Time structures of teaching and learning processes

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1. Introduction

The investigation of teaching and learning processes (in physics) under the paradigm of conceptual change is one important aspect of research in (physics) education. Referring to the conceptual knowledge that is taught and learned, studies mainly investigate whether concepts are "correct" and at what levels these concepts are constructed. However, it is not only the content of the concept playing an important role but also the time structure in which the concept is developed and taught. Teachers may present a concept rather quickly and thus it may not be easy for students to follow the presentation even if they would be able from a cognitive point of view. Or, two learners may construct the same knowledge (in respect to content and level of abstraction) but one needs only a few seconds whereas the other has to think about it for a few minutes. Moreover, also assessments are (intuitively) structured on the basis of time spans. For PISA, students were given a mean of 5 minutes to solve a task, teachers plan their exams in respect to expected rapidity of students. So, it has to be noted that although time dependency of teaching and learning seems to play an important role, only a very view investigations are carried out to analyse the impact of time structures on the development of knowledge. This is even more surprising as psychologists as well as neurobiologists stress the importance of limiting time spans for cognitive activity. In educational psychology different time spans for the working memory and the short term memory are introduced, ranging within seconds and minutes (cf., Anderson, 1995). Neurobiologists argue that the brain has only 3 seconds available to bind internal and external signals together to one meaning or mental image (cf., Pöppel, 1994; Damasio, 1994).

Within research carried out at Bremen, the time structure of teaching and learning processes was systematically investigated and theoretically modelled (cf., S. v. Aufschnaiter & Welzel, 1999; S. v. Aufschnaiter, 2001). Methods used and results gained upon students of different age and with different experiences in physics are presented in the following sections.

2. Methods

Within the last 15 years a lot of process based investigation in respect to physics learning have been carried out in Bremen. Setting and participants, contents, and duration of these studies are presented in Table 1. In all cases processes of the group work were completely documented with video (in the classroom focusing on two groups).

Setting and participants	**Content**	**Duration**
Experimental settings, in total 45 groups of two to three students. Students of grade 8 and 11, after grade 13, after their 5th semester of studying physics, and after their physics diploma.	Electrostatics and electrodynamics. Tasks and instructions written on cards to make processes within and between cohorts comparable.	Three to five lessons on a weekly basis, each lasting about 90 minutes.

Field settings in two classrooms, two groups of three to four students in each classroom. Students of grade 8 and 11.	Electrostatics and electrodynamics. Tasks for group work written on cards, instructions were given by the teachers.	Five to seven weeks, with about 50% of group work and 50% of class-room work.
Field settings in four classrooms, two groups of three to four students in each classroom. Students of grade 10.	Electrostatics, electromagnetism, physics of atoms and nuclei, radioactivity.	Comprising the whole school year (90 minutes per week)
Field settings in the University physics labwork, in total 41 groups of two students each. Students studying physics or engineering in their first two years at University.	Mechanics, Optics, Electrodynamics.	A laboratory session comprises about 2 to 3 hours. In total four to twelve sessions per group

Table 1. Studies carried out in Bremen (cf., C. v. Aufschnaiter & S. v. Aufschnaiter, 2003; Haller, 1999; C. v. Aufschnaiter, 1999; Meyer-Arndt, 2000)

In sum, the cognitive processes of about 250 students in school and university while working on physics tasks have been investigated as well as the teaching processes of six teachers. Using protocols and transcripts of teachers' and students' activities, time structures for working on tasks and instructions as well as time structures to present or to work upon coherent contents on small time scales (seconds) were measured. Results are presented in the next section.

3. Results

Results on time structures of cognitive processes show surprisingly high similarities between the students of all age groups in respect to two time scales:

- Related contents are constructed on time scales of less than 30 seconds (with an average of about 12 seconds). They normally comprise three to eight more or less connected mental images (often not needing 3 seconds each). Within this time span, students try out one way to solve a task. If this way does not lead to a solution, students turn to a different content (and may come back to the previous aspect later on).
- Students work on tasks or subtasks not longer than 5 minutes (with an average of about 90 seconds). Within the time span of 5 minutes they try out different ways to solve the task. If students are not successful within this time span they skip working on the task, mainly expressing their experience of failure. If such experiences take place too often, there are indications that this leads to a decrease of interest in (the specific topic of) physics.

When investigating teachers it might be assumed that there should be different time scales as teaching is normally not related to (larger amounts of) learning. However, analysing teachers who are "normally" prepared for their lessons again these time scales were found. Also teachers do not explain longer than 30 seconds following a specific content (or strongly related contents). Although teachers might experience their explanations to be coherent for a longer time scale, switches can be found within the time span of 30 seconds. Moreover, like the students, teachers do not deal longer than 5 minutes with a specific (sub-)task during teacher centred instruction. However, it should be noted that the content and the level of abstraction

developed while solving tasks (largely) differ from students' constructions. Besides the problem of the mismatch between content and level of abstraction between teachers' and students' situated understanding, teacher centred instruction seems to have at least one more crucial problem concerning time scales. Teachers' ways to solve a task are usually attempts to find appropriate questions or hints for students to answer a larger problem (the task from the teacher's point of view). However, students often understand each teachers' way to solve the task as a task itself and therefore do not understand "what this is all about".

4. Conclusions and Implications

Outcomes of studies like they are described above may contribute to the following aspects:

- A more detailed understanding of the constraints in teaching and learning situations.
- An explicit improvement of instruction in which time scales are used to structure questions and tasks, so that students can experience success within 5 minutes.
- Take into account that the development of interests may be based on repeated experiences of success (experiences of competence) on time scales of less than 5 minutes.

5. Bibliography

Anderson, J.R. (1995). *Cognitive psychology and its implications.* New York: Freeman and Company.

Damasio, A.R. (1994). *Descartes' error. Emotion, reason, and the human brain.* New York: Avon Books.

Haller, K. (1999). *Über den Zusammenhang von Handlungen und Zielen*. Berlin: Logos.

Meyer-Arndt, M. (2000). *Interaktionen im Physikpraktikum zwischen Studierenden und Betreuern*. Berlin: Logos.

Pöppel, E. (1994). Temporal mechanisms in perception. *International Review of Neurobiology, 37,* 185-202.

von Aufschnaiter, C. (1999). *Bedeutungsentwicklungen, Interaktionen und situatives Erleben beim Bearbeiten physikalischer Aufgaben.* Berlin: Logos.

von Aufschnaiter, C. & von Aufschnaiter, S. (2003). Theoretical framework and empirical evidences on students' cognitive processes in three dimensions of content, complexity, and time. *Journal of Research in Science Teaching* – accepted for publication.

von Aufschnaiter, S. (2001). Development of complexity through dealing with physical qualities: One type of conceptual change? In H. Behrendt et al. (Eds.). *Research in science education - Past, present, and future* (pp. 199-204). Dordrecht, Boston, London: Kluwer.

von Aufschnaiter, S. & Welzel, M. (1999). Individual learning processes – A research programme with focus on the complexity of situated cognition. In M. Bandiera, S. Caravita, E. Torracca, & M. Vicentini (Eds.). *Research in science education in Europe* (pp. 209-215). Dordrecht: Kluwer.