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Johannsen, Bjørn Friis; Rump, Camilla Østerberg

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Foundation or Intellectual Gratification?

Bjørn Friis Johannsen[1] and Camilla Østerberg Rump[2]

Department of Science Education, University of Copenhagen, Denmark
[1]bfjohannsen@ind.ku.dk
[2]cr@ind.ku.dk

Abstract: When a student decides to start in a particular field of study, a natural component of their subsequent learning involves a continuous negotiation and renegotiation of that decision. This paper reports findings from a comprehensive interview study of this continuous negotiation. Twenty six students were interviewed periodically during their first year in the physics programme at a traditional Danish research university. The interviews were primarily concerned with uncovering links between intrinsic interests, reflections on course work and their subjective idea of the general field of physics. A central theme that has emerged during the analysis of the interview data is that when students study a subject for the purpose of gaining a solid theoretical foundation, some of these students do not feel intellectually gratified by the activity. Instead, what gives the students intellectual gratification are those activities that they can connect to a subjective idea of the general field of physics – for instance linking laboratory work with physics activities at CERN. As learning activities become more complex and demanding for the students they struggle to connect their activities to these subjective general ideas of physics, and instead rely on an ability to defer their need for intellectual gratification. This requirement comes at a cost for their quality of learning.

Keywords: Attrition and retention, curriculum development, intellectual gratification.

1. Introduction

A central issue for educational development in Science, Technology, Engineering and Mathematics education (STEM) is attrition, because obviously improving retention-rates will have drastic effects on the quality of potential drop-outs' learning.

Currently, the most thorough inquiry into why undergraduates leave STEM convincingly concludes that the most prominent difference between students who stay and students who leave is their initial interest in science [1]. Students who stay are often *intrinsically* interested in the subject and conversely, students who leave, are often *extrinsically* interested [1]. However, it is still an area for research how studying affects students' motivation and vice versa. In social psychology and economics however, it is emphasized that extrinsically motivated incentives will undermine self-confidence or appreciation of the task [2].

A study of attrition at a research-intensive Swedish university concludes that two types of introvert discourses dominate students' explanations for prematurely leaving physics [3]. Either students explain their choice of leaving by crafting an argument

around not being 'good enough' or the argument ultimately rests on a perspective that 'things just happen the way they do' (e.g. you find a girlfriend in another city). Both discourse-models [cf. 4] are introvert. They do not concern causal references to the strictly external educational context – like curriculum structure and teaching method. Thus these types of interviews hardly provide suggestions for feasible solutions at the systemic level, i.e. for educational development.

To circumvent this issue of introspection we propose to perceive of attrition as complementary to retention. This means that we perceive of the students who stay as those special cases of leavers who did not leave. Likewise, as is often done in studies that attempt at not invoking 'blame-the-students theories of teaching' [cf. 5] we do not want to think of those who leave as different from the students who stay. Instead, we want to think of the choice of leaving *vís a vís* staying as results of different coping strategies – some obviously more successful than others.

This study is an inquiry into the successful coping strategies among first year students of physics, at the University of Copenhagen. In the Methodology section we describe our research design in detail.

4. Methodology

To gain insight into successful coping strategies we chose a longitudinal research design; since we are interested in capturing students' coping strategies as they develop and unfolds in response to the students' actual experiences. The data that is used for analysis here was obtained during one particular cohort's first year in a traditional three+two year university physics programme.

Central to our inquiry is the question of 'choosing physics'. That is, choosing to study physics and choosing to continue studying physics, since the ability to cope or change behaviour according to the contextual requirements is ultimately strongly connected to choice [cf. 6].

4.1 Sampling and Interviews

26 students participated in individual interviews performed by the first author. In total our dataset consists of approximately 100 interviews carried out during the course of one particular academic year.

Based on what information was available to us before the start of the academic year the students who participated in the study were purposefully selected so as to represent a logical sample of the entire student population that enrolled into the physics programme at the University of Copenhagen this particular year. Criteria used for evaluating our sample were gender, age and entry qualification (type of education and grade-point average). Before study-start all students who had been accepted into the physics programme were asked to fill out a semi-qualitative questionnaire about their self-perceived motivation for studying physics and self-expected strategies for learning physics. Once a student had been selected a viable candidate for interviews the student's answer to this questionnaire functioned as one last, but qualitative, sample-consistency check. The final criterion for a student participating in interviews was that the student was not vacating during the first

interview-round and that the student was willing to participate. To our pleasant surprise almost all students wanted to contribute.

Three different interview formats were employed; all semi-structured [cf. 7].

The first interview took place during the summer months before the students enrolled into the physics programme. This was deliberately planned to ensure that the conversation took place before the students had had a chance to meet, experience and be influenced by their new study-environment. Each conversation usually took 1½ hours and was focused on one question: "What is it about physics that make you want to study it full time for five years?" During the conversation the interviewer and participant co-constructed three different themes that on the one hand informed the answer to the interview-question and on the other hand needed to be further informed through experience. One example of such a set of individually relevant themes is i) *developing understanding and room for thought*, ii) *passion for the study of physics and the desire to learn more*, iii) *To be exceedingly busy*.

The second and subsequent interviews were each semi-structured around one of these themes. At each interview the participant was asked to choose one and sometimes did. In other situations it was more sensible to follow up on a previous interview.

The final interview was loosely structured around one question: "What is it about physics that makes you want to continue to study it?" Each conversation lasted between 1 and 2 hours.

For triangulation purposes [cf. 8] an additional and representatively identical set of 26 students were selected and not interviewed. Of the 26 students who were interviewed 15 were interviewed periodically over the course of the academic year. Given the setup and an interview style that closely resemble that described by Kvale [9] as *actively confronting interviews* all were interviewed in a fashion that were perceived by both interviewer and interviewee as critical and intense. The participants noted on several occasions that the interview space had a quality resembling that of a therapeutic space. Thus the remaining 11 students were only interviewed on two occasions: Once at the beginning of their first academic year, and once at the end. We have observed no difference between the two interview groups.

In the next section we will present our results and elaborate these with commented interview excerpts.

5. Results

Relatively early in the study it was clear to us that a majority of the students who participated in our interviews felt intellectual gratification by connecting their interest in physics to general conceptions of physics.

To give an example of this connection between interest in physics learning and the subjective idea of the general field of physics we bring a short excerpt from the initial

interview with a female student. The context of the conversation-bit is Big Bang in relation to other stories of creation:

> Asta (I): And that particular story is the one that happens to be scientifically accepted. The one that physics work is centred on. And it so happens, that this is the one that I've embraced.
>
> Bjørn: ... what do you think the physics programme will give you in relation to that story?
>
> Asta: ... first and foremost general insight into the workings of the world, the forces of nature, the universe and the world surrounding us. And more to the point, I am going to be engaged with those disciplines that are concerned with this issue. I mean cosmology, astrophysics, particle physics. And at the end, those'll hopefully allow for me to work with it. I would like to do research on it. One thing is that the learning process will give me this generalized insight into nature, another is that it will actually lead me onward towards being allowed to work with and get the sense that it is something that I am working with on my own. A sense that I am not just learning from others... or learning what others already know. I want a go at discovering something new too... or... a go at developing and addition to something we already knew.

Here it is evident that Asta expects of the content of her studies that it will point her towards a practice that involves discovery; and not just 'learning what others already know'. For Asta, the point of studying physics seems to be, not merely to know about the world, but to get the tools to begin discovering the world on her own. That is, learning is intellectually gratifying to her when it allows for her to connect to (what we choose to call here) a subjective idea of the general field of physics.

What is meant by a subjective idea of the general field physics we intentionally leave unspecified; however it is that general context towards which the teaching discipline lends its purpose. An appreciation of how teaching and learning is connected to the general field of physics gives a sense that learning physics serves a purpose that transcends passing the examination. It is often a subjective and personal purpose. The purpose could be that of gaining access to the research discipline, but it could also be gaining intimate and expert insight into a political construct that refer back to global warming.

We will argue in the following that as long as the task is seemingly simple, it is also easy for students to connect themselves to the wider world of physics (section 5.1). But as they progress through their first year and the content becomes more complex, we get a sense of a diminishing appreciation of how the curriculum content and related activities can be connected to a subjective idea of the general field of physics (section 5.2).

We observe that when complexity in the programme's curriculum content increases students struggle to convey the intrinsic value of their activities in a coherent manner during interviews (section 5.2.1) and thus struggle even harder to connect their experience to the general field of physics (section 5.2.2). As a resort they come to rely on being able to defer their need for intellectual gratification (section 5.3); a reliance that has implication for the quality of learning in relation to the content and curriculum structure.

In the following sub-sections we elaborate these observations, one by one.

5.1 Seemingly simple tasks

The first example is from a recorded conversation between the first author and two male students that took place during a physics lab. The students are working on a standard assignment involving the harmonic oscillator:

Bjørn: Why are you doing this experiment?
Bertil (lab): Of course, to test if what it says in the book is correct.
Conrad: It's also to get some practical insight into experimentation. It seems like these experiments are slowly preparing us for working on our own.
Bertil: And also, it wouldn't do if you arrive at the world's largest machine at CERN, and all you've done previously was read books.

It is interesting to note how they explain their intellectual outcome in terms of gaining familiarity with the physics equipment in ways that are necessary for later stages of their career. What is particularly interesting in this context is that it clearly shows how these students, when prompted, 'automatically' connect themselves and their learning-activity to their subjective idea of the physics field.

Underneath we return to Asta, this time during the second interview where we are reflecting on the purpose of the second physics course – still mechanics, but now a bit more complex since the subject concerns rotating bodies:

Asta (II): [...] it's like with physics 2. Things that turn and stuff. Basically it's shit boring, right? Like a cup that is turning like [Asta makes her empty coffee cup wobble across the table top], who cares, right? But then again... When the professor sorts out these connections between linear mechanics and rotational.. then you just sit there and *Wow!* it's fantastic! And you just have to be this special type of person to get this glint of passion in your eyes because of this kind of stuff right. But people here, we *are* just those kinds of people that are fascinated by stuff like that. Really, the turning cup, it's absolutely immaterial. But the *way* you can describe it, right... and feel that you... that you gain better insight into how reality functions, right. That's what satisfies me..

Asta wants to become a researcher. The content of the curriculum has become somewhat more advanced but examples used to illustrate a rigid rotating body are still simple. She does not connect the specific content and the example to her subjective idea of the general field of physics – since it is 'shit boring' and practically inconsequential. Instead Asta appears to find intellectual gratification in the shared sense of belonging to the general field of physics that is conveyed by the passion that accompanies the derivation of the relevant mathematical modelling. In the next section we will bring excerpts concerning physics when it becomes even more complex.

5.2 Tasks become complex

The next interview excerpt is from the initial interview with a male student. Here we explore his interest in physics across the physics disciplines.

Ditlev (I): It is the little things. Like, I bought a set of lamps for my bicycle that are powered by induction. I think that's extremely cool! Or that you are about to fall when the subway sets into motion. That's because of acceleration right. And that you are not following. You need to hold on to follow into motion.
Bjørn: Yes... how about the more advanced physics? Like quantum mechanics? I mean the harder branches of physics that are more difficult to observe in everyday life... like really understanding what light is?

Ditlev: Yes, but that's not something you think about every time you look at light. But sometimes you do, eh... I mean... if you look at the population as a whole, not many know about light. So in this manner it becomes attractive to... You know, learning about light, feels like being confided something that only few are granted. I mean, I don't know how relevant light is, but I think it's weird that you don't *want* to know what it is.

As with Asta, Ditlev finds it easy to connect his everyday world and interests to the more tangible physical representations, but when the physics is more advanced he invokes a sense of belonging, in this case, to a select few who want and are granted insight into what light is; knowledge that he perceives somewhat inconsequential in his everyday life.

A somewhat graver example is from the final interview with Bertil. He is the guy who saw the relevance of the harmonic oscillator in relation to his future plans of working at CERN. He tells:

Bertil(F): I let myself fail the thermodynamics exam. I thought it was among the most exciting subjects so far, and when I feel like that, then it's just a pity only scratching the surface. But I don't think it's supposed to be like that. From their perspective I don't think the re-exam is supposed to be used as an… opportunity for immersion. When I did it felt like I was giving up.

This time it is not an easy matter for Bertil to connect to the general field of physics. He is trying to, in the sense that he feels that he needs a deeper appreciation of the physics involved in the course. But this seems to be contrary to his experience of what is required by the outside authorities. It is tragic that when he decided *against* giving into these requirements and instead pursue a deeper understanding of physics, he 'felt like he was giving up'. This brings up the theme of thinking curriculum structure in terms of foundations: It involves a certain risk to students when faculty decide that it is necessary for students to master the basics before they can be let loose on 'the real stuff'. Bertil obviously has an intellectual need for also getting a sense of 'the real stuff', but he appears to know that this need is contrary to institutional expectations.

5.2.1 Struggle to convey the intrinsic value

In the previous interview excerpts there are examples of how students struggle to convey the intrinsic quality of their interest in physics. Above Ditlev admitted that sometimes he thought about what the physical nature of light might be, but from what he says it could appear as if the most attractive quality about physics knowledge is that only few people have it. Instead of thinking Ditlev as superficial it might be reasonable to think of his statement as an example of a student struggling to convey their appreciation of physical phenomena and physics learning.

Another example is once again from an interview with Asta. This time it is the third interview and she is talking about a somewhat advanced experimental project that she did at the end of her first half year as a physics student. The project was about the Mach Zehnder Interferometer:

Asta(III): I wouldn't say that I've learnt much during this project. Maybe I got a bit of insight into, ehh... the scientific process, that you've got a theory that you want to verify or something. And I guess I got some insight into how it really is to do inquiry. That it takes longer than you think even if it is relatively

> straightforward. Compared to this some of these real hardcore boys, they did stuff with non-newtonian fluids, like fluid dynamics that involved like mental hardcore mathematics. Now they are wicked at doing partial differential equation 'cause of that project. I didn't really learn anything of that sort. I mean, I didn't evolve physics-wise. Maybe at the experience-level of course I got something from it. But I didn't learn any cool mathematics… which I guess is kind of unfortunate.

It is noteworthy how Asta's interest in physics appears to have evolved. When she started she couldn't wait to start working with physics on her own. But now that she got a chance of sorts – a Mach Zehnder Interferometer experiment – her reflection on an outcome is somewhat diffuse. At the experiential level she admits that it gave her an outcome, but it did not give her anything to show for it like the 'hardcore boys' and their newfound partial integration skills. She has to settle with just knowing that experimentation takes a lot longer than you would expect. It seems like she has substituted her initial fascination by the way physics provide us with insight into nature, with a somewhat more instrumental fascination with people who can do advanced mathematical manipulations. We recognize the same pattern when she attempted at explaining her fascination of a mathematical model that describes a wobbling coffee cup.

5.2.2 Struggle to connect to an idea of the general field of physics

Like all other participants at the final interview, Asta is asked what it is about physics that makes her want to continue studying it. Right away she expands on her apparent shift towards being fascinated by advanced math instead of the explanatory power of physics:

> Asta (F): you know, its so easy to become so... lets call it fascinated by nature. Oh it's so fantastic to understand, right? But it's just that it contains so much complex mathematics, you know. Often, this sense of perfect purpose, it kind of disappears in mathematical manipulations and... formalism and that kind of stuff, right. And it, I don't know if I would call it disappointing... but I think that maybe there were a lot who, when they started studying, had a somewhat romanticised idea about it. Especially now when we had electrodynamics. Everybody just thinks Wow electrodynamics, right? And then it's just so, sooo heavy on the computational side. I don't know if I can say that I was disappointed, but it has definitely been different compared to what one had expected...

Obviously Asta is going through some turmoil identity-wise. At one point she is talking about her own feelings of disappointment and at the next she appears to be projecting her feelings onto other students' experiences and at the end she talks in third person as if she just cannot get herself to admit openly that she is disappointed. It is not easy realising that what you thought you knew, is apparently not so. It is hard for Asta to keep up her initial level of physics-passion; but still she acknowledges that what they are involved with during lectures is the real deal. But it just does not connect to the general field of physics as Asta originally had envisioned it.

5.3 Deferred intellectual gratification

Let us return once more to the final interview with Asta. Here she gives us a good explanation for her ability to cope with her disappointment to a degree where she almost does not need to explicitly admit to it:

> Asta(F): It is *evident* that you need to know that mathematics and have the mathematical foundation to be able to understand it at all. That's only logical. I mean, it's not weird or strange. But I think many became somewhat surprised at it. Or, I mean, that it meant *that much* mathematics compared to physics, right. And what can you say? This understanding, we won't get it until two years time, three years when we know all this compulsory stuff and so on. At least I hope it will. But this big revelation hasn't come to me yet. But of course, I'm only at the end of my first year…

So Asta has been waiting impatiently throughout her entire education to be admitted into the physics programme to become intimately acquainted with 'the workings of the world, the forces of nature, the universe and the world surrounding us'. She had to wait a year, so she can wait another. But she hopes that she does not have to defer her need for intellectual gratification more than two years more. Until then she will have to learn a lot of mathematics; and as we have seen, she is practicing her ability to like this too – maybe because a condition for belonging is the ability to think that 'hardcore mathematics' is actually hardcore.

6. Conclusion

Students identify with their subjective ideas about the general field of physics while activities are seemingly simple. But as they progress through their first year and the content appears to become more complex, the sense of an appreciation of the general field of physics diminishes. Some of the students we interviewed struggle to convey the intrinsic value of their activities in a coherent manner and thus struggle even harder to connect their experience to their subjective idea about the general field of physics. As a resort they come to rely on being able to defer their need for intellectual gratification; a reliance that has implications for the quality of learning. For instance we see that Bertil in section 5.2 is beginning to suspect that maybe a deep appreciation of the subject is not at all the purpose of physics learning. It appears as if a curriculum that is foundations-focused might impede students' opportunity for immediate intellectual and academic gratification. Thus it is worth considering whether a gratifications-focused curriculum comes at the cost of foundations – or if we are just in the habit of believing so?

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