue…

As we see, Clas interprets his lack of commitment as a lack of strength; something that was lacking from within himself. He starts out by attempting to explain that he just needed a year to let what he had learned fall into place. The interviewer hints at the peculiarity of the notion that you learn physics by distancing yourself from it. Clas does not attempt at explaining this, but instead he elaborates his sentiment by saying that it is about "strength". He needed to rest to regain some quality of his, without which he could not function well in the physics programme. It is also worth noting, how he describes the programme as quite relentless and immutable, and that he considers the programme 'black-boxed' much the same way it is in the two research strands of assimilation and institutional services.

One student describes how the ability to perform and the ability to pull through can be seen as related: in case you do not possess the needed abilities, you must exert yourself better or more. If you do not have what it takes to muster this exertion, you leave. This sentiment is apparent in the interview with Karl, who is the seventh student that was interviewed:

Karl: […] it should be possible for most people [to study physics] (5.3.5)

I: In terms of archetypes, do you think that there is something that, I mean, a quality that you have to possess to be able to do well in physics?

Karl: …. No I don't think so. I think you have to have the qualities that all people have to have to succeed. I mean, I don't think you have to be brilliantly smart. I think you can compensate by working very hard for example. […]So I think you have to choose to be good in physics, you have to believe that you can do well in physics. And if you believe you can do well in physics and want to do it, then you can.

Clearly Karl describes the situation in terms of the material cause: in terms of qualities that people either have, do not have or choose to have. His sentiment, although turned on its head, is related to Sheila Tobias' explanation of mathematics anxiety: "Confidence in mathematics, especially among females, is not a necessary outcome of exposure to the subject or even of achievement in it. Instead what appears to link students of very diverse mathematical 'ability' is a collection of what might be called ideological beliefs or prejudices about the subject" (Tobias 1985, p. 62).

Karl's idea is that everyone can do it, if they choose to believe they can. In the previous subsection, we saw that students have difficulties estimating their own ability and in this subsection we have seen that it is hard for students to 'will' a belief that they can, once they have experienced that they cannot. When asked, Karl is of the impression that "at this university they were pretty good at bringing everyone along." But then again, Karl tells that he did not leave the physics programme because he experienced difficulties. He explains that he "wanted to work with people." Also, the sentiment implied by Karl's Discourse above is that if you do not "choose to be good in physics" you will not be able to be good at physics. If we wanted to further our understanding of this sentiment, we would have to ask what prevents students from making such a choice. Because in all fairness, we cannot reasonably expect that students who start at university have decided from the outset that they do not want to be 'good.' Marie for one was a student who had not, and Anita (transcript line 5.1.3) hints at also having come to believe that she could not become 'good' after she was exposed to the programme.

A place to start looking to find what make students believe that they are inherently deficient is to look where the students look first: the introduction to their first physics text-book. Here, it says:

> Listening to lectures is not enough. All processes of learning are somehow connected to active participation, and the learning of physics is no exception. To underline this viewpoint we have, at the beginning of the course, always written on the blackboard, as a kind of motto: ***At Home, by Your Desk.*** Nearly all the chapters in the book are followed by a set of problems. Very few of these problems are simple "plug-in" exercises. Most problems will demand some independent thinking. If you cannot solve all the problems at first try, do not despair. We have good advice which has worked for many students: study the text, and in particular the examples, one, two, … many times over. In the end you will succeed. (Knudsen and Hjorth 2000, p. VII, emphasis in bold and italics in the original)

Obviously, the authors have got the concept of "active participation" wrong (cf. Laws 1997). Instead they seem to equate active participation with individual reflection. They emphasize "independent thinking" and stress that independent work is something that is done in solitude, at home – not at the university.

If this way of thinking about teaching and learning permeates the environment in which our interview-participants had once studied, then we come to understand their reasoning a great deal better. Clas wanted to stay at home, away from the institution, in order to let the physics fall into place. Thomas and Joanna both thought that they were supposed to be able to learn by studying the book alone. Clearly this was a strategy that did not work well for these students. Marie left because she apparently thought that she needed to compete against the others, on her own, and thus positioned herself in opposition to the aspect of the university-experience that is about social interrelations. Susan was left alone, and did not fare well at all. Both Anita and Clas thought that everyone needs to confront physics, to see if they are "meant to study it" (transcript line 5.1.2 and 5.1.3).

All, they insist that the main cause of their departure has to do with themselves, their abilities, internally, individually. Only material causes are suggested and accepted.

Now of course, had we taken the students at their word, we would have come to understand that they had chosen the wrong programme, that they did not have sufficient abilities, and that they were not sufficiently motivated – precisely as the ‘institutional services strand’. But alternative causal explanations than those that are explicit in students’ narratives exists. By exerting ourselves in interpreting interviews focusing especially on efficient causal linkages between students’ experiences of their participation in their field of study and attrition they become evident. These linkages, in turn, translate into institutional circumstances that make academic integration difficult for the students. Now framed as circumstances that also resides at the institutional level, student difficulties are accessible to institutional planners, teachers etc.

The case of mistaken agency: it was the institutionally and culturally embedded discourse that did it

In this paper, student discourse on attrition in university physics is critically analysed as it unfolds in seven interviews about causes for early departure.

We start with a critical overview of attrition and retention literature and find that it is necessary to take on a perspective of attrition and retention conceptualized as an issue of ‘interactions’: an issue of possible mismatches in the interplay between student and institution. We use a discourse analysis framework that emphasizes the constructed, taken-for-granted aspects of discourse in order to penetrate this interplay, and add to this Aristotle’s four causes as a layer that illustrates our interpretation. We find that students make use of an ‘introspective Discourse’ to explain all aspects of their departure. They insist that their reasons for leaving only pertain to themselves: their lack of ability, lack of strengths, lack of persistence, or how they are or were meant to be. These reasons all refer to one type of cause: the material cause.

Compared to Seymour and Hewitt’s study of attrition and retention in science, mathematics and technology college education in the US, this is a peculiar result. To craft the argument that all students have similar experiences but different reactions, they compare interviews with switchers and non-switchers and find, for example, that 90% and 74% respectively complain about “poor teaching by SME faculty” (1997, p. 33). As stated above, we find that students do not complain about teaching or anything teaching related, and we cannot help but wonder why. It might be a matter of different cultures (e.g. US commodification of education versus Scandinavian massification of education). Had it not been for the fact that Seymour and Hewitt's results echo through space and time, it might have been just a matter of different times. In 1976 Briggs reported that disinterested Australian students "blame the way [physics] is taught" (p. 487), and so did researchers from USA in 2005 (Perkins, et al. 2005). In a paper from 1999 though, Andrew Elby, also a North American physics education researcher, notes (with a reference to Seymour and Hewitt's study) that students who learn by rote and consequently experience difficulties on physics examinations, do not attribute these difficulties to an inadequate learning strategy. "Instead [they] take home the lesson that the test was unfairly difficult or that they're just not good at physics" (p. S56).

In sociology, however, the phenomenon of self-referential reasoning has long been recognized as a symptom of individualization. Ulrich Beck (1992, p. 136) argues that in the individualized world the only viable reaction to any systemic contradictions is the biographical solution: "an *ego-centered world view* … which turns the relation of ego and world on its head, so to speak … The institutional conditions that determine individuals are no longer just events and conditions that happen to them, but *also consequences of the decisions they themselves have made,* which they must view and treat as such" (emphasis in original). Likewise, but from different perspectives, Nikolas Rose (1999) talks about the individual as incorrigibly self-governing, and Pierre Bourdieu about symbolic violence as the social mechanism that ensures cultural reproduction whilst rendering the individual unable to specify precisely the cultural processes through which (s)he was reproduced (cf. Jenkins 2002, p. 130ff).

As educational researchers, we are interested in getting at aspects of the students' educational experiences as they pertain to the institution and the institutional setting and especially as they pertain to issues of what Tinto (1993) terms 'academic integration.' In interviews, one therefore tends to emphasise a focus on issues that relate to the efficient cause. We found that students on the other hand focus on the material cause. When these different perspectives confronts, it appears as if the interviewed student builds a 'wall of introspection' that is impenetrable to the interviewer who searches for efficient causes. But considering introspective reasoning a reply based on a premise that is different to that of a question that assumes all learning experiences ultimately externally rooted in action and interaction, we find that by being sensitive to issues of internal consistency in the way students model their discourse introspectively and link reasons for leaving with causes for leaving, the researcher is allowed occasional peeks through this wall of introspection. Such peeks reveal some of the institutional deficiencies that may lead students to opt out.

It must be emphasized that the argument we make, is not that the large attrition rate characteristic of physics programmes (and mathematics, technology and many other science programmes) are necessarily bad because they are large. Instead, we argue that even if students who opt out of physics confirm that they do not meet the 'idea of the good physics student,' this idea might still not be a good idea at all. Seymour and Hewitt (1997) provide evidence that the difference between students who stay and students who leave is their ability to cope. Since it would be a mistake to assume that a student's agency in coping equates to learning, we owe it to both the students who stay and those who leave to work hard to ensure that institutionally and culturally embedded ideas about how students ought to act and be are justly biased and aligned reasonably with the scientific practice that their education is supposed to prepare them for. It bears repeating that it simply does not suffice to base such notions solely on what kinds of students do and do not choose to continue a career in our disciplines (Tobias 1990).

Ultimately, we see no reason not to extend the same sentiment to all university education, why we strongly recommend for researchers and teachers involved with any evaluation practice that includes student testimonies, to take into consideration that young people of late modernity societies might make use of introspective reasoning by drawing on aspects of cause that pertain to the material cause only. Therefore, if one wishes to gain insight into issues external to the individual student that might be addressed at the institutional level, interpretation needs to be performed accordingly. This paper presented and discussed an example of such an interpretational analysis.

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11. Paper II: Deferred gratification

As is mentioned previously in this thesis, I designed my interview study to study attrition. Unfortunately (with regards to the research design) only three students in my sample decided to leave the programme while I was interviewing, one of which did not want to be interviewed again. I reframed my perception of the problem I was studying, to instead perceive of the students who stay as those special cases of leavers who do not leave. The upside of this framing is that it circumvents the 'deficit discourse', the idea that students who leave or have difficulties learning are different or 'deficient' compared to those who do not, and who can (cf. Lawrence, 2002).

Instead I think of the choice of leaving *vis a vis* staying as results of different coping strategies – some obviously more successful than others.

In this paper, I, Lene Møller Madsen and Camilla Østerberg Rump explore these successful coping strategies. Framed as an issue of interest, situational and personal interest, we explore how students cope – what they need to cope with, and their strategies for doing so.

What we find, is that several of the students who thrive seem to perceive of the content of the physics programme much the same way they perceived of the contents of secondary education physics: as something you need to learn, and while you do it, it is often interesting. Those students who work hard to cope, do so because they partly expect that their physics learning will gradually lead them to alter their perception of physical reality, alter their ability to understand the world, or generally make their journey towards becoming physicists themselves evident. The contents they are required to engage with, and the type of engagement that is required of them, does not make this journey evident however. Their strategy for coping is to defer their need for this type of intellectual gratification.

From a perspective of learning, this strategy seems unsatisfactory. To learn well, you need to find ways of becoming personally engaged with the task. The learners who defer their need for intellectual gratification also defer their obligation for intellectual engagement. This is the theme of Paper III.

From the perspective of the individual student, however, this continuous deferral of one's interests and intellectual 'impulses' must be frustrating and stressful, as is partly evident from some of the interview excerpts in the paper. Moreover, the students are not explicitly aware that this is what they do. They sense that something is amiss, but cannot put a definite finger on what it is.

Based on the interviews we posit that the main thing the students need to cope with is that they are not aware that physics-as-curriculum different from physics-as-research. They think that physics education in some ways reflect what it is physicists do. They are deeply secure in their interest for physics, they just cannot recognize what they are interested in, in a real sense, when they are engaged with their physics learning. And they do not know why. As is the subject of Paper One, students turn to framing this frustration in terms of themselves; in terms of their own laziness, wrong strategies, not being able to come up with interesting perspectives, feelings of helplessness and so forth.

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Deferred gratification: how students cope with university physics education

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Abstract

In this paper we explore strategies that students employ in order to cope with studying university physics. We base the analysis on a dataset consisting of longitudinal individual interviews with 26 new physics students. The students were interviewed before they started, and on an on-going basis for a year afterwards. The purpose was to capture the continuous negotiation of expectations as these expectations meet reality. Specifically we employ a perspective on coping as the outcome of dynamic interactions through time. We find that some students struggle to cope, and others thrive. We explain the difference between the two groups as two characteristically different ways of perceiving and dealing with physics-as-curriculum and physics-as-research – both of which are legitimate but inherently imbedded in physics-culture. Our interpretation of the interviewed students' strategies is that many cope by deferring their immediate needs for intellectual gratification.

Introduction

This paper is about staying in physics. Seymour and Hewitt (1997) did an impressive study of attrition and retention in science, engineering and mathematics. They interviewed nearly 500 students who had declared their intention to major in one of these disciplines from an array of both private and public institutions of higher education in the USA. At the time of the interviews, approximately half of the students had opted out or changed major, while the other half were still in the progress of finishing their degrees. Interestingly, the authors could not make a clear distinction between those students who leave, and those who stay. All students experience similar problems, but react differently. The authors hypothesise that in order to stay in science, mathematics or engineering, students need to adopt coping strategies befitting their individual needs for coping with "the structure of the educational experience and the culture of the discipline" (ibid, p. 392).

Bean and Eaton (2000) characterize coping as the conscientious adaptation of one's behaviour to the environment. They argue that to better understand retention it is necessary to focus on the psychology of the individual, rather than on sociological circumstances. When Yorke and Longden do as suggested and construct a model for inquiring into reasons for attrition "that bear, via the student's psychological state, on retention and success" (2004, p. 84) they find that students leave either because they made the wrong choice or because they experienced difficulties in their learning (2008). In the United Kingdom 'wrong choice' is marked the most prominent of reasons for leaving (Davies & Elias, 2003). Yorke and Longden (2008) suggest that the considerable economic burden that this sort of attrition causes, can be eased by making sure that credits are transferable to greater extent than now, and by prioritizing better pre-entrance guidance. But such an interpretative perspective on attrition and retention completely disregards Seymour and Hewitt's important find: students who stay are no different from students who leave. No, what Seymour and Hewitt tell us is that the problems students experience, pertain to the institutional setting, and not to students individually as either predetermined or disassociated from the institution.

Thus it seems that if we want to actively engage with the issue of retention – if we want to change the landscape of attrition rather than just remedy the effects – we need to take a look at what students experience while they are still at it. Seymour and Hewitt suggest that we need to take a look at how students react to 'the structure of the educational setting' and how they interact with 'the culture of the discipline'. Once we begin to do so, and begin to understand our students in interaction with our educational programmes, it will also be possible to start a conversation on reasonable ways to remedy the problems we discover.

Currently, aside from studies of gender and science, few have followed up on this suggestion. In a review of 40 years of research into higher education, Haggis ends with a call for "attempts to document different types of dynamic interaction and process through time in relation to 'learning' situations in higher education" (Haggis, 2009, p. 389). Partly in response to this call, and partly in response to concerns like those outlined by Seymour and Hewitt, this paper presents a longitudinal interview study of student retention in the physics programme at the University of Copenhagen in Denmark. We focus on coping strategies, but not as strategies for 'conscientious adaptation to the environment' as Bean and Eaton (2000) suggest. Instead we follow Haggis' thread, and seek to understand coping as an 'outcome of dynamic interaction through time.' Thus, in this paper, we identify what it is that students need to cope with particular to the structure and culture of this physics programme. Then we describe how they cope.

Studying physics in Copenhagen

In this section we characterise the physics programme. We start by a general description of the programme structure –an outside look at the 'structure of the educational experience.' Afterwards we offer a look into the 'culture of the educational discipline'. The overall aim of this section is to lay out the contextual foundation that the analysis in the Results section relies on.

The structure of the educational experience

The setting of this paper is the physics programme at the University of Copenhagen. Students enrol by specifically applying for this programme. Nominally they are awarded a BSc degree after three years and an MSc two years later. Beginning already after the first half year students gradually specialize by combining physics with mathematics, astronomy, geophysics, meteorology or biophysics.

The physics content of the programme, interlaced with mathematics, is sequenced in the traditional sense. The students begin with classical mechanics and are gradually introduced to the modern physics disciplines. All courses at the introductory levels are taught in lectures followed by recitations and occasional laboratory exercises. Most young faculty members participate in a pedagogical professional development programme while many of the senior faculty are involved with improving the quality of teaching and learning. Consequently most courses have undergone research based reform or attempted reform (cf. Ditlevsen, 2011, Splittorff, Flensberg, Døssing, & Kjærgaard, 2011).

During their first year, students are required to choose from an array of authentic pre-designed physics experiments provided by researchers at the university. These problems are thought of as a chance for the students to do independent but supervised experiments in a real physics research-environment. For the researchers it is a chance to test ideas for teaching on small groups of students (cf. Henningsen, 2011).

All things considered, the structure of the educational experience can be characterized as traditional, but in a contemporary sense.

The culture of the educational discipline

The culture of the physics-discipline particular to the programme in Copenhagen was characterized by Hasse (2002a, b), a Danish anthropologist who enrolled in the programme to study the gendered enculturation of students first hand. She noted how everything, from student chatter and lecturers' emphasis to programme structure and descriptions, points towards research – that the spirit of research, the admiration of the elitist, the prestigious and the godly, is a driving force of the culture inherent to the institution – and like Traweek (1988) who compared physics cultures in Japan and USA, wondered at the preoccupation by both students and teachers with the individual achievements of prominent historical physicists. Hasse (2002b) cites Traweek for explaining that this cultural character of the physics society is one that ensures that physics is a discipline that transgresses national borders – "a culture of no culture" (Traweek, 1988, p. 162).

But if we compare physics education in Copenhagen with physics in Uppsala for instance, it is noticeable how traditions differ. At the Niels Bohr Institute students come to prefer theoretical physics over experimental physics (Hasse, 1998). At the Ångström Laboratory that houses the Uppsala University's physics programme, research practice is traditionally centred on the experiment, why laboratory teaching is thought of as very important (Danielsson, 2011b). It is probably no coincidence. Niels Bohr's institute was always an institute of theoretical physics. Ångström on the other hand was a painstakingly precise experimentalist like several other famous Uppsala naturalists, and a certain spirit of accuracy still presides the halls of this large laboratory building.

So of course, we gain invaluable insight into the culture of the physics programme by observing the daily goings of the laboratory student life. In a recent issue of this journal Danielsson (2011a) identifies two distinct physics masculinities (i.e. cultural expressions that are associated with the masculine) from her interviews with students about laboratory work. One masculinity is inclined towards experimentation – ‘tinkering’, playing with the equipment and the unrestricted exploration of the practical; and the other is focused on the analytical aspects of the laboratory exercise – on reading instructions, analysing data, reasoning and finishing the report to document understanding.

Some physics students explore in a playful manner, while others do it in a more inexorably meticulous fashion. Both are needed, and both are legitimate. From laboratory instructions and end-of-chapter exercises and so on, studious behaviour is required; but according to some faculty members, playfulness is “rewarded for being creative and showing initiative” (Hasse 2002a, p. 260).

Danielsson (2011) characterises the successful ‘analytical student’ as one who recognizes the contribution of ‘the practical student’. For some of the women Hasse interacted with during her fieldwork, a coping strategy was to *not care* when they did not understand the behaviour of their male counterparts, and instead just assume that it was a just another game girls were not included in. But as Hasse and colleagues in later studies (Hasse, Sinding, & Trentemøller, 2008) follow the careers of Copenhagen physicists, they find this playfulness that was also characteristic of the male first-year students now mixed with a ferocious competitiveness. Together play and competition are aspects of the “insatiable *professional* curiosity” or intrinsic interest characteristic of the ideal professional physicist (p. 65, italics added). Seymour and Hewitt (1997) suggest that for students too, intrinsic interest might be an all-important condition for coping overall.

Interviewing in Copenhagen

It seems that the object of the students’ interest, whether it be the experimental practice of physics or the analysis of physical phenomena, is an important aspect of coping. Especially when we want to characterize what it is, students need to cope with.

We deal with the issue of interest as a psychological concept in the next section. But first we describe how the empirical data were obtained, and at the end of the section, how data was analysed.

Interview design

For this study we interviewed 26 physics students several times in a not too distant past. First, 15 students were interviewed before they had begun studying. The remaining 11 students were interviewed during their first month in the programme. The intention was to interview as many students as possible before they had a chance to meet and start sharing ideas and aspirations regarding their choice of studies.

The 26 students were selected so as to be proportionately representative of the whole cohort that started this year. Criteria were those that were known: Sex, secondary education grade average, type of secondary education. The final selection was based on a preliminary questionnaire in which all new students had been asked to characterize how they expected to be and become as physics students. Students who described themselves eloquently and reflectively were contacted first. All in all you might characterize this selection a proportionate-stratified-purposive sample (see Robson, 2002, pp. 262-5).

The first 15 students were then interviewed periodically during the course of their first year in the programme in intervals spanning from monthly to quarterly. The remaining 11 students were interviewed twice: Once at the beginning of the year, and once at the end of the year. In total the data comprises of approximately one hundred hour long individual interviews. The three students in the sample who left the programme during their first year are not included in this study.

Interest as a topic for conversation

Although Seymour and Hewitt (1997) conclude that students who stay are not different from those who leave, they did note that students who stayed with their major often cited intrinsic interests as a reason for choosing this major. Naturally interest would be a good place to start, when interviewing students about studying in physics - not least because we all relate to interest instinctively (Labouvie-Vief & González, 2004). But as a psychological concept it is a little bit tricky.

When psychology was still primarily an experimental science, interest was tugged away, together with other affective variables such as motivation and volition, and regarded at most as disruptive variables (Boekaerts & Boscolo, 2002). But taking a closer look at people of different trades and occupations it seemed as if their interests were relatively stable over time; as if a person's interests become better and better established as he goes through life (Strong, 1951). So interest is not necessarily just a coincidental, disruptive state of mind. In Strong's study, interest is conceptualized as a sum of activities. The author notes that interest is not at all a stable personal characteristic until the person chooses his occupation. Of course, this study was performed in a time when people did not readily change their occupation and still habitually inherited it from their parents. Even so, it introduces an interesting link between interest and activity or situations, why it proves useful to distinguish between personal and situational interest.

We can think of personal interest as a personal orientation, something that has stable relevance for our sense of self, a product of our cognitive make-up if you will (Krapp, 2002). As the sentiment goes it is in situations that we realize and further develop our cognitive make-up. At school we are placed in situations that are specially designed to accommodate such realizations – potentially causing affective reactions that help stabilize situational interest to a degree that ensures a shift "to a more or less enduring individual interest" (ibid, p.399).

What is tricky about this way of constructing the psychological mechanics of interest is that interest invariably ends up in an interrelated feed-back loop together with activity and cognitive development. But both cognitive development and activity each call for an array of different psychological constructs such as volition, motivation, ability, engagement etc. (Dai & Sternberg, 2004). Quite soon they are no longer notions related to interest, but aspects *of* interest (Troelsen, 2006). When you try to pull it all apart analytically to see which came first, for instance when scrutinizing interviews with people who talk about their interest for physics, you invariably end up realizing that they are all "closely interrelated and seem to be almost mutually interdepend" (Rødseth & Bungum, 2010, p. 12 own translation). And as it turns out, we, in conversation, have a rather convenient manner of remembering what we are interested in depending on what situations and choices we face (Holmegaard, Ulriksen, & Madsen, 2011).

'Trickiness' is no reason to give up concerning interest, however. It is just a good reason to be a bit careful in characterising its psychological make-up. When the new physics students were interviewed the first time for this study, they were asked: "What is it about physics that you find so interesting that you want to study it for many years ahead?" Their answers can be summarized and understood in terms of situational and personal interest. Sometimes students were talking about situations that they found interesting, and sometimes they talk about what they, themselves find interesting. It is this distinction of interest that formed the basis for the analysis of interviews.

At the end of each initial interview, the interviewer and the interview participant discussed 'a way forward' in the interview sequence. Together they constructed a number of themes that were contextually rooted in each student's characterization of his or her interest in physics. Remember, the first interview was performed before the students actually started studying physics, why the conversation naturally had an underlying theme of expectation. Such a theme could be: "What situations confirm your sentiment that learning is about *figuring out*, rather than *being told*?"

The individual themes were used as an interview protocol during the consecutive interviews. But as a general agreement between interviewer and student, the student was asked to choose the one theme they felt was especially relevant at each interview.

During the final interview all students were once again posed a slightly modified version of the initial question: "Thinking back on this last year; what is it about physics that you find interesting and make you want to continue studying it?" The themes from the initial interviews were also revisited.

Analytical method

It was no surprise to discover that all students are at some point struggling with something and coping with it in the various ways that seems suitable at the time. This is in good accordance with the outset that is sketched in the introductory sections of this paper. Some students had already devised strategies for coping even before they had started their studies in physics. Other students had radically changing perceptions of their educational experience from one interview to the next. Many students contradicted themselves in explaining connections between reasons and experiences several times during their first year in the programme.

One marked difference stood out at the end of the year though. Approximately half of the students in the study seemed to flourish. They went from being somewhat insecure of their prospects and reasons for studying physics to sitting upright telling how everything was going according to plan. The other half went through a surprisingly similar, but completely reversed transition. They started out explaining about their passion for physics with sparkling eyes and waving arms, to being hunched down, disillusioned. One half seemed to cope just fine, while the other half was struggling to cope. It seemed like one group was key to understanding the other group.

Thus, we focus on the longitudinal nature of each student's experiences individually as it relates to other students' individual experiences. For this, a thematic analysis (cf. Braun & Clarke, 2006) seemed enduring. "Thematic analysis is a method for identifying, analysing and reporting patterns (themes) within the data" (p. 79), through a six step process (p. 87) that is largely iterative: 1. Familiarization with data. 2. Initial codes generation. 3. Thematic searching. 4. Thematic reviewing. 5. Definition and naming of themes. 6. Reporting.

Mainly, our intention in designing this inquiry as a longitudinal interview study was to be able to explore relations between expectation and experience. Especially with this focus, aspects related to interest and coping will be of importance. That is why primary attention during analysis was paid to passages or themes emerging in the interviews that revolved around 'personal interest', 'situational interest', 'coping', 'frustration' and 'thriving'. Other themes were also explored as they emerged thematically or specifically in conversation. At a later stage when it became clear that Danielsson's (2011a) description of the 'Practical Student Discourse' and 'Analytical Student Discourse' could be brought to bear on the interpretation of interest, these were introduced as central themes in the thematic analysis. To assist in the analysis, ATLAS.ti, a computer-software designed for qualitative analysis, was used. Given the large amount of data that is included in this inquiry, the 'raw' audio-recordings were coded, and only the coded passages were transcribed verbatim.

Results

In this section we lay claim to some general tendencies that are evident across the entire data-set, which we in turn present as evidence of a general insight into the structure of the educational experience of the physics programme at the University of Copenhagen. Generalization is a much debated aspect of the outcome of qualitative research; but a consensus seems to exist in the field that, although problematic, generalizations are necessary and attain credibility through rich or thick descriptions (cf. Falk & Guenther, 2006). A method to ensure richness is not only to describe in detail the context, content and outcome of analysis, but to deliver and confront multiple perspectives evident in the data in ways that also allows for transparency regarding the authors' construction of analysis (Denzin & Lincoln, 2005; Kincheloe & McLaren, 2005).

Thus an argument is built on tales of five students. Each tale carries with it aspects that also carry across the entire data-set. To ensure richness and rigidity, attention is given to each story. To begin the analysis we tell about Conrad, because he stands out in ways that nicely contrast and at the same time bring together the other tales. The mode of analysis in this first sub-section is extra rich, in order to allow the reader a detailed feel for the way we analyse, and serves to contextualize or 'set the scene' for the rest of the results-section. In the subsequent sub-section, in order to bring forward a disagreement that exists between interest and expectations, we characterise two kinds of students according to the ways they are interested in physics. To characterize this disagreement and identify what it is the students' in the programme need to cope with, we then utilize the concept of Didactical Transposition. Finally we describe the strategies students use to cope. All students' names are made up.

Solitary passion

At the beginning of the first interview all students were asked to account for their interest in physics. Most often a kind of standard-explanation was utilized by the participant that revolves around a need to "understand nature and everything." Thorough discussion, however, often revealed a more complex story that both involved situational and personal aspects of interest in various forms. Conrad was different. Right away he distanced himself from what we might only infer, is his take on this standard-explanation:

I:	What is it about physics that interests you?
Conrad:	Well, it was actually a kind of side-track. Of course it has something to do with physics, but it hasn't anything to do with schools or anything else. When I grew up, I was always a little fascinated by the weather. The wind. Why it blows. How it moves around corners.

> It's always really fascinated me. […] I am sure this fascination of physics isn't something that comes from going to school. […] It didn't happen until later, when I started thinking about things. For a number of years actually. When I worked outside as a postman and was outside feeling the wind and the weather. Then I started forming this idea, that yes maybe, this was actually where my interest really lays.

Much of this interview is about how Conrad envisions that studying physics in combination with meteorology might allow him to realize his need to understand the weather. He has already characterised his interest for physics as distant from the situational experience of school physics. He openly lays out all his weaknesses: He is not a quick thinker, but maybe a thorough thinker. He does not cope well with stress, but when things slow down too much he gets lazy. He has two strategies for dealing with his weaknesses: One involves thinking of the mandatory courses as tools for getting at an understanding for the complexities of weather. The other is to make sure to get involved socially and ask for help, even before he really needs it.

Conrad quickly formed a stable study-collective with two other students, Gustav and Bertil, who also happens to be participants in this study. They both have strong personalities, and Conrad describes his role in the group as that third leg that holds the whole thing together. Gustav is good at programming and Bertil is good at the theoretical parts. Conrad is good company and good at setting up the equipment – and good at asking the right kind of questions that get the other two going. It seems like Conrad finds legitimacy among two very theoretically oriented students, by utilizing the exploring type of masculinity that Danielsson (2011) describes. But it also means that his particular interests will have to yield Gustav and Bertil's interests that are more obviously connected to the content of first year physics than is Conrad's down-to-earth interest for wind and weather.

During his first year Conrad fails some courses. The final interview explores what the reason might be, and invariably focus on what it means to be good in physics. Conrad tells that it is possible to pass examinations without really understand the subject. He is asked if this has consequence for his aspiration to become a meteorologist:

I: Does this mean that even if someone has difficulties with the standard physics courses, but not with the geophysics-courses, can think in good faith that he is good at physics?

Conrad: Of course. I'd say of course. It all comes down to finding a place where you belong.

I: Yeah… have you found such a place?

Conrad: Not yet.

We already know that Conrad has some weaknesses that he felt he would have to deal with. And he did. But failing all comes down to laziness he claims. In many a sense his explanatory framework is alike the 'no-problem Discourse model' that Case and Marshall (2008) reports on "in which students construct an upbeat portrayal of their experience of a course, despite experiencing crises induced by assessment events" (p.200). And Conrad does construct an upbeat portrayal of his experiences of the first year:

Conrad: There's just this connection. A connecting thread through everything. And I think it is completely-totally cool that you always have this sensation that we are reasonably close to finding this thread. That we have this idea that, just a little further, just a little. I think it is cool. I do.

But having also interviewed Gustav and Bertil, Conrad's sense of a connecting thread (which is probably more about the project of physics as a research discipline than about his failed courses in classical mechanics) is a familiar echo of how Gustav and Bertil describe their interest in physics. It is upbeat, but at the same time, also a sign that Conrad attempts at fitting in; an indication that in reality he feels alienated. Later in his final interview, the indication of feeling alienated is much more prominent:

Conrad: In some ways you need the enthusiasts to kind of look up to. An role model for what it is you want in the future, what you want, what you are looking for.

I: When you say 'you', is that you?

Conrad: It is me, but I mean in general. When I look around and when I know how I feel myself. […] There are never any people around that makes you go 'this person he has really got

> something going on!' […] I remember a student from my year who suddenly found such a project. And it was crazy! You could almost feel how he was burning with passion because he found such a role model and had an outlet for all this. […] I mean, in some sense, there is a need for such a driving force. People kind of fade away and it… it… yeah… I feel it myself. I am starting to look around for a role model because… well…

'Because as it is, there is no-one around to share my interest with' we sense. Conrad is different from the other students in his particular interest for wind and weather. To get through his physics studies he needed someone to study with. He found them, but to keep a legitimate place in the group he had to join the other members' explorations of their personal interests at the expense of his own. Conrad's story is an indication that some personal interests are shared among the students to larger degree's than the type of personal interest for physics that Conrad has. In the next section we will locate and characterise these other kind of interests.

Two kinds of students

To explore the type of personal interest that is common among the first year physics students, we take a look at Asta and Julia. In the beginning they appear very alike in their description of their interest. Julia's interest started suddenly in her early teens when she attended a popular science lecture: "It is like love, I can't explain it at all!" She is explicitly aware that the physical view of the world is not complete, and emphasizes that physics cannot explain it all. But it is especially the domains that physics cannot explain yet that have infatuated her so. She characterises this effect that physics has on her as plain old curiosity. Physics makes her curious about the world. It is not that she wants physics to be the means for her development as a knowing person in the world. It is simply that physics makes her want to know more.

Asta is the same that way: "I want to add some concepts to the idea of existence, to add some data. I want some particles that I can relate to. Basically I want to figure out how the universe was created. It's not that I want to find my place in the world. It's fundamentally a need to understand the other issues." This need is deeply and personally rooted in Asta. She expects she will go crazy if she is not soon engaged with the fundamental issues of the world.

A year later though, things look very different. Asta thinks that her interest has changed. “This thing about understanding the world is so romanticized.” Instead Asta finds herself faced with the fact that the courses in particle physics that she is so longing for, will not be offered until her fourth year in the programme. Presently she has to deal with standard physics courses where big-issues-physics “drowns in plug and chug and formalism.” Whenever the interview is turned to exploring how her interest has changed to accommodate these circumstances, she insists that she finds the standard physics courses both engaging and exciting – but the lecturers alienating. They act uninviting, unengaged: “These crap lecturers… might just be a little autistic and reserved.” Asta is trying to make sense of the conundrum she is experiencing. When they teach, why can’t these people who are supposed to be cutting-edge physicist relate just a little bit of their passion? The theme she keeps returning to, is that her feelings of alienation is caused by a personality issue among some of the faculty (a proposition that finds merit in Hasse and Trentemøller’s (2008) study of the ‘Hercules’ culture among professional physicists), but which, according to Asta only indirectly and probably unintentionally interfere with the quality of the education. “Things are slowly changing” Asta interjects, “but I guess it will take another twenty or thirty years before we get a more dynamic spirit going.”

Julia just shrugs it off: “I don’t go to lectures, partly because of laziness.” Instead she has engaged herself with the course literature. “I understand light!” she exclaims right after having studied the ninth chapter in the electrodynamics textbook. “Electro was a very self-contained course. You read these seven chapters, and then there was a conclusion. Like a story. You feel like you got it, you are done with it, and you got something out of it” she later explains. When Julia was still in school and did her homework, she had to put off doing the physics till last because she knew that once she started, she would not be able to stop until she had to go to sleep. During the last interview she talks a lot about how she is looking forward to the quantum mechanics course after summer. Because she has already started reading the book she is very specific about just what it is she is looking forward to.

At the apparent level of the first interviews, these two students appear very similar in their interests and reasons for choosing physics. A year later, their educational experiences clearly differ though. We can understand the source of this difference, by comparing the two students' stories.

In the beginning, Asta talks about a need to know, while Julia wants to know. Julia relates this 'want' to her situational experiences while she was still in school, and it is the same kind of 'want', her curiosity, that she still employs at the end of the first year. Contrary to this, Asta talks about a personal interest that she depends upon being able to fulfil. It is a need that has always resided in her, that was never satisfied, but which she expected would be when she started at university. A year later, when she describes her frustration it is always related to her situational experience.

Generally speaking one group of students thrives; one group of students needs to cope. The thriving group of students initially related their personal interest for physics to situational experiences, and they still do when they talk about studying in the physics programme. The other group of students, the group that struggles to cope, initially made a point of explaining how their interest in physics was different from their school-experiences of physics and now recount their situational experiences only to explain about their frustration in the programme.

Both ways of reacting to the programme might very well be legitimately imbedded in the culture characteristic of the institution, since both students who thrive and students who cope, do so by drawing on Discourses that others found to be aspects of different, but legitimate ways of approaching physics studies. The students who thrive explain how they do so, by emphasizing their joy of 'physics reasoning' which is an aspect of Danielsson's (2011a) characterization of the 'Practical Student Discourse'. The students who need to cope with the educational setting, do so at the expense of their need to wildly wonder *at* nature; a playful, creative mind-set that Hasse (2002a) identifies as a legitimate and condoned quality among physicist; which Danielsson (2011a) in turn relates to the 'Analytical Student Discourse'.

Physics-as-curriculum and physics-as-research

The students in this study who struggle to cope with the physics programme appear to be caught between an idea of what the educational experience of physics was supposed to be, and their actual experience. At the root of this struggle is the idea that studying physics is supposed to entail hard and rigorous work towards making their heartfelt initial interest into a professionalized academic interest. Instead they experience a rigorous continuation of the type of physics and content they knew from secondary level education.

To illustrate this disagreement between expectations and experience we turn to Brousseau's (2002) model of the didactical transposition.

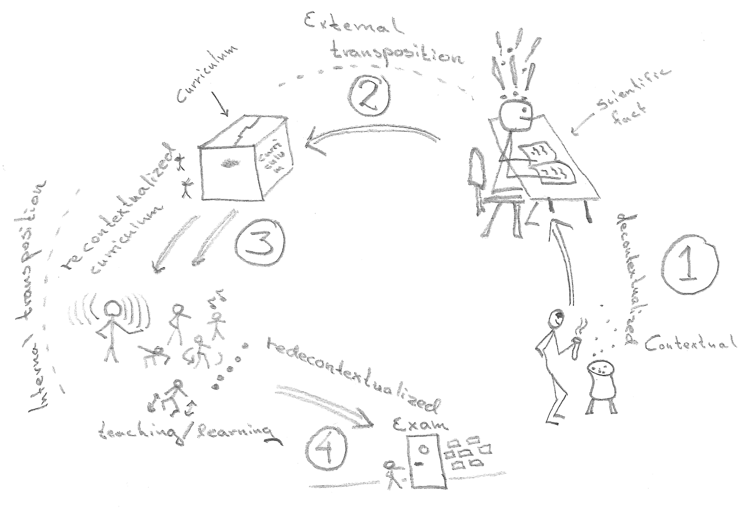

Figure 1: The first author's illustration of Brousseau's concept of the didactical transposition.

The "didactical transposition" assumes that knowledge taught in schools was at some point the solution to a problem that someone posed. Over time, this knowledge has been altered, adapted or transposed to fit the school curriculum at given levels. In the case of physics, we might think of the original production of such solutions as physics-as-research. The altered version used in schools we name physics-as-curriculum. Entailed by the transposition of physics-as-research into physics-as-curriculum is first, the decontextualization of scientific knowledge necessary in order to promote establishing the knowledge as scientific fact. This decontextualization is in essence the practice of reducing the mess that research often is, to a format that is presentable in international journals fit to be reproduced (or recontextualized) by other physicists in other laboratories. Second, once established, this decontextualized knowledge is introduced and adapted to the curriculum. This process is what Brousseau calls the external didactical transposition. Third, the curriculum is recontextualized as it is introduced to the learners. Fourth, teacher or students will need to do a redecontextualization of their situated experience for transfer purposes.

Of course, the above model is wildly simplified. The first and fourth step involved in the didactical transposition, regarding a (re)decontextualization for instance is debatable. For one, van Oers (1998) argues that the notion of removing context from the context is senseless when learning is thought of as situated. Naturally he has a point; but this point is easily remedied by thinking of the decontextualization as the act of idealizing context.

Much more important is it to realize that there is no reason to believe that learning about the physics-curriculum resembles practicing physics-research. Still, this seems to be the case for the students who need to cope. They expected a better match between physics-as-curriculum and their notion of physics-as-research. This misunderstanding lies at the heart of causes for their need to cope.

It is not an unreasonable misunderstanding. When students start studying physics, they are not physicists. When they graduate, they are. So somewhere in between, it is reasonable if students assume that they will be taught how to become one.

This misunderstanding can be found in educational research as well. For example when we conceptualize a research-community as a community of practice, and education as a negotiation of access to such a community (Ashwin, 2009). Students of science are not legitimate peripheral participants of science research (Bowen, 2005). A standard laboratory exercise does not allow students to act as if they are doing scientific inquiry (Johannsen & Jacobsen, 2010). A physicist does not study the content of his physics textbooks in a historically descending order if there is something about the Standard Model that troubles him. Learning physics is a completely different practice compared to practicing physics. Curiously, this is a thought that never struck any of the students who participated in this study. But it seems that such considerations might be the key they are looking for to ease their frustration:

Bertil:	How can you be so sure of yourself, that this [study physics] is what you want to? And you really want to. And then, when time comes and it is time to achieve, you can't make yourself read. You can't make yourself do the exercises. You simply can't pull yourself together.

> […] If I really want this, why don't I get my reading done, my work done, and so on?

If we think of Bertil as a student who started in the physics programme because he wanted to be involved in physics-as-research, we can now understand the source of his frustration. He is unaware that what he struggles to engage with is not physics-as-research. It is physics-as-curriculum.

Strategies for coping

Given the considerable amount of frustration that the students, who struggle to cope, deal with, the next step is to explain how they cope.

The students exhibit all modes of Merton's (1968) typology of individual adaptation:

- They *rebel*: "the lecturers have given me the motivation to exert myself to become a role model. Show that it is possible to be an ordinary sensible person and still study physics."
- They *retreat*: "I've started searching through TED.org to find interesting things. Things that can help motivate. Things I'd like to work towards."
- They *ritualize*: "I'm trying to change. Even the courses that don't make me go 'wow!' right from the start. I will need to make just as big an effort, right from the start."
- They *innovate*: "In the beginning of courses it is always reasonable simple, and you slow down. Then suddenly it gets difficult while you are still slow. So for next year, I wanted to sign up for five courses [i.e. three extra] to be sure to be up and running right from the start. But you couldn't do it. The website wouldn't allow it; unless you went through first the physics department, then computer science, and then mathematics to sign up for courses separately. That worked."
- But most of all, they *conform*; they defer their need for intellectual gratification: Asta is ready to wait until she has graduated; Conrad is waiting for a role model; Gustav attempts to short-cut the programme a few years by taking the intro-courses five at a time.

Interestingly, the strategy of deferred gratification is employed in every time scale as a fall-back strategy for coping that has near-universal applicability. If one course is perceived of as unfulfilling, the next is sure not to be. If the structure of undergraduate courses does not seem to support a desired mode of learning, graduate courses are sure to do. If the culture characteristic of the physics community is not agreeable at present, things are sure to change over time.

From the individual perspective, it is deeply unsatisfactory to be forced to defer ones need for intellectual gratification. But from the institutional point of view it is equally unsatisfactory to witness how students attempt to learn although they are unable to ascribe personal relevance to the content – a concern also raised by Ingerman, Booth and Linder (2007) regarding "the development of a 'physics learning object' as a programme goal" (p. 163). The students themselves do not have any alternatives to adaptation however. As Merton (1968) comments, regarding what happens when individuals of low power-status attempt at doing anything but adapt to structurally supported norms: "Typically, the individual goes, and the social structure remains." (p. 433).

Conclusion

This paper was about staying in physics. In comparing two kinds of students we find that those who thrive appear to do so because they were correct in expecting that university physics would be a continuation of school physics. The students who need to cope expected to meet a kind of physics that to greater extent resembles their notion of physics research, compared to their school-experience of physics. These students are not aware of this disagreement between expectation and experience. They sense a mismatch, get frustrated, but cannot place it. As an important and effective mechanism for coping with this untargeted frustration, the students turn to deferring their need for intellectual gratification.

We started by distancing ourselves from Bean and Eaton's (2000) notion that coping is 'the conscientious adaptation of behaviour to the environment.' Instead we followed the thread laid out by Haggis (2009) and perceived of coping as the 'outcome of dynamic interaction through time.' Curiously, we find that students cope by conscientiously adapting their behaviour to their educational experience. We do not, however, perceive it a reaffirmation of a psychological state. Instead our path led us to identify this behaviour as a structurally induced condition for studying physics. From the individual perspective the two sets of expectations are not unreasonable, but find merit in the discourse characteristic of the physics education culture. The faculty too, support the notion that physics-as-curriculum is gradually supposed to lead (at least some) students towards physics-as-research. By not making explicit to the students in a credible way how their learning is supposed to support their development towards becoming physicists, traditional physics teaching in the contemporary sense is the reason students need to cope.

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12. Paper III: Approaches to pro-active engagement

In Paper II, I and Camilla Østerberg Rump explore how students' involvement with their learning evolves as they gradually become accustomed to the setting of a 'stem-and-branch' structured physics programme.

Framed in terms of proactive engagement – i.e. learning with the purpose of being able to do something different, and differently – we find that as a consequence of certain students' strategies of deferring their need for intellectual gratification, they slowly adopt approaches to their learning, that resembles surface approaches; a strategy that is consistently reported in research to be unrelated to quality learning outcome.

It is especially worrisome to see, that in adopting these strategies some students seem to have found a way to reconcile their initial frustration with studying physics by reframing their initial expectations of what the purpose of studying physics is, and by setting aside or forgetting their initial disposition for proactive engagement.

The paper builds on a particular characterization of deep learning that had previously been identified among fourth year students in a problem-based learning setting in Sweden, and thus also serves the role as a comment on this study. Here, the authors very cautiously posits that the problem-based setting of their study, might be the reason that they find deep learning approaches relatively widespread among the students they interview. This paper confirms this position. Considering how effectively the setting of an educational programme can prevent students in engaging proactively, it seems extremely likely that if proactive engagement is found common among fourth year students in a problem-based setting, such a setting is likely to support proactive engagement.

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A longitudinal study of the evolution of approaches to proactive engagement in learning

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Abstract

This paper reports on how students' approaches to learning evolve as they study in a university programme structured according to a vertical, stem and branch, 'basics first' logic. The specific approaches that are studied here share characteristics with a set of learning approaches that are characterized according to what students' expect to be able to 'do' rather than what they expect to 'know'. An exploration of longitudinal interviews shows that students' perception of the primary task in a course is not to 'do' anything with their learning but show on examinations that they have learned to 'know'. Surface approaches prove necessary to comply with such requirements, even though students at the outset are disposed to engage in more proactive manners.

Keywords: Approaches to learning; proactive engagement; educational framing; longitudinal studies; physics

Introduction

In previous volumes of this journal Haggis (2006, 2009) put out a call for longitudinal studies of students' learning and engagement as it develops dynamically in interaction with the context and contents of their studies. In another volume Fyrenius, Wirell and Silén (2007) reports on an investigation of fourth year medical students' learning in a Problem Based Learning environment where they identify a set of deep and surface learning approaches that McCune and Entwistle (2011) have later associated with 'the disposition to understand in 21st century university education.' Fyrenius, Wirell and Silén end their paper by suggesting that their results are also investigated in relation to larger populations or different contexts.

In response, this paper uses Fyrenius, Wirell and Silén's (2007) characterisation of learning approaches as an interpretative lens to investigate how the particular structure and context of a traditional physics programme impacts the evolution of students' approaches to engagement with their learning. This particular structure is characterised in the next section.

The structure and logic of a traditional physics programme

Scholarly work in every scientific discipline can be characterised by sets of particular rationalities and strategies (i.e. ideologies) for making relations between established and new knowledge, many of which are echoed in the practices that are required of students in these disciplines (Bernstein, 2000).

When a physicist approach the bulk of knowledge that make up the science of physics, his rationalities and strategies are different from e.g. a historian's. The historian is astutely aware of the subjective nature of his empirical data. The physicist's job on the other hand, is to make sure to disallow any empirical find that might be based on subjective interpretation, to thus assure that his contribution to the bulk of physics knowledge is as intelligibly objective as the rest. It is of crucial importance to the quality of his work that he can make claim to having gained access to a measurable reality that in all essence can be reduced to a system of physical interactions free of human motives and behaviour. A system of physical interactions that can be described mathematically and ideally be reproduced by anyone, anytime, anywhere. Interestingly, this characterization implies that a lot of the work a physicist does in the laboratory involves shielding his experiment from the immediate reality of the laboratory. Thus, one of the first tasks a physics student is given in the laboratory is to confront his or her sources for error.

The appreciation of a reality that exists independently of human interaction is an ideological component that spans both physics research and –teaching (Traweek, 1988). Another component is the love for reducing complexity to simple mathematical formulation and modelled ideals (Cartwright, 1980), and to think of the bulk of physics knowledge as coherent, systematically principled and hierarchically organized (Bernstein, 2000, p. 160). The ideological components that are characteristic of the research discipline might, however, be more or less arbitrarily echoed in the teaching discipline: "Irrespective of whether there is an intrinsic logic to physics [as a research discipline], the rules for its transmission are social facts. And if they are social facts, there are principles of selection." (*ibid*, p. 34).

Among the ideological components of the physics discipline that is most immediately evident of the framing of a traditional physics programme (and many other higher education programmes) is the hierarchical structure of knowledge. Christiansen and Rump (2008, p. 545) has designated this curricular framing *stem and branch structure*: "At stem level students are introduced to a range of basic science subjects (typically math, physics and chemistry), and only encounter the scientific specialty of their choice (the branches) after a relatively long time – typically 1-2 years." This structure seems to be modelled on the notion of 'basics first' which carries a certain logical rationality, but also carries with it assumptions about both the nature of learning and about the discipline (research *or* education) that are somewhat problematic. Thus another component that needs consideration too, is the pedagogical component. For this paper this component is considered in terms of the impact that a stem and branch structured physics programme has on the evolution of students' approaches to learning as they 'move up' the stem during their first academic year.

Theory and application

This section is a sketch of the theory that frames and is applied to this investigation.

Approaches to learning

In 1976 Marton and Säljö published two papers that have come to revolutionize our understanding of how the outcome of learning links to engagement in learning (cf. Case, 2009). They randomly divided 40 students into two groups that were both asked to engage with three different texts. One group was asked questions that directed the students towards learning the intentional contents of the text. The other group was asked to memorize certain aspects of the text. Concluding the experiment the authors could link particular ways of engagement – what they call deep and surface respectively – to a particular outcome. Not only did they find that their efforts to direct students to engage in different ways led to different outcomes. They found that the set of students who were directed towards deep learning gained and retained a qualitatively better outcome than did the group of students who had been asked to memorize (Marton, 1976).

Decades of research into student engagement and outcome now allow a confident characterization of engagement for better learning: "By accounting for differences between different ways of experiencing a phenomenon in terms of the underlying complex of aspects in awareness [i.e. underlying layers of experience less easily accessible to reflection,] some *learn* better than others […] – in certain situations, in relation to certain criteria" (Marton, 1997, pp. 209-10, emphasis in original)

Perkins (2008) agrees with this position. He distinguishes between knowledge possessed, knowledge performed and knowledge proactively deployed. The possessive and the performative types of knowledge, which in all essence are the types of knowledge that Marton and Säljö's (1976) students were asked to engage in acquiring, allow the knower to recount and apply knowledge to routine problems, and to apply knowledge to novel problems respectively. To deploy knowledge proactively, opportunistically, the knower needs to take his knowledge beyond understanding. He needs to "map it far and wide … within [and] outside settings of formal study" (p. 8), and feel intrinsically motivated in doing so. McCune and Entwistle (2011) calls this a disposition for 21st century understanding "fit for the requirements for coping in an age of supercomplexity" (p. 304) where not just problems and their solutions are open-ended, but where "ideas, perspectives, values, beliefs and interpretations" in themselves are always considered provisional and open to revision (Barnett, 2007, p. 36 & p. 99).

Environments for 21st century understanding

The only means to prepare students for the unknown (i.e. the future) are by means of what we already know. We thus need to engage students by ways of widening their range of possibilities of seeing the things we see, to see them differently (Bowden, 1998, p. 7). We need to make certain that students are offered at least the opportunity to approach the contents of their choice proactively, deeply, opportunistically.

In literature there is no hesitation in asserting that the context of teaching and learning has immense impact on students' approaches to their learning. Ramsden (2003, p. 80) for example, brings a list of aspects of teaching, learning and feedback that associates with surface and deep approaches to learning. Perkins (2008) continues the list by emphasizing the significance of self-directedness on the students' part viz passionate involvement with the subject on the teacher's, thinking fluidly within the subject (not just about), and notably, he also hints at a somewhat overlooked aspect of students' engagement in learning: The learner needs also to be invited to formulate some of the learning tasks' specifications – e.g. framing the studies and negotiating the rules and principles for contents selection and for learning and teaching designs.

Browsing Entwistle's (2009) comprehensive "expanded heuristic model identifying important influences on student learning," this point is made more evident. The model reflects the contemporary state of research into learning in that it 'now justifies a separation of teaching from the rest of the teaching-learning environment' in terms of *"*the *inner logic of the subject and its pedagogy* that binds together content and teaching approaches" (pp. 115-6, emphasis in original). Bernstein (2000) on the other hand, argued that 'inner logic' does not exist, but that the structure of a subject and its pedagogy is the product of a set of social rules. These rules we have grounds for thinking of in terms of sets of somewhat arbitrarily developed habits that each serves a purpose not immediately pedagogic but most often economic or political in aim (cf. Snyder, 1973; Nespor, 1994; Barnett, 2007).

Still, aspects of the social rules that define any given subject or discipline most likely rest on the principled assumption that an 'inner logic' exists to which certain pedagogies are necessarily tied. To characterise or improve on 'important influences on student learning' it is thus necessary to explicitly question and challenge assumptions about how pedagogy and 'inner logic' is enacted through teaching.

This paper intends to do so by asking how students engage to learn physics and how and why they change their engagement in response to learning physics. For this, aspects of the notion of proactive engagement are used as a lens (presented in Table 1) to systematically analyse interviews on the subject. The next section presents this lens.

Synthesizing an analytical framework

Recently Fyrenius, Wirell and Silén (2007) characterised a set of deep learning approaches that McCune and Entwistle (2011) highlights as good examples of modes of engagement that can lead to performative and proactive knowledge respectively. The characterisation is based on interviews with 16 Swedish students who had been studying for four years in a medical programme that has applied problem-based learning activities to their educational activities for nearly three decades. The authors identify two distinct variations of a deep approach they call 'Building' and one distinct variation of a surface approach that they call 'Sifting'. Table 1 is a synthesis of their descriptions placed within a two dimensional outcome space that is inspired by, and to some extent corresponds to the two dimensions of the structure Marton, Watkins and Tang (1997) use to capture the variation in ways of experiencing learning. There is a temporal dimension and a depth dimension. The temporal dimension comprise of ‘acquiring’, ‘knowing’ and ‘making use of’. The depth dimension is comprised by variation in the experience of the temporal aspects of learning. Fyrenius, Wirell and Silén’s (2007) descriptions of learning approaches carries some resemblance to this two-dimensional structure, in that their characterisation also carries a temporal facet. This facet can be interpreted in terms of ‘the learning act’ or process, ‘intention’ or goal, and ‘expected outcome’ or relevance. Like Marton, Watkins and Tang (1997) they also categorize the approaches according to depth. In addition the authors offer a third parallel dimension that addresses how students experience the relationship between learning details and understanding wholes.

Table 1. Marton, Watkins and Tang’s (1997, p. 35) two-dimensional structure of ways of experiencing learning collated with a synthesis of Fyrenius, Wirell and Silén’s (2007) characterisations of approaches to understanding.

Ways of experiencing learning	Temporal facet		
	Acquiring	**Knowing**	**Making use of**
Committing words to memory	Memorising words	Remembering words	Reproducing words
Committing meaning to memory	Memorising meaning	Remembering meaning	Reproducing meaning
Understanding meaning	Gaining understanding of meaning	Having understanding of meaning	Being able to do something Something differently Something different
Understanding phenomenon	Gaining understanding of a phenomenon	Having understanding of a phenomenon	Relating
Approaches to reaching understanding	Temporal facet		
	Learning act (process)	**Intention (Goal)**	**Expected outcome (relevance)**
1: Sifting *Linear:* knowing details equates to understanding	‘Take in’ understanding from books and teachers. Copying and condensing	Verification	Those that the system demands

2: Building	Constructing knowledge through relations.	‘Owning’ understanding	Ownership
2a: Holding *Competing:* Details and wholes are studied separately.	Structured reorganization of information	Reaching a final goal. Sealing knowledge against threatening alternatives.	Control in the learning act. Ability to explain properly.
2b: Moving *Collaborating:* Details and wholes are studied simultaneously.	Strive for variation using multiple learning modalities and inquiry techniques.	Refining understanding in an open ended process.	Ability to apply knowledge in novel situations

Sample and procedure

A representative third of a cohort that started studying physics a few years ago was asked to participate in a one year longitudinal interview study. Fifteen students were interviewed individually before they started studying, and then periodically a couple of months interspersed during their first academic year. Another eleven students were interviewed individually once at the beginning of their studies and again at the end of the year. Since three students opted to leave the programme during their first year and because of scheduling difficulties with three other students, only 20 final interviews could be performed. The interviews were loosely structured on the subject of how expectations regarding purpose, content and learning activities are renegotiated in response to their interpretation of their experience of studying physics at the University of Copenhagen.

Table 2. Overview of time and number of interviews collated with an overview of the informants' required course activity. In total 26 individuals were interviewed.

Summer August	**Term 1** Sept-Nov	**Term 2** Nov-Jan	**Term 3** Jan-Apr	**Term 4** Apr-Jun	**Summer** Jun-Aug
15 interviews	21 interviews	13 interviews	15 interviews	9 interviews	20 interviews
	Course Plan				
	Introduction to Mechanics and Relativity	Classical Mechanics	Thermo-dynamics and Project	Electro-dynamics	
	Introduction to Mathematics	Linear Algebra	Mathematics for physicists	Cosmology, Climate physics, Biophysics, MathematicsF2	

This paper focuses on the aspects of these interviews that can be interpreted in terms of learning approaches. For this purpose Table 1 was used as a coding scheme to identify instances in the first interviews where students expressed corresponding learning approach preferences. Next these instances were examined to determine how the students connect these preferences to certain curriculum features and processes of interaction. This process was repeated for each of the consecutive interviews to thus map the evolution of these approaches to learning preferences as they evolved in parallel with their interpretations and renegotiations of their experience of studying physics. The result of this analysis is presented in the next section.

Results

Using Fyrenius, Wirell and Silén's (2007) characterization of learning approaches as a primary analytical lens, this paper investigates the evolution of learning approaches among first year students who study in a traditional five year physics programme. The first section offers an overview of the results, and the consecutive sections present aspects of these results through a more detailed and nuanced longitudinal analysis of student interviews.

Overview

Not surprisingly (cf. Lizzio, 2002) students' approaches to learning appear to be very much connected to their perception of the learning context. It is not surprising either (cf. Ramsden, 2003) that students in this study adapt their approaches to best meet what they perceive are the formal requirements. Nor is it surprising (cf. Trigwell, 1997) to see that the students' perceptions of their study environment and learning, and of the formal requirements are different at different times and in relation to different contexts.

Although students' perceptions of their study environment, learning approaches and perceived outcomes "form a pattern of reasonably complex interrelationships, rather than simple direct correlations" (Kember, 1996, p. 356) the longitudinal nature of the present study reveals a clear pattern across the dataset that can be accounted for in terms of features of the curriculum and of processes of interaction around the curriculum. This pattern is illustrated in Table 3.

Table 3. Estimated distribution of how students predominantly characterise their engagement with learning at the beginning and towards the end of their first year.

Predominant forms of engagement	**Early interviews**	**Later interviews**
Expressions of proactive engagement reminiscent of the 'Moving' approach.	~50% of informants	<25% of informants
Expressions of surface approaches but also engagement characterized by intrinsic motivation	~50% of the informants	>75% of informants

Students' who at the outset of their first year in physics report learning approaches that resemble Fyrenius, Wirell and Silén's (2007) characterization of the 'Moving' approach turn to a common type of surface approach in the natural sciences and engineering that was also described by Rump, Jakobsen and Clemmensen (1999). In this approach a quality learning outcome is associated with the successful reproducing of meaning and with problem solving competences. This approach shares characteristics with the 'Sifting' approach, but while medical students 'sift' to manage large amounts of declarative knowledge, students in the natural sciences and engineering solve problems to verify their 'understanding' of theory.

Students in this study who at the outset of their first year in physics report learning approaches that resemble the surface approach just mentioned, comfortably stays with this approach throughout the year they were interviewed. As also noted by Entwistle and Entwistle (1991), many of the students are aware that a deeper approach to learning might be more in line with what their teachers intends is the proper outcome of learning in the programme, but have to weigh this awareness against complying with their perception of actual formal requirements that do not test nor allow for a deep engagement with the course content. Additionally it is evident from the interviews that since only rare provisions are made in course content, programme structure or formal requirements to allow for opportunities to exercise any ability to apply ‘knowledge in novel situations,’ ‘to something different’ or ‘differently’ such attempts are practically futile.

To understand this, somewhat complex negotiation between expectations, perceived requirements, approaches to learning and perceived learning outcomes in relation to features of the curriculum it is necessary to leave behind Biggs (1993) conceptualization that deep and surface approaches are “founded in intrinsic interest in that *particular* task” (p. 7, emphasis in original) and guided by an intention that is “extrinsic to the real purpose of the task” (p. 6) respectively. Because, from interviews with the students it is evident that in proactive engagement the relationship is quite the reverse – depending on who defines ‘the real purpose of the task.’

A more nuanced account of these results is offered in the next two sections. Here the story that one of the students, Tania, tells is used to impose structure to an otherwise complex and messy analysis. As her story is laid out, it is related to other interviews and so shows tendencies that exist across the dataset.

The early interviews

This section focuses on the interviews that were performed just short of study-start. Thus, most of what students say about their intentions is rooted in expectations about what studying physics is like before they are exposed to the reality of university education.

Engagement with the field of study

Tania was among the 15 students who were interviewed just short of study start, and common among all of the students is that they have a rather manifest relationship to the field of physics. Tania tells that she “never believed in the biblical version of how the world is constituted." Instead she believes that physics offers an alternative and "true" version of what the world is like. A different student thinks of physics as a chance "to take close, systematic look at Gods creation." To most of the students, physics offers them a way of seeing, perceiving and understanding the world. In many a sense, the choice of studying physics is deeply and personally relevant to these students. As far as Biggs' (1993) conceptualization of deep learning as "founded in intrinsic interest" (p. 7) goes, students' characterization of their motivation for commencing studies in physics are promising.

To other students, 'intrinsic interest' in the subject matter is the mere beginning. For these students Perkins'(2008) characterisation of proactive engagement seems more fitting. For instance one student, Gustav, has a hard time pointing out precisely what makes physics special "because everything is connected!" To illustrate he explains that when he taught himself to write computer code "the most important outcome was what it taught me about human relations." To him, physics offers the same potential for opening up ways of seeing that he, as yet, cannot predict.

Bertil's perception, although strictly tied to the physics domain, is similar: "Physics is everything! But not truth incarnate as written by a Newton or an Einstein never up for revision. It is models, but damn good models that we presently think describe the world as precisely as no one ever did. And which will probably be revised in the future... Like, it is almost impossible to imagine that to the end of history we won't describe light better than 'well, it is wave, sometimes." – referring to the wave-particle duality. These are students who appear to be intrinsically motivated, not only by the task of learning itself, but by a potential extrinsic to the task itself.

Students who talk about their motives and engagement with physics in ways that are predominantly reminiscent of surface approaches tend to take a more distanced stance. Niels, for example, started studying because he was interested in astronomy, but that reason applies to his choice only. His intended engagement with physics is different: "My plan is to notice how I feel about the different subjects before I make my final choice. And if something makes my interest change then I'll follow it." He expects that the first half year "will just be a continuation of gymnasium" – the Danish secondary school – and does not realize that some of the course content, like the special theory of relativity, has the potential to speak to his interest for astronomy. What makes physics interesting to Niels is when you can "see it in reality," when you can recognize physical laws at play in your everyday life. This, however, appears to be more an outcome expectation than an actual characterization of how he intends to engage with his learning. When he talks about special relativity for instance, he does so, as if it is knowledge that is self-contained. “I want to have it thoroughly elaborated on so I understand it completely and know how to do it,” as if someone can explain to him, a story about special relativity that is whole and complete. “In the beginning they will be very describing because we kind of have to get started, and you need to have the background theory in place before we get to the point where the inspirational stuff comes.” In learning, Niels is very much on the receiving end of teaching, which is central to the ‘Sifting’ approach.

Modes of application

Tania shares many of her expectations about studying in the physics programme with Niels and other ‘Sifting-like’ students, but she plans her engagement in learning rather differently. She is also interested in astronomy, and is also very open to new interests emerging as she studies, but as soon as she mentions astronomy she also mentions special relativity as a subject that feeds into her interest. In characterising this interest she defines modes of engagement and consequent implications for her understanding: “I mean, generally it helps you to understand if you feel like it’s not just something written on a page. You need to experience it in several ways. You need to be able to see it, hear it and you probably need to be able to do it too.”

At an immediate level, Marton and Booth’s (1997) characterization of learning makes it reasonable to expect that Tania is among the students who will ‘*learn* better.’ An integral part of their characterization of learning, and of the ‘Moving’ approach however, is that the learner actively seeks the ‘ability to apply knowledge in novel situations.’ Emil is one such student. “As I feel, physics is an opportunity to utilize my mathematics for something tangible. And physics is an opportunity to utilize the astronomy. Maybe math points towards physics, and physics towards astronomy, but astronomy also points towards physics.” The formulation of ‘my mathematics’ is not coincidental. Emil aims at making the contents his own, to the extent he needs in relation to his aspiration of utilizing physics, astronomy and mathematics in certain ways – perfectly consistent with the characterisation of the ‘Building’ approach.

This is not Tania’s aim. When Tania speaks of the ability to relate knowledge to contexts outside of any one course-domain she characterises the purpose of this ability as extrinsic to the knowledge itself: to be able “to discuss your knowledge with people from other fields.”

To deal with those physics courses that do not interest her she explains that "no matter what, I want to do the best I can. It doesn't matter if I'm not interested in the task at all." "*I realize that the university is a lot like school, but don't you think there comes a time when you have to stop doing things just because you are told to?*" "And do them because you want to? Or because you need it for something? But that's what I'm hoping for. That we are allowed to choose later."

At the initial stages of her education Tania thus appears to have foreseen that she will make use of a 'Sifting' approach for when she is not interested in the subject – and so had several others. But as to take control of her learning, Tania admits that potentially circumstances might arise that will make her do so: "Alright! If I was asked to learn something that I knew I would never ever, in any way be able to use, and at the same time thought very, very, very not interesting, I guess I wouldn't do it." This is merely speculative however: "I expect that things where thought through. That there is a reason for doing what we'll do."

When Emil is confronted with the sentiment that not all courses might feed directly into his immediate interests, this is a situation that he has already considered: "When I first realized this I was a little like 'boo!' because now I had taken this huge step to start studying. But I think this is where physics becomes an instrument. Here at the beginning I'll need the physics-instruments before I can really get into astronomy… And it's okay. I can spend this first half year to figure out how things work here at the university." A strong indication that Emil takes on a lot of responsibility for making his learning meaningful – a contrast to Tania who expects that the structure and content of the programme *is* meaningful.

The later interviews

To illustrate the evolution of students' characterization of their engagement in learning as it relates to their experiences of learning in the physics programme aspects of the later interviews are presented to the extend they relate to the early interviews.

The read thread

Tania begins the fourth interview by talking about the issue of "perspectives in physics… mostly in relation to Linear Algebra. It is the kind of discipline that can be a little hard to see what is good for. Someone actually asked and the lecturer was a little like 'ehm, you'll see later.' And we've talked to a lot of older students who tell us that 'of course, you'll need it for quantum mechanics.' But no one ever tells us precisely what it is good for." She continues to explain what her trouble with this mathematics course is. She likes to "know that it is to be used for this and this, or that you can see the connections or the red thread. Otherwise it quickly becomes strange and mysterious and alienating and abstract."

In a study of Swedish physics learners Booth and Ingermann (2002, p. 497) explain that the 'read thread' is a Scandinavian term "for the logical structure that is either planned or apparent. It is a very common term among students, who demand them, and teachers, who try to make them apparent both in individual courses and in programmes of courses." This search for 'the read thread' the authors associate with an adherence to authority and thus with surface approaches since the learner acts as if 'the read thread' exists to be found independent of the learner himself. A student who is proactively engaged in learning would most likely work to establish his or her own 'red thread.' But as Tania comments, the absence of 'a read thread' and the lecturers response to students who attempt at creating one is alienating. This find nicely complements Mann's (2001, p. 7) suggestion that surface approaches are expressions of "an alienation from the subject and process of study itself" and Case's (2008, p. 330) investigation which yields that alienation often ensues from "attempts to succeed in often disempowering assessments systems".

An acute example of the alienation that ensues from attempting to create meaning beyond what the assessment system requires and encourages, is Bertil's attempts at proactive engagement. In several interviews he complains that he can find no time to engage the way he needs. He so wishes that he could occasionally follow up on a hunch or just disappear in a direction parallel to the direction that the course is taking instead of always doing precisely what he is required to do. In the third interview he needs to change because "maybe I am at the wrong. Maybe I just need to do these things every day. But it is *so* easy to hit this slippery slope where you just get the urge to try out something different." He did not manage to change however. At the final interview he explains that he failed the final examination in electrodynamics on purpose. He was dissatisfied with what superficial treatment of the contents he felt he had been allowed. "But I don't think we are supposed to. From their perspective, we are not supposed to use the re-examination to extend the time for studying. It is only for when you don't know it. If you fail, then you take the re-examination. I'm not sure they think you can use it just for immersion. But that's what I'm doing." With his decision to proactively create 'room' for engagement Bertil feels morally at odds with his teachers and the system they represent.

Bertil's reaction to the physics programme and his feelings of insufficient opportunity for deep engagement with the content can be interpreted as a reaction to the set of social rules that dictate how students should engage with the content. "The goal is that we just need to know certain things. Nothing more" he explains in the third interview. Clearly Bertil would have liked 'more'. He takes the premise of his education very seriously and incorporates the stem and branch structure of the programme as "a prerequisite for creativity and innovation in the discipline." Other students react by downplaying the gravity of the 'inner logic' of the programme and of their engagement. Tania remembers a situation in electrodynamics where they were asked to imagine a solid sphere, at the centre of which an electrical charge has been placed "and then someone asked 'how on earth can you get a charge inside a solid ball?' And we were just like 'hush! We just pretend we can'."

The real purpose of the task

Much of what physics is about is 'pretending' in ways of reducing complexity mathematically and of idealizing reality. It is about speculation, calculation, modelling and approximating (Hacking, 1983, pp. 210ff.). Maybe this could be 'the real purpose' of scientific practice and with good reason suggest that the real purpose of physics education is to practice this practice. Among the students however, significant confusion exists as to what the purpose *really* is, regarding the reduced complexity that is typical of the physics courses.

Like Niels, many students expect that the introductory courses provide a solid foundation or a set of instruments for later life in physics. What the teacher does is thus to reduce the complexity of reality to a level that students can comprehend.

Parallel to this perception of purpose is the notion that the laborious focus on theoretical details in courses, content and teaching is "because we need to know the true version of the explanation." Tania explains that when she was in Gymnasium and were taught about the magnet, they were told that it consisted of "tiny small magnets. Then you ask 'what does the tiny magnets consist of then?' And then it's like 'that is something you'll learn later'… and now we have." She sincerely feels that she knows the 'true' explanation, although the explanation is not complete. She can explain why magnets are magnetic but not why other substances are not. For this “we need quantum mechanics,” she explains.

The idea that the purpose of physics courses is to hand students the ‘true explanation’ to the extent they can handle it, is closely tied to the excessive attention to closed ended problem solving that is required of the students. In their minds, the purpose of problem solving is to ensure a theoretical understanding. Although students suspect that alternative relations between details and wholes may exist, that a search for a consistent ‘real purpose’ is not futile, such thoughts are invalidated by the structure and design of the courses. “I would imagine that if the purpose was to argue and analyse deeply, then the exam would be different,” Tania reflects. “At the exam all we do is just to sit and use it, and write ‘this is the result’.”

Discussion

The previous section stated that a group of students who start out by predominantly reporting an intended approach to studying that is reminiscent of the ‘Building’ approach slowly turn to an approach to learning that is focused at acquiring problem-solving ability but which is otherwise like the ‘Sifting approach.’ Students who utilize a surface approach are never challenged in ways that make it necessary for them to change their approach. Students who intend to engage proactively on the other hand, are. Examples from interviews across the dataset explain why: Only rare provisions are made in the programme structure, content, modes of teaching and formal requirements that allow for students to engage proactively – ‘outside the setting of formal study,’ ‘differently or on something different.’

Opportunities for deep engagement

Interestingly the physics course in Term 3 does make use of educational designs and technologies that break with an otherwise uniform programme structure. The course in Thermodynamics brings the experimental aspect of the discipline into the lecture hall to allow students a more integrated treatment of the content, while the ‘Project’ offers opportunities for the students to engage with open-ended problems of their own choice. The students, however, react to these opportunities in a surprising manner. A number of the students who seemed to be very much disposed for proactive engagement are severely disappointed and thoroughly frustrated by this experience. At the same time a student like Tania suddenly experiences that content and courses come together into a coherent whole to confirm her in her interest for astronomy.

A possible explanation for this phenomenon, still consistent with the overall pattern illustrated in Table 3, is that students who at the outset are especially disposed for proactive engagement live through a rather strenuous renegotiation of what they thought were right – as was illustrated by Bertil's case in the previous section. During their first courses such students sense how other modes than proactive engagement are more in line with the social rules that govern the programme. During the third term, however, they meet a course that encourages what was previously 'prohibited'. Their initial disappointment they had learned to deal with on their own terms, but the sudden inconsistency seems almost cruel. Naturally some frustration ensues.

Other students who did not experience the same tension between their aspirations and what opportunities the courses offered are not perturbed the same way, and thus react differently. Like an excursion into proactive engagement suddenly offered, they 'tag along' knowing that when the term is over, normality returns.

Concluding remarks

This paper explored the evolution of proactive engagement among students during their first year in a traditional stem and branch physics programme. Specifically the analysis focused on aspects of proactive engagement that resemble Fyrenius, Wirell and Silén's (2007) characterisation of a deep approach to learning they have termed 'Moving'. As such, the paper is in part a response to the authors' request that "the transferability to other educational settings" (p. 163) is explored further. In part it is a response to Haggis' (2006, 2009) call for studies that explore students' experience of learning in specific disciplinary contexts over time.

As an analytical construction Fyrenius, Wirell and Silén's (2007) characterisation of approaches to learning proved transferable and highly useful. As an actual approach to studying the first academic year in a stem and branch physics programme, it was clear how it is not. Proactive engagement, so characteristic of the 'Moving' approach, is in part a quest for coherent meaning and purpose across and beyond settings of formal study, but is also innately pointless in a systematically principled, hierarchically organized, insistently coherent educational setting like physics.

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