FROM PROMISING APPROACH TO REGULAR CURRICULUM - EDUCATIONAL INNOVATION IN MECHANICS AT DUTCH UPPER SECONDARY LEVEL

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ABSTRACT
The Dutch curriculum for mechanics is being revised with a focus on educational approach rather than on content. By integrating effective designs from small-scale research projects and using cyclical feedback from teachers who implement the design, an effective balance is sought between educational innovation and practical effectiveness. Each cycle of the design process consists of phases of writing, implementation and evaluation. From 2006-2008, two complete cycles and a third writing phase have been completed. This study analyses how the designers construct and justify their design, primarily to themselves, through a negotiation of design ideas, educational objectives and pedagogical concerns. Participatory action research is used to reconstruct the process from internal and external communications. Design ideas are most actively produced and negotiated during the writing phases, so that differences between designers stand out prominently. These are interpreted as based in different 'cultural orientations' between educational and research backgrounds. What emerges is a still-evolving compromise rather than a consensus view. During and after classroom trials designers have to consider whether and how to accommodate the concerns of the teachers. The teachers too appear to have various and divergent concerns. For an important part, these differences can be understood as different 'curriculum emphases'. This paper argues that concerns of different kinds of experts on the same design issues are likely to be difficult to reconcile, and presents provisional approaches to reconciliation that were constructed in this project. Our interpretation of teachers' concerns is shown to guide the continuing revision of the design. Further research will be directed at establishing the stability of these solutions and determining effective professional development strategies for aligning designers' and teachers' concerns.

KEYWORDS
Curriculum reform – mechanics education – implementing research – justifying educational design

INTRODUCTION

How can we use the research findings we obtained over the past decade in regular physics classrooms? This question, fundamental to this study, relates to Anderson's (2007) observation that although 'as a field' we understand why education does not result in scientific literacy, 'we need to find better ways to use this understanding as a basis for design work in science teaching and teacher education – programs and strategies that move beyond existence proofs to help large numbers of science learners' (p. 27.) This study is meant to contribute to this search in the context of mechanics and current Dutch Science Education reform. A team of designers coordinated by the author has worked since 2006 on an educational design for Newton's Laws of Motion. It matches curricular intentions and at the same time translates research into practice. The quality of the design is subject to research but not the topic of this paper. Here we identify the ideas which govern the various phases of construction of the design, its implementation and evaluation. We discuss how these ideas combine, clash and are being synthesized.

Curriculum innovation in the Netherlands currently focuses on the Sciences and Mathematics at upper secondary levels (ages 16-18). Its physics branch is known as 'NiNa', an acronym that translates as

‘New Physics’. So one might ask: if we need a new physics, then what is wrong with the old one? Documents that set out the goals and intentions of NiNa (see e.g. the Keynote Address by M. Pieters at this conference) describes Dutch school physics as consisting of an overloaded set of ancient, undeniable truths that offer insufficient challenges, contemporary contexts, and room for the fascination and curiosity of students. New, relevant contexts may provide meaning and background to modern concepts, e.g. in Biophysics or Relativity Theory. For mechanics, however, no renewal of contents and contexts is intended. Textbooks already utilize a context-based approach while the mechanics concepts are too fundamental to be replaced. Innovation in mechanics is sought not in *what* is taught but in *how* it is taught. The challenge is to teach Newton’s ‘truths’, published in 1687, as modern and exciting rather than ancient and undeniable, and to tap into the fascination and curiosity of students even though this part of physics is highly mathematized and conceptually strict.

The design team, in this case, includes teachers as well as academics. Together they determine how the challenge is met, through their understanding of what it is the design is required to accomplish, how that can be attained, and how the particulars of the educational setting should be taken into account. The design process is partly determined by their efficiency in negotiating, out of these educational objectives, design ideas and pedagogical concerns, a common approach or strategy for their design. Specifying these guiding principles, the differences between them and the ways they are negotiated may help us gain understanding of the problem of utilizing researchers’ insights in teachers’ practices. It may contribute to developing a more effective design process.

Putting a design into practice involves change – including a change in concerns. The experience brought into the design by the teacher-writers cannot represent the concerns of teachers at large. As additional concerns are raised, how are these accommodated? What concerns do teachers have, and what arguments do they use to support them? How do designers decide on an appropriate response? These issues may provide further insight into the problem of translating research into practice, which brings us to the following research questions:

1. *Which ideas, objectives and concerns govern the design of a teaching sequence for Newton’s Laws in this case, where teachers and academics collaborate as designers?*
2. *Which further concerns of teachers emerge during the cyclical evaluation of the design of a teaching sequence for Newton’s Laws in this case? What differences exist among the teachers?*
3. *How are the differences between ideas, objectives and concerns negotiated, and how does that affect the design process?*

The outline of the designed teaching sequence is presented as a backdrop that highlights the results of negotiations of designers’ concerns. Similarly, the plans for revising the design after classroom trials are presented to clarify how teachers’ concerns were accommodated.

THEORETICAL BACKGROUND

The guiding ideas for structuring the educational design are in this study based on a ‘problem posing’ approach (Klaassen, 1995). To explore how these ideas are translated into a functional design, we need a model to analyse the way the designers express, validate and negotiate their ideas. Arguments are understood to constitute the main elements in this discourse, which we analyse using Toulmin’s (1958) model. Labaree’s (2003) notion of the different ‘cultural orientations’ of education and research will help us understand the differences between designers. Differences between teachers, on the other hand, will be discussed using the notion of ‘curriculum emphasis’ (Roberts, 1982; Van Berkel, 2005). These elements of the theoretical framework of this study are discussed in turn below.

Design research and a problem posing approach

The search for a best way to teach mechanics has been so thorough that it has been called the ‘Holy Grail’ of physics education (Taconis, 2006). Research underpinning the current project differs from much of this literature in its characterisation of students’ prior knowledge (Dekkers & Thijs, 1998). Students’ causal thinking is used as a starting point (Klaassen, Westra, Emmett, Eijkelhof & Lijnse,

2008) in an educational design where students build their new knowledge on the basis of what they already know. That does not require a replacement of many incorrect beliefs; their initial beliefs are largely correct (Dekkers & Thijs, 1998). They do need to add to, extend, refine and differentiate these correct but (scientifically speaking) limited ideas in order to describe, explain and predict events in a way that is as accurate, precise and general as possible. This development is fostered through a 'problem posing' approach (Klaassen, 1995) in which questions are made to emerge that are valuable and meaningful from the *students* perspective, and on which the students work in a way they actively choose and appreciate. Yet the design enables them to develop answers in which the scientific concepts and ideas are developed that *we* (the designers) want them to learn. If the design succeeds, the students understand what they are learning as purposeful and meaningful since it contributes to answering an overall question that they value.

A 'problem posing' approach is not easily accomplished though 'existence proofs' were established for various topics and objectives (Lijnse & Klaassen, 2004) while 'low threshold' versions were designed and implemented (e.g. Hooyman & Vollebregt, 2006). But these successes were obtained in one or a few classes, with limited topics and no more than a few teachers, who were often intensively coached (Taconis, 2006). Can the approach be applied to a larger subject area and be made suitable for many teachers and schools? As a preliminary move towards answering this question, we explore the ideas that influence the designers in dealing with this challenge.

Toulmin's Layout of Argumentation

Designing education means making choices. At any time during the teaching and learning process a range of choices is available, most of which have lasting design consequences. Individual designer's preferences are a result of, e.g., their personal views and values, experiences in teaching and research, and professional expertise. So educational design is a matter of much debate and argument by nature. Toulmin's (1958) analysis of the structure of argumentation is useful in that regard. According to Toulmin, arguments essentially consist of a 'claim' based on 'data' supported by 'warrant'. A 'claim' is the position on the issue at hand: it is the purpose of making the argument. 'Data' are the evidence or facts on which the claim is based, originating from experiences that may be obtained in more or less systematic, objective and quantitative ways. 'Warrant' is the reasoning by which a logical connection is made between *data* and *claim.* This is where, in a rational argument, its presenter attempts to convince the audience. This attempt may be reinforced by 'backing': material based on various levels and kinds of experience which adds to the convincing power of the 'warrant'. Through 'qualifiers' the presenter of the argument may indicate how strongly he is convinced of the claim he makes. A 'reservation' may be added to express exceptions to the claim. What matters here are the different types of *backing* used by designers and teachers in their claims about the quality of the structure and content of the design. On the basis of their claims we will attempt to identify their ideas, objectives and concerns. In this paper we will try to explain problems in making design decisions on the basis of that analysis.

'Cultural' differences among designers - science teaching and educational research

In his analysis of curriculum development in Dutch physics education Lijnse (1998) highlights developmental research as an alternative to top-down (teachers implement materials developed by academics) and bottom-up (teachers develop and implement their own materials) approaches. Developmental research systematically brings general educational understandings together with the specific practices of the classroom. Lijnse proposes that academics collaborate closely with physics teachers in this research, on a basis of 'equivalence'. This is the type of research we are trying to do. But what does 'equivalence' mean, exactly, in this context?

If teachers do not understand or see the point of curricular change, it will not materialise (Van den Akker, 1998). Therefore, innovation projects similar to ours use extensive professional development to obtain more appropriate translations of new curricula into classroom practices (e.g. Pintó, Couso and Guttierez, 2004). Conversely, teachers possess relevant expertise that is often unavailable to academics, such as insights into the prior knowledge of students, classroom culture, expectations of students' (home)work, ways in which extracurricular activities interfere with regular teaching, assessment procedures, etcetera. And yet utilizing expertise in a design is not simply a matter of ‘equivalence’. Since a delineation of areas of expertise does not exist, making choices in the process of design is much more a matter of negotiating clashing concerns than one of assimilating equivalent inputs.

According to Labaree (2003) the differences between teachers’ and researchers’ jobs are ‘irreducible’, and lead to worldviews that cannot be easily reconciled. Analysing the difficulty of becoming a researcher he describes these differences in terms of ‘cultural orientations’. Due to the nature of their work teachers are oriented towards a normative, personal, particular, and experiential point of view. Researchers, however, tend towards an analytical, intellectual, universal and theoretical perspective.

In teaching, valued outcomes are to be produced efficiently: teachers are required to justify their actions using normative judgements. The researcher’s mission, on the other hand, ‘is not to fix a problem of educational practice but to understand more fully the nature of this problem’. His job is to decide analytically which approach works. Teachers deal with the individual problems of those in their care from a position of personal responsibility. Researchers however resolve problems at a more general and systematic level. The quality of their arguments matters, while the quality of the practical solution for an individual is secondary. This promotes a cultural orientation that is intellectual rather than personal. Similarly, teachers tend to focus on their own particular context; their personal experiences determine largely their course of thought and action, while researchers would need to take a broader perspective and look for structure. The researchers’ interest is in the general, underlying issues, and in solutions and understandings that are valid universally. Teachers deal with day to day problems directly, so as to keep the business of education going. Only a practical approach serves them in doing that, a reflective approach in which the underlying causes are determined and interpreted in a coherent framework, though crucial for the researcher, is not a teacher’s job.

Labaree (ibid.) argues that on closer inspection, the cultures are less conflicting than the preceding paragraph may suggest. Yet, these dichotomies provide the extremes of a continuum in which the concerns determining our design process may be analysed effectively.

Different concerns among teachers - curriculum emphasis

In addition to differences between teachers and academics, we must take into account differences *among* teachers. Teachers differ in many ways, for example in terms of what they want to accomplish through their teaching. As a result, they will respond differently to an educational design both in terms of how they implement it and in their views on the suitability and quality of the design. In interpreting these responses, Roberts’ (1982) concept of ‘curriculum emphasis’ is useful. A curricular emphasis is a coherent set of ‘meta-lessons’ (educational objectives of the curriculum). Roberts distinguished seven sets, but others have been proposed since, while the notion has been used not only to analyse curricula but also teachers’ beliefs, e.g. by Van Berkel (2005) with Dutch Chemistry teachers. We apply his three emphases with slightly different labels and meanings:

- *Processing Knowledge*. Theory is presented to learners, because they need it to satisfy the requirements of the school subject (in terms of tests and exams) which in turn enables them to understand relevant phenomena in daily life. After a clear and concise explanation students develop understanding and the ability to apply the new theory through exercises and tasks to solve various problems in a range of contexts. Thus, mastery is accomplished through *processing* of the knowledge. For example in our design, Newton’s Universal Law of Gravity is essentially presented as a given. Students apply this complex formula in a variety of exercises to get a feel for its use and applicability, understanding of the relationship between the variables appearing in it, and skills in doing calculations with it.
- *Utilizing Knowledge.* Emphasis is on the role of science in technological approaches to address societal issues. Knowledge is seen to have an empowering and enabling function. With this power comes the responsibility of using it wisely. Students are expected to learn how to *utilize* knowledge to address practical problems, and to take into consideration the consequences of their actions. For example, in the design studied in this paper, students explore whether a rule-of-thumb used in

highway traffic, 'keep a distance of 2 seconds' between your car and the one ahead, produces safe outcomes in emergencies.

- *Developing Knowledge.* Learners carry out activities which emphasize learners' own efforts of constructing knowledge. Partly, that involves exploring historical and philosophical aspects of how our current knowledge has come about. In this emphasis, an understanding of physics content and its value are developed alongside that of the tentative and provisional character of this knowledge, its empirical basis and its social and cultural origins. For example, students in our (revised) design explore Kepler's and Newton's explanations for the orbit of Mars around the Sun, and determine for themselves why Newton's approach was eventually favoured above Kepler's.

Processing, utilizing and developing knowledge are all needed to satisfy the curriculum, but their prominence may vary. No teacher can afford to neglect 'Processing', but 'Utilizing' and 'Developing' knowledge often receive less attention than curricula suggest. These alternative emphases are central in the design's innovative intentions but may easily be 'lost in translation' from the textbook to the actual lesson.

METHOD

Design

This study uses participatory action research, where cycles of 'Think', 'Act' and 'Look' (Stringer, 1999) follow the phases of the development of the educational design: write, implement, and evaluate. The emerging product: an educational design consisting of a tested justification of the teaching sequence, and its elaboration in the form of teaching materials and teacher manuals. At present, the third 'write'-phase has just been completed.

The designers' guiding principles are their views on what the educational design should accomplish, on what is required to accomplish that, and on how specific aspects of the educational context should be taken into account. These principles are discussed mainly during 'writing' phases. Since one of the shared objectives is to produce a design adapted to ordinary classrooms, the views of teachers involved in implementation are collected during the 'evaluate' phases. This paper identifies the teachers' concerns (or rather: the designers' interpretations of these concerns) and the way they affect the design.

Participatory action research is appropriate here because the main aim is to establish personal and professional opinions of collaborating practitioners in a cyclical approach to optimizing an educational design. No theoretical basis can predict how the approach will evolve, yet since the negotiation of beliefs is experienced as occasionally troublesome by the team, it would be valuable to develop ways to make this negotiation more efficient, and report these to our professional community. Action research does so in ways that take the understandings, experiences and values of the participants into account.

Data sources and analysis

During phases of 'writing', regular meetings of the designers' team take place in which plans are drafted, draft materials presented and comments discussed. Email discussions sometimes accompany these meetings. Early on, discussion documents were produced through which a common view on the design was sought. Agenda's and reports of meetings provide the precipitate of some of the discussions, as do the emails and discussion documents. The scope of this paper does not allow for a reconstruction of the entire process. Instead, the global and structural agreement among the designers is summarised in a brief description of ideas underlying the structure of the teaching sequence. To highlight concerns that were hard to reconcile, some illustrative vignettes have been extracted from the listed documents.

Teachers' views and inputs into the design were sought through various means. In the first implementation round, the teachers met every 4-6 weeks to discuss progress. Initially designers presented their ideas at these meetings, later the teachers' experiences and comments became the focus. In the second round of implementation, opportunities for contact were fewer. The materials and educational approach were introduced in two three-hour sessions. Teachers reported back in one session held close to the time they completed their teaching. One teacher was interviewed individually by means of a semi-structured, open-ended interview: a summary of this interview was used to structure partially the informal discussions with 8 teachers (of the 10 involved) during that final session. The interview was summarised by the author, the discussions by two other designers. Five of these teachers also answered a questionnaire on their experiences.

Teachers provided a great deal of information on the implementation process on all these occasions, e.g. on the circumstances at the school that prevented a smooth teaching process, anecdotal evidence on problems of students, and opinions on how students responded to the design. Extracted from these is an overview of the main concerns teachers presented in arguing for particular major changes in the materials. (Other inputs also influenced the design in minor ways but are not in focus here.) Rather than reporting teachers' statements directly, the designers' interpretations are given since these are the actual ideas that affected design revisions. The overview illustrates the main concerns and the designers' responses; it provides a condensed account of key issues rather than a comprehensive one.

Participants

The designers' team consisted of five members at first, all with an experience of at least 20 years in physics education and 10 years in educational design. In the actual writing, two members provided the most influential contributions. The first of them has an extensive experience as materials developer, is involved in a wide range of innovative projects, and teaches at a Dutch secondary school. He was nationally elected Physics Teacher of the Year in 2007. The second has a track record of 2 decades in educational research in physics education, with a focus on mechanics, and has supervised several PhD studies in that area. As one of the main developers of scenario-based design research and a problem-posing approach he has strongly influenced our institution's research programme. He participated only in the first design cycle. He and the remaining members have PhD's in physics education research. One was a physics teacher for over 10 years and became a teacher educator two years ago. In our team she is the one best able to consider an educational design from both the classroom and a research perspective. Our fourth team member has had several decades of experience as a curriculum developer and as chief editor of one of the top physics textbook series in the Netherlands. I, finally, joined this team after it had collaborated in earlier projects, as coordinator and co-author. I have been involved in research, design and teaching of physics / science education, including teacher professional development, with an extensive experience outside the Netherlands.

In the first design cycle, 8 teachers from 4 different schools participated, while in the second cycle, 22 teachers from 10 schools participated. However, of both groups only about half of the teachers have contributed substantial feedback. All teachers participated on a voluntary basis, by signing on to a research or innovation project. All were qualified physics teachers working at the upper levels of Dutch secondary schools (age group 16-18) with a teaching experience of several years.

RESULTS

Establishing common ground - designing a teaching sequence for mechanics

Dilemmas and discussions in the designers' team

Labaree (2003) suggests that most teachers favour a normative, personal, particular, and experiential perspective, while researchers tend towards an analytical, intellectual, universal and theoretical point of view. Our team of designers clearly does not consist of run-of-the-mill teachers and researchers. Yet, our problems with establishing a synthesis of our design ideas and a reconciliation of our concerns can be explained remarkably well with Labaree's suggestion. Of course there were many issues we, as designers, did agree upon. In answer to the first research question, a summary of our shared design ideas is given below. There was further agreement on, e.g., the kinds of topics to be included, the expected role of the teacher, the way ICT is integrated in the course, and the style, lay-out and language to be used. And yet, it has been difficult to let our various areas of expertise complement and reinforce each other, too often we used our differences to defend our own ideas rather than to augment those of others. The sections that follow should be read as reconstructed illustrations of the main clashes of ideas and concerns we experienced. Toulmin's model was very useful in analysing the debates and reducing the arguments to their 'cultural' essence. Space, however, does not permit a description of that process, only the main claims that emerged are given here. An interpretation of these vignettes in terms of the different 'cultural orientations' of educators and researchers brings out the kinds of differences that made it difficult to foster synergy and provides the rationale for the third research question.

Rational coherence vs. Creative flexibility
In the designed activities, concepts acquire meaning through their functionality in practical contexts. But agreement on this matter does not provide a structure for the materials. Should the learning process primarily meet the intellectual challenge of solving the problems and questions that emerge from the contexts? Or is this just one aim among several equivalent aims; is it equally important for students to experience success and pleasure in doing science, and develop self-confidence in applying it? Our deliberations stretched out over several months, and involved verbal discussions, exchanges via email, proposed teaching materials, educational scenario's, and comments on these in a cyclical design process. From this written record, the main views that determined the discussions were the following.

Table 1. Explore-Plan-Execute-Reflect (EPER) structure of the design

EPER phase Guiding problem	Mechanics topic	EPER sub-structure	Example of sub-question
Explore What is mechanics? How useful is it?	1. Explaining the movement of objects	E: Explore situations and practical problems in sports, traffic, research.	
Plan What is a suitable method for explaining movement?	2. Newton's method for explaining movement	E: Identify common causal structure P: Construction method + causal assumptions E: Construct the movement of the comet Kirch (and the planets, a satellite, the Moon, etc.) R: Summary: 1st and 2nd Law, Law of Gravity. Can we use this approach elsewhere?	How does a comet move? What makes it move in that way?
Execute How can the method be applied to practical situations?	3. Apply to: a. constant force	E: Which problems involve a constant force? P: Find a force-law, apply Newton's assumptions and construction. E: Construct uniformly accelerated movement. (Free fall, braking in a car, collision etc). R: Equations of and graphs for uniformly accelerated motion. What if the force varies?	Is '2 seconds apart' a safe rule for keeping your distance on the highway?
	b. variable forces	E: Which problems involve variable force? P: Find force-laws, apply Newton's approach through computer-simulation E: Study movements by manipulating variables (time trial, parachute, Tacoma bridge etc). R: The computer produces practical solutions to problems involving movement. What can we do if we do not know the forces?	Could Fignon have won the Tour de France in 1989?

Reflect What has been gained and which questions remain?	Laws of motion, concept of force, various force laws (e.g. friction, Hooke)	R: What have we learned? Which sorts of problems and situations can *not* be handled yet?	Can we explain and predict how objects move in many situations?

Academic's view: "To make learning content meaningful, the learning process must be purposeful. Start with a problem that is worthwhile to students. Follow with steps that they can rationally appreciate as being directed towards an eventual solution, offer activities and information that they can understand as part of their construction of that solution. The design is a rationally coherent justification of the sequence, to be translated into educational materials. A proper design takes into account all the pathways towards the final goal. A deviation from these pathways is not purposeful and should be avoided, it disturbs the process."

Educator's view: "To make learning content meaningful we should help students relate it to what they already know and to the ways of thinking they are familiar with. Start with a problem that is worthwhile to them. Offer activities that reveal how the concepts and methods of science can be used to solve it. Show how these concepts and methods are interrelated and form a connected whole. Let learners experience that they too can use these concepts and methods, in coming to understand and solve various practical, relevant problems. Most important is that tasks are feasible, familiar, clearly formulated and concise. Deviations are fine if they build motivation and (self)confidence in students."

Consequence: Materials designed from the educator's perspective are coherent in terms of the conceptual structure of the subject, but learners do not need to see how their work solves the central problem until they reach the solution. For the educator this is not a problem if students are productive and successful in the activities leading to it, and (are believed to) see the point of these activities in retrospect. If it happens that learners cannot see the point of a particular task, this is often interpreted in terms of personal, particular classroom experiences, not in structural terms. Even if it is seen as a structural problem, the educator's view suggests that *different activities* can improve matters. It remains pointless to construct a rational justification of the sequence, since the design is not understood as an attempt to predict and justify purposeful learning, but one to make the learning experience feasible and enjoyable. From the academic's perspective revisions of this kind cannot result in improvement. Frustration will ensue, since 'academic' inputs and suggestions seem to be ignored or rejected.

Deep exploration vs. maintaining the momentum

Introducing the concept of acceleration and the formulas for uniformly accelerated motion took three lessons in the initial design, in which students constructed the actual motion of a falling object and the corresponding graphs using Newton's stepwise approach. Teachers appreciated how the concept of acceleration was constructed but they preferred to have students work on exercises sooner. We discussed how to respond to teachers' views over a period of several weeks, during meetings and via email, and by commenting on suggested modified teaching materials. In extremely brief summary, the following views can be extracted from the written record of these exchanges.

Academic's view: "Central in learning is whether students see the point of what they are doing. If they do, if they feel that they are making progress, if they attain purposes and develop new goals as foreseen, the design does what it is meant to do. Other issues are secondary, since a worthwhile physics problem addressed in this way will naturally involve, e.g., developing suitable concepts, substantial inquiry, use of mathematical skills, appropriate ways of working together, etc. More time will be used for some aspects of the problem than for others, but as long as there is a purpose to students' work, the time is well spent. E.g., if it takes three lessons to come to terms with one particular concept, there is a problem only if it the concept does not, from the students' point of view, help them reach their goal."

Educator's view: "Whether students engage in what is offered depends on whether they see the point, but on many other issues as well. Their perception of the value of an activity may change. For example, if students feel the activity becomes tedious, is too odd, is socially suspect or requires more effort than expected, only the most tenacious will persevere. It is useful to vary the way in which students cooperate, to include inquiry, to keep tasks short, and chunk topics into lesson-size bits. Even if it disturbs the overall purpose, variation may be needed to maintain the pace of learning and the interest of students. If teaching any specific concept takes three lessons, learning will be thoroughly disrupted."

Consequence: materials designed from the academic's viewpoint may require deep exploration of, e.g., a concept by students. This may be feasible in an educational research setting but less so in regular classrooms. An educator might reason that students' and teachers' expectations differ from those of the designers, and therefore promote varied activities orchestrated by the teacher with regular experiences of achievement and success by students. From the academic point of view, variety and pace of the activities are secondary to their being purposeful, but for the educator they are means to the main ends. The academic's revisions will strengthen the purpose which, to the educator, is beside the point. Frustration ensues as the academic feels that his research experience is not taken seriously and the educator fails to see why the problem is ignored.

Common ground - the 'EPER-structure'
Clearly both perspectives have merit, and yet a productive synthesis was not easy to find. As a plan of escape from our unproductive debates we made an overview of our design principles and an outline of the content, to establish as precisely as possible the issues we did agree upon. We divided the writing tasks among us so that each was responsible for a whole chapter or theme. Comments were at this stage used only to correct simple mistakes. A final edit of the whole ensured a detailed match between parts.

The overview allowed us to produce a design based on our shared objectives despite the differences in concerns. We constructed a phased structure which has stages of *exploration* of situations and establishing a guiding question or problem, *planning* an approach for handling it, *executing* that approach and *reflecting* on what was learned and what problems remain. Table 1 shows this structure of the overall design as well as the chapters within it. (A final section is omitted due to space restrictions.) The table is derived from discussion documents, the teacher guide and the teaching materials.

In answer to the first research question, the elaborated EPER structure based in a problem posing approach captures the essence of the designers' areas of consensus in terms of the ideas, objectives and concerns that governed the design, whereas the preceding vignettes illustrate the main areas where this consensus was lacking. We found a way to progress productively despite our inability to resolve our differences.

Establishing teachers' concerns - revising the design upon its implementation
The teachers who used our mechanics teaching and learning materials in their classes argued for many changes. Some of these involved general, mostly professional and structural concerns that most of the teachers agreed upon. These referred to teachers' needs, e.g., the need for clarity about 'core' and 'subsidiary' sections of the materials. Or a need for materials that enable teachers to choose and select topics. The teachers also asked for, e.g., sample exam questions, additional exercises, illustrations in Powerpoint format, and model answers. These concerns were easy to deal with, because they broadly aligned with the perceptions and opinions of the designers. There was a broad agreement that the materials could be improved by addressing these comments.

Teachers did not agree on all matters, however. It was remarkable that very few of them responded neutrally or indifferently to the design. They were either very negative about the materials and the recommended approach, or very positive. 'Curriculum emphasis' appears to be a useful concept to understand their points of view and the marked differences between them. The comments that differed involved mostly particular, pedagogical aspects of the course. The arguments they offered for changing the design or materials were backed by references to 'wants' and 'needs' of (their) students. I.e., experience-based views phrased as '(my) students want…' (or 'like', 'enjoy', 'care about', etc.). Or '(my) students need…' (or 'require assistance / help / support with', etc). Wants and needs can be expressed in alternative ways, such as 'students dislike…', 'do not care for…', 'are unable to…', 'have problems with…', etc. Views of this kind express needs and wants indirectly, and specify what ought to be avoided in teaching. Statements of that kind have also been included in Table 2.

Table 2. Concerns of teachers and designers' responses

Concern of teachers: Students' wants and needs according to the teachers	**Intention of designers: Interpreted as a consequence for revision**
Common concerns of teachers (and designers)	
1. *Optimally support management and planning* Students: - need revisions of prerequisite knowledge. - need summaries, overviews, model answers. - cannot complete all activities in the allotted time.	*Optimally support management and planning* Improve structure of the materials, more clarity on what is essential and what is not.
2. *Address all relevant aspects of the subject* Students: - need more practical activities and investigations - need to be taught (more of) certain content, e.g. 3rd Law	*Address all relevant aspects of the subject* More practical work and inquiry activities are to be included. Some topics are to be expanded.
3. *Increase support for understanding abstract matters* Students: - need a gradual introduction and clarification of formulas - (some) cannot handle derivations / formulas / Newton's procedure for constructing movement.	*Focus on (conceptual) understanding* Deriving formulas is to be kept to a minimum, more time and attention must be paid to clarification.
Concerns teachers do not agree on with each other (or with designers)	
1. *Increase support for 'processing knowledge'* Students: - need clearer explanations of theory. - need more (straightforward) exercises for practice. - do not need history and philosophy of science (interesting but non-essential) - cannot construct knowledge (given the available time).	*Use 'developing and utilizing knowledge' in support of purposeful learning* Materials should indicate pathways for each curriculum emphasis and assist teachers in selecting the emphasis they prefer. (Professional development for non-processing emphases should be developed.)
2. *Structure the learning process (externally)* Students: - do not like to use their own ideas. - do not like explorative and reflective activities. - dislike when the answer to a question is not (immediately) given - do not like to sort things out for themselves.	*Make learning purposeful, knowledge meaningful* Exploration and reflection are reduced in size (to make them easier to fit into the lesson) Provide more support, avoid repetition, clarify the benefits
3. *Emphasize 'processing of knowledge'* Students: - benefit more from quantitative than qualitative exercises. - do not like debating the value of an approach or method. - do not like to read.	*Use activities that stimulate meaningful learning* Aspects of developing knowledge are simplified, made less dependent on learners' input. Texts are kept short.

Table 2 provides a very brief summary of generalised opinions and views that were forwarded on a range of occasions. From the transcript of a semi-structured interview with one outspoken teacher a collection of statements for discussion was derived and used in a subsequent meeting with nine of the NiNa teachers. The summaries of the discussions from the main basis for Table 2, which is augmented with teacher opinions expressed in emails and in a questionnaire answered by five of the eight teachers. Table 2 provides an answer to research question 2, in that it presents the concerns of teachers that emerged during the implementation of the design and highlights the similarities and differences among these concerns.

'Wants' refer to the maintenance or building of interest, motivation, confidence, appreciation of physics; 'needs' refer to the various kinds of support that enable students to do what is required, and to do it well. Superficially, teachers simply seem to want materials that help them make students happy, interested, active and successful. But there is a deeper level: if teachers attain their professional aims and objectives, they believe (for good reasons) that their students will enjoy and do well. The earliest and clearest symptom if that is no longer the case is when students cannot manage, lose interest and/or become passive (or disruptive). So it makes sense for teachers to discuss their *own* professional preferences, aims, objectives, values, etc. in terms of their *students*' wants and needs.

For example consider teachers who report: 'My students do not like the explorative and reflective activities; they prefer it when I just explain the theory and tell them what to do.' For some teachers who experienced this, it is a challenge that they want to take on and address. Many, however, thus express a curriculum emphasis that does not accord with the intention of enabling learners to give personal meaning to the knowledge they develop. The reported 'wants' are valid but contingent, dependent on the teachers' emphasis on 'processing knowledge'. This emphasis is not just a matter of choice, even if preferences do have an influence. It also depends on the teacher's approach to teaching: his way of managing the classroom, balancing independent work by learners with his own supporting and structuring role, or his handling of the 'guidance' and 'discovery' parts of the guided discovery approach of the design. It is related to his professional aims and objectives (in which the need for personal meaning of learners' knowledge may not be problematised) and his perception of the educational context (he may not see 'developing knowledge' as feasible given the time available). So the problem may not just be what students want or need, it may be the teacher's entire professional outlook. For him the intentions of this design may be a meaningless obstacle rather than an opportunity for change. A teacher who perceives the alternative emphases as *obstacles* can be expected to reject the innovative intentions. Those who see them as worthwhile *challenges* may accept the design intentions and try to accommodate them, even if they are critical of some aspects of the design. The notion of a 'curricular emphasis' of teachers explains in this way that few teachers respond neutrally to the design.

From our inventory of teachers' claims we derived a plan for design revision that is summarised in Table 2. It lists the 'wants' and 'needs' of students that the teachers expressed, and that we as designers regard as most important, with our response. As this paper is presented the revisions are nearing completion, and preparations for re-trial (from August - December 2008) are under way. Note that the Table implies that the designers' intentions for educational innovation may not be implemented by all teachers. Rather than forcing the issue, we have decided to identify those teachers who prefer a curriculum emphasis that matches our design, and to ask them to collaborate with us in developing appropriate teacher professional development strategies. This will be a theme for further research.

The stated needs and wants of students are the views of some of the *teachers,* not of the designers. For example, students can very enthusiastically debate issues of epistemology *if* these are pitched properly. If (some) teachers believe students are unable to do so, we ought to pitch debates better or develop a more effective approach for nature of science activities. Note also that Table 2 does not include positive claims of teachers about the design, since these gave no rise to revisions. Teachers who were positive mainly liked Newton's construction method as it helps students understand the scientific approach and concepts better, liked the way the material activates (especially strong) learners, and liked the innovative approach to the topic. A substantial number of teachers did accept the alternative emphases - although further research is needed to establish whether their teaching actually reflects these emphases.

DISCUSSION AND IMPLICATIONS

Summarising the findings, note that the answer to research question 1 consists of two complementary parts. Table 1 provides the ideas, concerns and objectives on which the designers agreed, and which guided the design process. The second part of the answer pertains to the problems experienced in the design process, which were illustrated in two vignettes. Labaree's notion of educational and research 'cultures' provided a useful perspective for interpreting the tensions that arose.

The results section provides a summary description of how the differences between ideas, objectives and concerns were negotiated during the design phase, in partial answer to research question 3. Clearly, using these differences productively was not trivial, establishing effective and efficient discourse appeared to be difficult. Our team combines many talents and areas of expertise which have complemented one another to produce an interesting, innovative design. However this took an effort much greater than expected. This may partly be due to personalities. But what we believe to be important and how we approach our goals, i.e. our concerns and how we handle them, are unlikely to be very different in other teams that combine teachers and academics. It may be *because* our areas of expertise are so closely related and yet irreducibly different in their 'cultural orientation' (Labaree, 2003) that we find it difficult to reconcile some of our concerns and translate the findings of research into effective classroom practice.

Although our concerns continue to differ in some areas, we seem to have found an approach that allows us to be and remain productive as a team, and forms a basis for working on reconciliation. The approach arose naturally but does appear to align with the preceding analysis of concerns. Its features:

1. Specify in as much detail as possible the 'common ground' in the team: the shared professional and personal objectives and concerns, and the shared ideas on how address these.
2. Translate this 'common ground' into a structural plan for the design, and as a team, commit to implementing it. (In our design, the EPER approach provided that structural plan.)
3. Divide tasks, then allow each to work out that task in his/her own way, with support on details but no further discussion on content or structure (unless the structural plan is compromised).
4. Appoint a chief editor to combine the different parts into a coherent whole.
5. Defer discussions on difficult matters so that new shared experiences can help clarify opinions or provide them with empirical support, and a new 'common ground' is given time to emerge.

As is common in action research, this analysis is meant to contribute to our discourse. It suggests that it is *natural* for teachers and academics in science education to differ on key assertions related to our field. Our expertise compels us independently to evaluate each claim rather than accept it based on trust in its presenter. But with each central assertion we have different data and backing, and different cultural orientations by which we value these. Unless *our expertise* changes, no reconciliation of concerns seems feasible. The easiest way to accomplish this is to develop further common experience and shared ways to evaluate it, especially in the areas in which assertions create trouble. This will obviously require a great deal of patience, trust, and willingness to learn. This is difficult enough but pointless without a sense of direction - something this paper tries to provide.

New ideas, objectives and concerns were raised during the implementation and evaluation phases by the teachers who used the designed materials in their classrooms. They provided useful input for the revision and for the teacher manuals on technical and structural aspects. On some issues, however, teachers' views diverged. An overview of their main views and the similarities and differences between teachers, as interpreted by the designers, was given in Table 2 in answer to research question 2.

In coming to understand teachers' views and the differences among them, the notion of a teacher's 'curriculum emphasis', involving the role and function of *knowledge* in the teaching and learning of mechanics, functioned well. Education unavoidably involves 'processing knowledge', where theory is explained and students learn to apply it. Some teachers, however, incorporate further, alternative emphases of 'developing knowledge' and/or 'utilizing knowledge', in which the status and nature of scientific knowledge, and its problem solving capabilities and societal values, respectively, play central roles. These alternative emphases also play key innovative roles in the design and resulted in implementation problems for many of teachers with a 'processing' focus.

Using this perspective, Table 2 shows how differences among teachers and between teachers and designers were interpreted in the implementation and evaluation phase, as a further answer to research question 3. Table 2 shows how these interpretations affected the designers' plans. Opportunities to collaborate with teachers in establishing a 'common ground' for implementing the design became limited at that stage. We therefore decided to maintain the EPER structure as the central innovative aspect of the materials, but to provide teachers with a choice as far as 'developing' and 'utilizing knowledge' activities are concerned. With those who are keen to use these activities, we intend to collaborate in subsequent research. It will involve the design of effective professional development strategies for these alternative curriculum emphases and the associated educational innovations.

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