DIDACTICAL CONTRACT AND CUSTOM: ANALYTICAL CONCEPTS TO FACILITATE SUCCESSFUL IMPLEMENTATION OF ALTERNATIVES TO STANDARD PHYSICS LABS

Bjørn Friis Johannsen[1] and Lærke Bang Jacobsen[2]

[1]University of Copenhagen, [2]Roskilde University

This paper is an inquiry into the practice of what we term 'standard physics laboratory work' in upper secondary school. We apply the concept of 'didactical contract' and 'custom' in analyzing the practice of three different Danish secondary education physics classes. The purpose is to characterise the set of 'common rules' that students necessarily infer from this practice and come to rely on in subsequent physics education laboratory settings that resemble those they have previously encountered – for instance when they start studying physics at university level and find the physics laboratory course-work resembling that of their upper secondary education. We argue that these common rules, i.e. the students' prior experience ex- and implicitly relevant to the activity, will have to be explicitly addressed if alternatives to the traditional type of physics laboratory activities are to be smoothly implemented.

INTRODUCTION

This paper sets out to investigate aspects of the praxis of 'standard physics laboratory work' in secondary education (labwork) that might impede the implementation of alternatives at later stages of education (alternative labwork). What we term labwork, is a notion closely related to Beney and Séré's (2002) description of the secondary education physics lab typical throughout Europe: "guidance through a labsheet, students working in pairs for three hours, apparatus available from the beginning of the session." (*ibid.* p. 66).

Our motivation for performing this investigation into labwork arose from having observed difficulties related to students' ability to accept the task when an alternative to the standard laboratory design was introduced at introductory level university physics. Subsequent analysis performed by the involved educators and researchers, concluded that students had difficulties understanding the ramifications of the task. It was suggested that one reason for this difficulty was that students infer a certain set of expectations from their upper secondary education about what labwork is supposed to be, that does not match the alternative labwork design. In this paper this 'set of expectations' is characterised – specifically by investigating the labwork at three different Danish secondary education school.

Before we continue with this characterisation of secondary education labwork, there will be an intermezzo in which we describe a bit further the specific incident concerning the implementation of an alternative labwork activity at university level. The reason is that this description offers a rationale and a motivation both for investigating the praxis of labwork in Danish secondary education and for our choice of theoretical framework.

Intermezzo: Clock-in-a-box

One year the group of first year students studying physics at the University of Copenhagen was at its very first encounter with the physics education laboratory asked to make a device for measuring time with the use of a selection of standard mechanics lab-equipment. The students could choose what they needed from a cardboard box, containing an assortment of springs, force meters, rulers, masses etc. The students were asked to construct a device that could measure out the passing of two minutes as precisely as possible. The designers had not planed to give further instructions, thus leaving the task as open as possible, allowing room for creativity.

As part of the design-phase, the designers of the task had invited a group of physicists who would also be part of the team of instructors, to try out the task themselves. Initially the instructors were somewhat hesitantly optimistic with regards to the purpose and outcome of such a task, but soon enough they were deeply engaged in applying to the task all sorts of physical theory and mechanical hypotheses. Reviewing their own engagement afterwards, the instructors concluded that apparently the task had stimulated them to engage with what they termed ‘real physics’ – in accordance with the intensions of the task-designers.

When the task was turned over to students for the first time, the instructors were surprised to see that a number of students did not engage in ‘real physics’ as they themselves had. Instead some students used their watches to count out how many times a spring would oscillate during a two minute interval, and suggested that counting in this manner was a viable solution to the problem. Puzzled the teachers realized that the students did not perceive this solution as cheating, but rather, as an indication that they had found an effective means of reaching the desired result – almost without applying any physics.

Naturally a posteriori analysis of the activity will yield a number of problems concerning this task. However, this is not the aim here. The activity serves as an example from which we will draw to the fore one conclusion made by the team of designers and instructors that transgress the immediate particulars of this task; namely that the reason the activity did not work as expected, was because, as they termed it at the time: ‘the didactical contract had not been properly negotiated’. We will return to the notion of the didactical contract in the Theory section, but briefly, what is meant is that the teachers had not made their intentions and expectations sufficiently clear to the students. Thus the students behaved in a fashion that was surprising to the instructors. One might argue that using a watch to construct another watch is a very reasonable way to solve the problem. Since the instructors had not realized this, and since they wanted the students to utilize their knowledge of classical mechanics, they perceived of this strategy as cheating – as breaking the rules. On the other hand the students had embarked on the task expecting that the intentions were different then they actually turned out to be. This in turn, might in all likelihood have come as a surprise to the students.

Since this activity was the very first physics-lab activity the students encountered at the university, one is left wondering how they could have expected anything of the task at all. A possible answer that we will explore further is that students carry with them their experience from previous activities resembling the present. The closest activity to the 'clock-in-a-box' activity is labwork in secondary education. Since no explicit effort had been made towards negotiating the rules specific to the 'clock-in-a-box' activity, we contend that the students believed that the rules that applied during secondary education labwork also applied at university level labwork. These rules, we will call 'common rules' for lack of a better term. This term will be further developed in the Theory section; but first a research question will be stated which is subsequently framed in the larger context of research on labwork and labwork reform in the Labwork Review section.

Research Question

The notion that a didactical contract serves to establish what common rules govern what is intended with a learning activity and consequently what type of engagement one can expect of students leads us to want to know what the students come to believe about physics laboratory work in general, by doing standard laboratory work in upper secondary school physics. This, because such insight would provide us with an indication of which of those beliefs specifically clash with the expectations implied in for instance our example of an alternative labwork setting.

Thus, we formulate two research questions: What aspects of standard labwork give rise to a set of 'common rules' that contribute to students' expectations of how labwork in physics should be approached? And how can this set of common rules be characterized?

Labwork Review

Activities in school laboratories have been part of the physics education at both upper secondary school and university for about a century. The role and purpose of labwork has been discussed for just as long. Historically, numerous shifts have occurred between two extremes concerning the role of labwork. Either labwork serves to help students gain conceptual knowledge of physics, or the activity is supposed to help attain procedural skills (Gott and Duggan, 1995). Both perspectives on the role of labwork can readily be criticised: Investigations dating back to the 1980s show a poor conceptual outcome from labwork (Hofstein and Lunetta, 1982). On the other side it would seem that gaining theoretical knowledge is easier and less time- and resource-consuming outside of the lab. Besides, one cannot help but wonder if procedural skills have much value outside the school laboratory. For a review of this type of critique see Hodson (1993). A comprehensive analysis towards gaining a full overview of the array of normative purposes of the school laboratory as described in literature concluded with an epitome categorisation consisting of four normative purposes: procedural skills, conceptual skills, epistemological insights, and personal/social skills see Jacobsen (2008).

Having seen two perspectives on the purpose of doing labwork, yet a third perspective remains: Doing labwork at school serves a goal in itself. According to this perspective, understanding the nature and role of labwork and becoming proficient with working in the physics lab will be the purpose of the activity. This in turn implies a requirement for students to appropriate experimental problem solving competencies. In such a case the four normative purposes change status from being *purposes* to become *means* for students to learn to become competent in solving experimental problems.

A large number of projects have set out to reform and improve laboratory activities. Often such change is aimed at including more authentic and open tasks, trying to make the students feel more like scientists than students in a school laboratory (cf. Roth, 1995, Trumper, 2002 and Karelina & Etkina, 2007). Often such alternatives are designed and implemented by engaged teachers and researchers who report that the results of these efforts are significantly improved learning outcomes and more motivated students. In the Intermezzo, on the other hand, we described an instance where engaged teachers and researchers tried to address students' aspiration towards becoming physicists by designing a task that from physicists' perspective appeared more authentic. Although the students were motivated, instructors perceived of some of the students' efforts to be far from satisfying.

We wish here to identify the underlying causes of this apparent collapse. Not by focusing the analysis on the alternative and on the individual participants, but by going 'behind the scene', looking into what general characteristics of the students' prior education, the common rules governing standard labwork, that can explain why expectations diverge when suddenly faced with an alternative. To do this, we need to utilize a theoretical lens through which we can perceive and analyse the common rules governing standard labwork.

THEORY

In this section we will give an account of our theoretical underpinning. The section is divided in three parts. The first 'Contract, Custom and Desiderata' is an explication of what we mean, when we in the previous section talk about 'common rules'. The second part 'Reprise' is a synthesising recapitulation of the first section. The third part combines the first two sections with a more practically oriented approach to characterizing the contract, costum and desiderata governing the physics education lab.

Contract, Custom & Desiderata

Previously, we argued that the reason that we saw efforts fail towards improving students' outcome of and experience with laboratory work is that students and teachers had not reached an agreement on the common rules that outline the teaching and learning activity. Thus far, we have not made explicit what we mean, when we talk about common rules. This is what we will do in this section.

It might be useful to start out this section by stating what distinction between teaching and learning we make use of here. One aspect of teaching is explaining or in other ways making clear to the students, in a broad sense, what activity is considered appropriate for them to engage in, in order to facilitate their acquisition of a given item of knowledge. Learning on the other hand, is the students' adaptation to or compliance with this situation, in bringing the target knowledge into play in ways that allows for each student to subjectively familiarise him- or herself with the knowledge-item, making the item of knowledge their own. This distinction was made by Brousseau (1997) who named this aspect of the act teaching, as described above, *devolution*. Devolution is to hand over a task for the students to engage with. An important aspect of devolution is to assure that the task will lead the students to 'discover' a piece of knowledge (on their own) which is "entirely justified by the internal logic of the situation" (*ibid* p. 30). This of course means that a central aspect of devolution is to justify the task, and possibly make explicit the internal logic of the learning situation. That is, make explicit in what ways the task relates to what has already been learned and in some situations, what will be learned. In the case where the student does not perceive the logic of the situation devolved, the teacher and student will have to return to the process of devolution. In other words, the teacher will have to try to explain better to the student what the task might be about, and what might be expected of the student.

It might seem trivial to some that student and teacher in the face of problems return to the process of devolution. Naturally a student will turn to the teacher for advice if he or she experiences having problems with the task. But for this to happen, either teacher or student will need to realize that a problem specific to the content exists. Indeed, this situation is an indication of the special relationship that exists between students and teachers that allows for specific teaching situations to be organised the way they are. It is not, however, the general pedagogical contract that governs schooling. Brousseau (1997) writes:

> [This relationship] determines – explicitly to some extent, but mainly implicitly – what each partner, the teacher and the student, will have the responsibility for managing and, in some way or other, be responsible to the other person for. This system of reciprocal obligation resembles a contract. What interests us here is the *didactical contract*, that is to say, the part of this contract which is specific to the "content" […]. (p. 31-32, italics in original)

Here Brousseau focuses on the distribution of responsibility between teacher and learner in relation to specific content. In their interaction, different roles are assigned. In a standard situation, the teacher delivers to the students what general content-specific information they need to solve a problem. Students in turn, will do their best to solve the problem, but the learners will also have to let the teacher know if any individual need for further information arises. Consequently the teacher is obliged to deliver this information by engaging with the students on a less general, more individual level. Accordingly the didactical contract is that system of reciprocal obligation, closely related to the content that enables the situation. In the Intermezzo we described a situation in which it appears that the situation had not been devolved sufficiently, thus, the didactical contract had not been properly negotiated (as the instructors and researchers also concluded).

As previously stated, the object of teaching must be clearly defined, but also, we argue, justified. This is done in the negotiation of the didactical contract. Essentially a didactical justification is to let students know the role of the items of knowledge involved in the situation. In one instance aspects of the activity in a learning situation might involve applying an already known item of knowledge on new domains and thereby permitting insight into this new domain. At another instance the rehearsal of the application of a knowledge-item is the purpose of the activity.

This means the didactical contract can be understood as the special set of social rules that on one side defines the didactical situations in which teaching and learning takes place, and on the other side constitutes the set of rules that enables this didactical situation.

Because of this specificity of the contract to the situation Brousseau (1997) goes on to explain that no detailed general description of the reciprocal obligations can be given. That is, you cannot explain how responsibility is distributed, unless you state what it is, agents share taking the responsible for. Instead, what Brousseau finds important, is the situations in which the didactical contract breaks – the situations where the distribution of responsibility is confused, when students do not turn to the teacher for further explanation, or when students progress differently with the task than intended. As previously stated this very much resembles our experience of the clock-in-a-box incident. Unfortunately this also introduces a paradox with regards to understanding and characterizing that which are the common rules of the standard labwork setting: Brousseau would hold that such general common rules cannot be explained by the concept of a didactical contract alone. The concept is defined as specific to the content and not the general activity, whereas we claim to have seen that the effects of the rules governing the general activity of standard labwork smother the efforts towards implementation of alternatives.

Balacheff (1999) appears to have solved this paradox of ours. Balacheff noticed in his research on 7th grade mathematics learning, that some rules governing the mathematical activity had a general legislative character of a deeper and more enduring order than can be expected of the rules set by a didactical contract (Balacheff 1999, p. 25). Because these rules were very much specific to the content, it does not suffice to dismiss the observed phenomenon as associated to the rules of a pedagogical or even social contract; both notions that otherwise do have this enduring quality noted by Balacheff.

Still restricted to *what is specific to content* Balacheff (1999) consequently introduces the notion of *custom*: Custom “regulates the social functioning of a given class across time”, while the didactical contract has “a local character and [is restricted to] being a key element in the process of devolution” (*ibid*, p. 26).

In a related research project we observed a specific instance during a mechanics lab at the University of Copenhagen, that can illustrate and add to our notion of contract and custom. The lab we observed was about Hooke’s law. The students were given a somewhat comprehensive set of instructions, in which the students were asked to begin by spending some time thinking about a set of specific problems inherent to the harmonic oscillator (i.e. a mathematical description of a mass connected to a spring). Such instructions constitute the didactical contract of this particular lab. Thus, all, including the teachers, and we, expected that the students would begin by engaging with these problems. However, one group of students skipped this first part, and engaged with the experimental measurements. When asked, the students explained that it was important for them to secure the required data, before engaging with interpreting it. They explained that they could always spend time at home understanding the activity, whereas getting good data, could only be done in the lab. Besides, they had been told that they were expected to engage with labwork in an individual manner, and they had decided that this way of prioritizing made sense to them. When the lab-session was over we confronted the instructor with the incident. He explained that he had noticed that this particular group had set aside the lab-instructions, but that he had not found it necessary to intervene. We infer from his statement that what happened was that the students made a decision to set aside the didactical contract – they did not breach it. Warrant for doing this was found in custom. Thus it appears that even though the didactical contract is explicitly stated, custom can at certain instances take precedence.

Still, we feel that a part is missing, before we can fully appreciate that which makes out the common rules that outline the teaching and learning situation. Namely the rules evoked in choosing the situation. Referring to Kuhn's (1983) account of how scientists make their choice between competing theories based on the scientist's professional perception of the desiderata (i.e. the 'goodness') of one theory compared to the other Christiansen *et al.* (2009) introduces the concept of shared desiderata in education:

> When engaging in teaching and learning activities, students are involved in types of […] activities that are characteristic of the scientific profession, and learn to make the same types of […] judgments in virtue of their education. […]. We […] retain Kuhn's basic insight, that […] while the theoretical perspective is crucial in normal scientific practice where the theory is 'taken for granted', the cultural perspective is crucial at times of theory choice. (p. 7-8)

What is argued for here is the view that the choice of teaching object or item of knowledge to be learned is very often 'taken for granted'. However, at instances where one needs to validate the choice of object, this choice is culturally validated vis-à-vis desiderata.

If we return to the previous example of two students in the lab who justified choosing data collection over spending time understanding the problem, this choice is a validation of what is important in the domain of possible activities during labwork (i.e. activities warranted by contract or custom and possibly pedagogical and social contracts). The students decided that obtaining data was more important than understanding the situation that allowed them to obtain data. Thus, this instance of domain validation tells us something about the shared desiderata in this particular physics lab; namely that obtaining data is valued over securing understanding; at least *in* the lab *performing* the experiment. Subsequent interviews revealed that the two students had engaged with understanding the problem subsequent to securing the data.

Reprise

We have now identified three dimensions that add to the common rules that outline a teaching and learning activity:

A: Reciprocal obligation.

B: Didactical justification.

C: Domain validation.

From Brousseau's notion of the didactical contract, extended to also encompass custom, a kind of implicitly standing contract, we identify A.: the reciprocal obligation of assigning responsibility between student and teacher. Also, as an important aspect of the negotiation of contract and custom is B: the didactical justification for the knowledge item at stake. Finally we use Christiansen *et al.'s* concept of shared desiderata in education as a means to domain validation: C.

In a general sense we conceptualize a separation of contract, custom and desiderata in terms of explicity. The contract is made up by the rules governing class (i.e. content engagement) that are explicitly stated (or explicitly *not* stated). The custom is that which does not need to be explicitly stated anymore. It is this, which goes without saying, because it has been said so often or clearly before. This concept we envision as the sum of the explicit didactical contracts that provide the implicit, but still content-specific rules that ensures that a teacher does not have to elaborately negotiate a didactical contract at the beginning of each lesson. Desiderata are the values (concerning content engagement) that emanates out of activity (although desiderata can be explicitly stated at some point).

A model for characterizing contract, costum and desiderata

As argued previously we interpret Balacheff's (1999) notion of custom as an analytical addition to Brousseau's (1997) notion of the didactical contract. Thus we split the didactical contract in to two parts:

1: The didactical contract as that which is explicitly stated.

2: The custom as that of the part of Brousseau's original perception of the contract which 'goes without saying', i.e. that of the contract that endures over time, present implicitly in the case of no explicit renegotiation.

This means that together with shared desiderata in education the custom is principally that set of 'common rules' this paper set out to characterise. It also means that to characterise the custom it is necessary to, not look at what is explicitly stated during a teaching activity, but to take a close look at the patterns of interaction that implicitly reveal the custom of the didactical situation. A model for doing this was developed by Hersant and Perrin-Glorian (2005). Although the model was developed with the intention of characterising mathematics teaching practice we find it applicable to characterising custom especially because of the authors' focus on characterising the teaching situation according to the way the teaching regulates the didactical contract, i.e. according to how the didactical contract can be determined from 'a characterization of a pattern of interaction' (Hersant and Perrin-Glorian 2005, p. 145).

To make this characterization Hersant and Perrin-Glorian (2005) operate with four dimensions of the didactical contract:

(1) The mathematical (in our case physical) domain.

(2) The didactical status of the knowledge.

(3) The nature and characteristics of the ongoing didactical situation.

(4) The distribution of responsibilities between the teacher and the students.

These dimensions, they state, are not independent. Instead they are an unravelling of the somewhat fuzzy content-specific social rules that make up the didactical contract.

To this end the authors distinguish between three levels in the structure of the didactical contract (see Figure 1): macro-, meso- and micro-contracts. These three levels correspond both to different timescales and different didactical aims.

The macro-level operates on a long-term timescale, which in the case of a labwork activity would be the entire labwork module. The meso-level accommodates the various subtasks of the labwork, such as configuration of equipment, collecting data, etc. The micro-level should correspond to very short timescale, such as in the instance the teacher answers a question posed by a student.

The didactic aims at the macro-level concern the teaching-objective of the activity, aims at the meso-level deals with the realisation of the activity, e.g. the organisation, while at the micro-level didactic aims corresponds to unities of interactions concerned with the physical content. The dimensions and levels in relations are summarised in Figure 1.

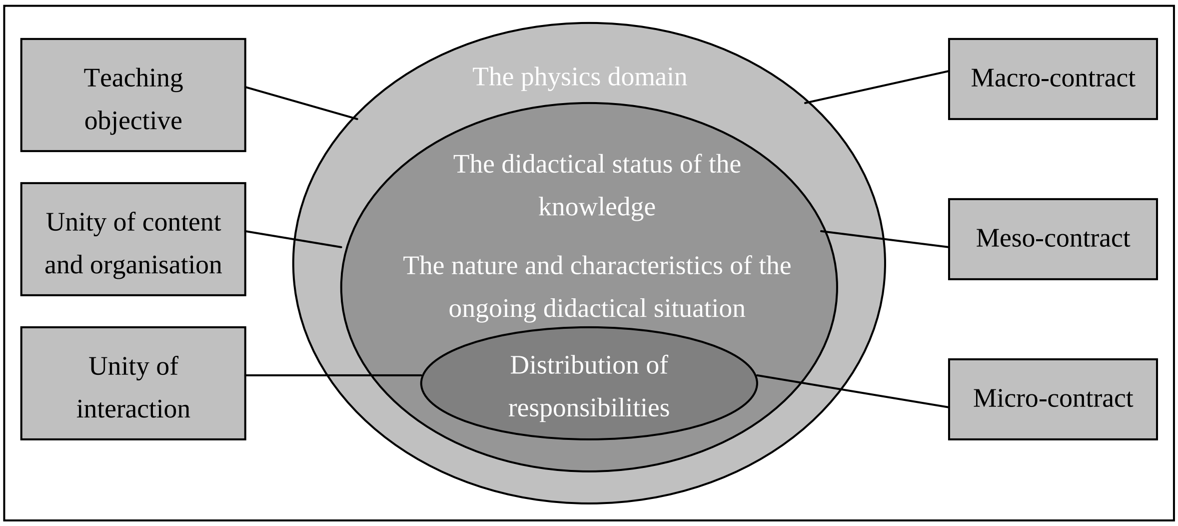

Figure 1: Structure of the didactical contract, adapted from Hersant & Perrin-Glorian 2005, p. 120.

The first dimension, the physics domain, deals with the physics knowledge to be taught. Certain types of physics domains mean teaching certain types of methods and techniques. The didactical contract of a labwork in mechanical energy differs from one in radioactivity by for instance what is found important, possible, what techniques are applied and what apparatus used etc.

The second dimension, the didactical status of the knowledge, deals with the knowledge to be learned, e.g. whether the knowledge is new or old to the students. For instance, some of the content that is applied in doing the task can be expected to be so well-established, that it can no longer be thought of as a teaching objective but rather of as a resource.

The third dimension deals with the nature and characteristics of the ongoing didactical situation in terms of the adidactical potential. The adidactical potential is the potential for students to work independently in producing knowledge. This potential is revealed by scrutiny of what of the content turns out to be utilized as a resource and what of the content offers resistances, i.e. provides actions dependent feedback to the students in engaging with the task. If the students meet no resistance in applying their resources, the task will probably be perceived as pointless. On the other hand too much resistance and no resources to apply will leave the students unable to produce any knowledge on their own.

The fourth dimension deals with how the teacher and students distribute the responsibilities within the activities at stake. E.g. in situations, where the knowledge used is new or found difficult by the students, the teacher takes on a larger piece of the responsibility compared to situations where the students are capable on their own.

Inspired by Christiansen *et al.*'s (2009) notion of shared desiderata, we wish here to add a zeroth dimension to the model for the didactical contract. This dimension deals with the assigning of value to the physical domain (dimension 1) at the macro-level.

In the next section we will briefly condense this section to give an overview of the analytical framework we applied in investigating the custom characteristic for labwork at three different Danish upper secondary schools.

METHOD

We perceive of the five dimensions of the model for characterizing contract, custom and desiderata to be closely related to the three parts of the didactical contract and custom described in the Reprise: the reciprocal obligations, the didactical justification and the domain validation. Specifically we perceive of the latter to be linked to the values of the zeroth dimension due to its very construct. But since a domain validation hardly makes sense if not a validation of something specific (i.e. content) we envision it connected to the physics domain. Arguably, didactical justifications will have some merits at all dimensions of our characterization of the didactical contract, custom and desiderata. However, to focus our analytical framework slightly, we limit our analysis of this part to only encompass patterns of interaction related to the physical domain, the didactical status and the nature and characteristics of the ongoing didactical situations. Last but not least, in characterising reciprocal obligations we naturally look to the distribution of responsibility, but as they slightly overlap, also to the characteristics of the situation. For clarification, see Figure 2.

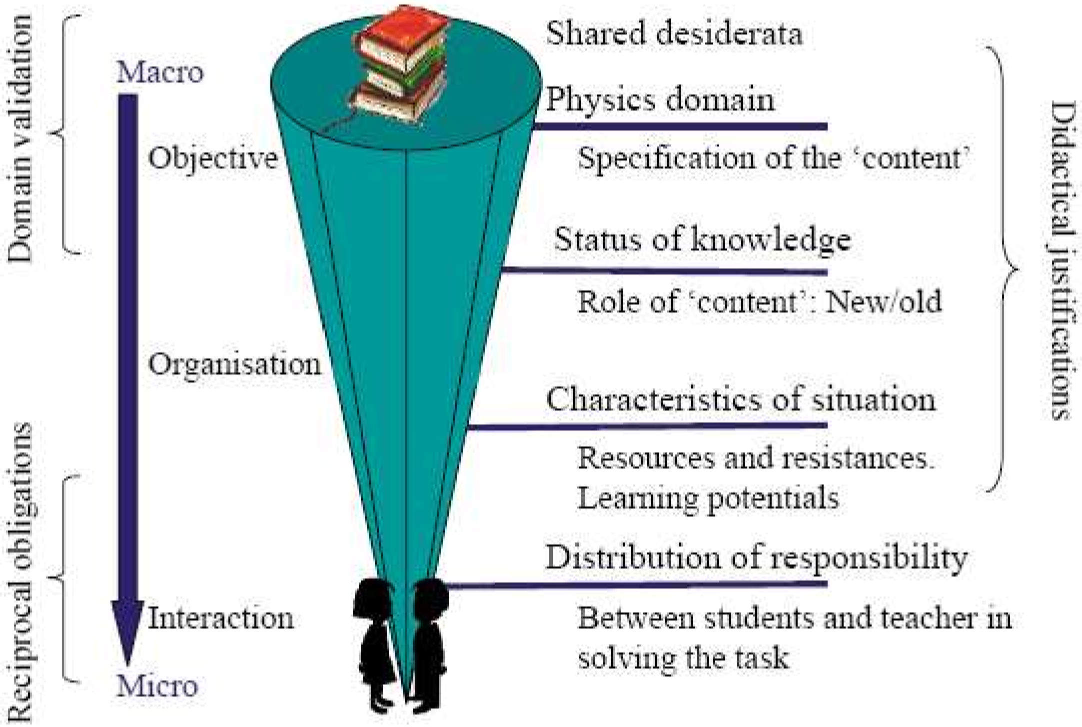

Figure 2: Analytical framework for investigating the custom characteristic for labwork.

To inform these dimensions (leading to a characterisation of the custom of labworks in physics) a comprehensive investigation of year 2 physics courses at three different Danish upper secondary schools was performed. Data comprises curriculum and task analysis, video-recordings of one labwork module at each school and of all the modules treating topics directly relevant for the labwork, student and teacher interviews and analysis of students' lab-reports. For further elaboration on methodological considerations we refer to Jacobsen (2010).

The teachers at the different schools all had different levels of experience. Their schools were chosen so as to represent as wide a socio-economical spectrum as possible while still being typical of Danish upper secondary schools. Each labwork treated a different physics topic. These choices were made to warrant at least some level of generalizability, with regards to a characterization of the custom or 'common rules' that contribute to new university physics students' expectations of how labwork in physics should be approached.

To further our claim of generalizability we look for similarities within the same dimensions of the didactical contracts but between the three labwork investigations.

RESULTS

Combining our theoretical analysis with Hersant & Perrin-Glorian's (2005) method for characterizing ordinary teaching practice, we have constructed a tool for an analysis of the patterns of interaction during labwork. By extracting similarities between three labwork activities, we characterize a custom for upper secondary school labworks. Step by step we will contrast and compare these characterizations to the alternative labwork example described in the Introduction.

Dimension Zero

The zeroth dimension concerning values or shared desiderata was informed through an analysis of student interviews and observations, which were compared to the outcome of a task-analysis according to the values expressed in and around interaction during the activity. Especially noticeable was that all labwork occurred as a verification of previously taught physical theories. Thus, implicitly, labwork is justified as a tool for underlining the 'correctness' of the theory: theory comes before experiment. As was the case of all labwork, data not verifying the theory are interpreted not as a falsification of the theory, but a mere result of poor data collection. Consequently such data will be rejected, or at least interpreted accordingly. As for the case of the educational value of labwork activities this 'theory before experiment' invariably instils a sense of labwork being the mere means for gaining the data necessary to further engage with physical theory.

In the alternative lab, the task is not to verify a given theory, but to measure out two minutes. The students were not given a specific theory to apply to the task. The students did not perceive this as a physically and educationally sound task, since it did not follow their ideas of what constitutes valuable physics engagement. The point of the task is to find a way of being able to measure out two minutes, but not necessarily doing it. Desiderata implies realizing this point. Students who approach labwork thinking that they need to collect data in order to verify theory can only become nonplussed faced with this sort of task.

Dimension One

The first dimension, the physics domain, was informed through task-analyses focusing on what conceptual, procedural and epistemological aspects students would hypothetically need to master, in order to independently complete the prescribed labwork. When analysing the skills and knowledge needed to set up, perform, understand and report a given labwork, we found the results to be quite complex.

The students should be able to operate on many levels of representations, be able to understand complex interplays between the mathematical model of the theory and the physical phenomena, interpreted through a setup etc. The theoretical part of the physical domain is always at the centre; no one is in doubt of what theories are to be used, since the point of the labwork is to verify a specific theory (or physical equation).

In the alternative labwork example, the phenomenon is put first, and the theories should only be used when needed. Instead of focusing on the theory part of the physics domain, students will have to apply their skills solving problems of a general nature. Such were never the requirements in upper secondary labwork tasks.

Although the problem of the alternative task by design falls within the physical domains covered by upper secondary school physics the domain plays a different role here. Specifically classical mechanics must be perceived as the means to reach a solution to the problem of measuring out two minutes. Thus realizing how to apply classical mechanics is the goal of the task – not just measuring out two minutes in any way possible.

Dimension Two

The analysis of the second dimension, the didactical status of the knowledge, was informed through curriculum analysis, observations of teaching prior to the labwork and interviews with teachers. It shows that always, students are expected to draw upon both new and old knowledge. However, in focusing their teaching the teachers emphasize the practical handling of the apparatus, thus assigning a status to apparatus as something hitherto unknown. Data handling and interpretation is in a general sense perceived as a skill the students master. If specificities are different from business as usual, they will be covered in depth by the teacher during the briefing just before labwork is commenced.

Theory, since it is covered during the modules leading up to the labwork session, is considered known and expected fully understood at the time the labwork sessions begins.

In the alternative labwork, both the necessary knowledge and the skills necessary to engage with the task is expected by the instructors to be known. Instead it is the situation to which knowledge and skills can be applied that is unfamiliar and new.

Custom as we see above is that the teacher makes sure to explain to and explicate for the students every little aspect of the new situation. Contrary to this custom the educators in the alternative labwork did not spent time explaining what the situation entails and how theory applies, since figuring that out was actually the purpose of the task.

Dimension Three

The third dimension, the nature and characteristics of the ongoing didactical situation, was informed by analysing observations, along with analyses of lab-reports authored by students and post-lab student interviews.

Analysis revealed that the tasks can be solved without (explicit) use of the skills and knowledge that could have appeared necessary from the analysis of Dimension One.

In practice, when students engage with the task they are supported thoroughly:

a) The labguide lays out a clear path through the labwork. Especially in fascilitating the use of equipment and securing appropriate sets of data.

b) The teacher is always ready to assist throughout the activity. Especially if the equipment does not behave exactly as predicted in the labguide.

c) Students seem to rely on a form of pre-rehearsed algorithm applicable to all labwork activity – especially to writing the report that reflects the labwork activity.

Applying this algorithm (rather than an understanding of the experiment or the theory) seems to be the most important strategy when students write a report. The algorithm is as follows: Do precisely what is written in the labguide when setting up the experiment and collecting the data. Chart data in a table separating the independent and dependent variables (and possibly some kind of mathematical manipulation of some of the variables). Make a representation of the table in a graphical form which can be interpreted applying a (linear) regression. Use this regression to obtain a 'fit parameter' and compare this with the theoretically expected value. If any error, calculate it and report as a percentage divergence. List possible sources of error (among which always mention imprecise measuring). Conclude that theory is verified through the experiment.

This custom of applying the algorithm provides the students with a shortcut through the complexity of the tasks we listed in Dimension One. The shortcut collapses the labwork to a task that does not require of the students to further their insight into the theory; the epistemology of physics; or their procedural skills – besides that which is necessary for manipulating specific equipment. The only resistance offered in the lab is to apply the algorithm to the task. All possible sources of resistance, other than unpredictable equipment are thus turned into resources.

Custom doing labwork is applying an algorithm. Faced with a task like the alternative labwork, to which the algorithm does not apply leaves the students without alternatives.

Dimension Four

The distribution of responsibility was uncovered through interaction-analyses of labwork video-recordings and teacher and student interviews. Here it was obvious how in all cases the distribution of responsibility was completely unproblematic. The students took on various roles without any negotiation. Typically one student took notes, one student read of the scale or display of the apparatus, one student changed the independent parameter etc. We bring a concrete example of two students' interactions immediately after the teacher has asked them to begin the labwork:

S1: We need a pressure gauge.

S2: I'll find it. And then measure the temperature.

[S2 leaves to find the pressure gauge. S1 turns on the PC and starts reading the labguide.]

S2: [Returns] How do you turn this thing on?

S1: [Confers the guide] There's some button on the back.

S2: OK. [looks over the shoulder of S1] what does it say here? 'Make sure the power adapter to LabPro is turned on'.

Notice that the students do not even attempt a negotiation of who does what. Nor do they touch upon the purpose of the experiment before engaging with setting it up.

In the same manner, the student-teacher relation came about smoothly; the teachers' role was primarily to help the students operate the apparatus. Another example, here the teacher is explaining to a group of students how to perform the experiment:

T: The very first thing you do, is to press collect. Then you press 'what volume'. And when you are there, it's just to press 'keep'. That's how you measure the volume exactly there at the point you want to. And then it figures out what the volume is.

The above is a very typical example of the exchange between teacher and students during the labwork. In a few cases the teacher was called upon to explain some features of the data, which did not follow the otherwise obvious functionality of the data points, for instance if one point represented graphically did not follow the curve of the other points. It is quite striking how the students do not talk physics (neither about the theory or the interpretation of the data) during their labwork. The teacher is called upon to make sure the data is collected, and in the few instances to give explanations on inconsistencies that would otherwise be a cause of problems when writing the report. How to do the report, how to interpret data, how to interpret differences between predictions and experiment etc., was never discussed.

In the alternative task, those students who was expecting that custom from labwork could be applied would probably have been at a loss. Or they would be disappointed with the instructors for not fulfilling their part of the responsibility for maintaining custom. Being used to traditional labwork at upper secondary school the viable path towards solving the alternative labwork task must be very hard to conceive of. In this light, the students who pulled out their mobile phone to get it over with, actually did take on responsibility in a situation where no one would or else wise could.

Comment

As a additional note, we find it interesting the pattern of contradictions between dimensions (0 contradicting 1, 1 contradicting 3; 2 contradicting 4). It appears to be an indication of a hierarchical relationship across the micro- to macro-levels which, if understood, could have implications for our approach to educational change. Although this has interesting implications for future research, a detailed discussion is beyond the scope of this paper.

CONCLUSION AND DISCUSSION

Taking departure in the theory of didactical situations we focus on the concept of the didactical contract. Applying Balacheff's modification of this concept by introducing custom, we conceptualize the didactical contract as the explicit content-specific social rules given for a certain activity, such as a labwork in physics education, while allowing for that which does not need to be stated explicitly (anymore) to become domain-specific custom. We further extend the scope of contract and custom with the concept of shared desiderata for education, ending with a three-fold characterisation of the common rules outlining a teaching situation as: reciprocal obligations, didactical justification and domain validation. Central to this account is Balacheff's modification that allows us to utilize Hersant & Perrin-Glorian's methodological tool to estimate a general custom, i.e. the common rules, outlining labwork. On all dimensions, these rules diverge with those implied by the instructions accompanying the alternative 'clock-in-a-box' labwork. This divergence, we claim, is to a large extent responsible for the failure of the clock-in-a-box lab.

We expect that failures of this sort can be avoided if instructors explicitly address the differences between the didactical contract of the specific alternative labwork and of standard labworks, emphasizing a renegotiation of the common rules that outline standard labwork. Hart *et al.* (2000) reaches a somewhat similar conclusion in ascribing the success of an alternative labs implementation to supporting students in gradually coming to understand the purpose in terms of intended learning outcomes. Our addition to this insight is that also other relevant dimensions should be articulated in the cases where these differ from the standard labwork custom.

We wish to highlight here our find that prominent of the labwork custom is the adherence to an algorithm that allows for students engaging with traditional labwork to simply shortcut every adidactical potential of the task. Thus our analysis suggests that what actual physics secondary education students might learn, is not learned in the lab. However, an aspect we have not looked into, is that there is the possibility that students in writing their report have an opportunity for reflection. This opportunity might actually lead to a learning outcome, but this, we have not investigated.

Subsequent to having investigated the standard labwork setting, we did a case study interviewing two first year physics students and a physicist who had embarked on a drastically alternative labwork trial. The task was designed as to resemble authentic research as much as possible and dire emphasis was put on a continuous negotiation of the didactical contract. We wish to end this paper by letting one of these students explain from his perspective why this lab-design appeared to have been successful:

> We set out to explore in complete darkness. But always, we knew that if we got lost our teacher was right behind us, ready to let us cling to his leg, while he led us back onto track, shedding just a bit of light on the surroundings. To be able to work like this, we really had to trust him. And we did.
>
> (Quote adapted to highlight the essence of a longer conversation)

REFERENCES

Balachef, N. (1999). Contract and Custom: Two Registers of Didactical Interactions. *The Mathematics Educator*, *9(2)*, 23-29.

Beney, M. & Séré, M.-G. (2002). Students' Intellectual Activities During Standard Labwork. In: D. Psillos & H. Niedderer (Eds.). *Teaching and Learning in the Science Laboratory* (pp. 65-78). Dordrecht: Kluwer Academic Publishers.

Brousseau, G. (1997). *Theory of Didactical Situations in Mathematics.* (Edited and translated by N. Balacheff, M. Cooper, R. Sutherland and V. Warfield), Dordrecht: Kluwer Academic Publishers.

Christiansen, F.V., Madsen, L.M. & Rump, C.Ø. (2009). *The Essential Tension in Learning GIS.* Manuscript in preparation.

Gott, R. & Duggan, S. (1995). Changing views of practical science. In: *Investigative work in the science curriculum* (pp. 17-24). Buckingham: Open University Press.

Hart, C. et al. (2000). What is the purpose of this experiment? Or can students learn something from doing experiments? *Journal of Research in Science Teaching 37(7),* 655-675.

Hersant, M. & M.-J. Perrin-Glorian (2005). Characterization of an ordinary teaching practice with the help of the theory of didactic situations. *Educational Studies in Mathematics 59,* 113-151.

Hodson, D. (1993). Re-thinking old ways: Towards a more critical approach to practical work in school science. *Studies in Science Education 22,* 85-142.

Hofstein, A. and V. N. Lunetta (1982). "The Role of the Laboratory in Science Teaching: Neglected Aspects of Research." *Review of Educational Research* **52**(2): 201-217.

Jacobsen, L. (2008). Formål med eksperimentelt arbejde i fysikundervisningen. *MONA 4,* 22-41.

Jacobsen, L. (2010). *[Title Unknown]*. PhD dissertation in preparation, Roskilde University, Roskilde.

Karelina, A. & Etkina, E. (2007). Acting like a physicist: Student approach study to experimental design. *Physical review special topics – physics education research 3(020106),* 1-12.

Kuhn, T. S. (1983). Rationality and Theory Choice. *The Journal of Philosophy 80(10, part 1),* 563-570.

Roth, W.-M. (1995). *Authentic school science – Knowing and learning in open-inquiry science laboratories.* Dordrecht: Kluwer Academic Publishers.

Trumper, R. (2002). What do we expect from students' physics laboratory experiments. *Journal of Science Education and Technology 11(3),* 221-228.