Conceptual development in physics: Does conceptual knowledge precede activity?

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1. Introduction

Research on students' conceptions forms a major part of the investigation into the teaching and learning of science (cf., Duit, 1999). Such research is largely concerned with four fundamental assumptions about students' conceptual knowledge:

(1) Successful completion of a task requires conceptual understanding.
(2) Students entering a physics classroom will have prior conceptions.
(3) Students' conceptual knowledge will not necessarily match that of scientists.
(4) Students' conceptual knowledge can change when they are shown contrasting models illustrating 'correct' conceptions (Posner et al, 1982).

These assumptions seem to be a common feature of most theoretical frameworks, yet investigations seldom analyse whether they describe the <u>processes</u> of developing and using conceptual knowledge. Assumption number (1) would suggest that human activity is initiated by conceptual knowledge. However, our everyday experience seems to indicate the opposite: we are able to switch on a TV and choose a specific programme without having learnt anything about the function of a switch in an electric circuit and how the picture emerges on the screen. To do the washing up, we do not need to know about surface tension, nor about the role that washing-up liquid plays in reducing the surface tension which enables any fat to dissolve more easily. These and similar examples support an alternative hypothesis that conceptual knowledge emerges out of experience and does not need to be in place prior to the undertaking of an activity. Therefore, it may be considered that:

(1) students' activities and statements emerge without a theoretical foundation: "I'll just do it this way" (*explorative*).
(2) students' activities and statements are based on intuitive rules developed through repeated activity: "I don't know why it works but it does" (*intuitive rule based*, see also cf., Stavy & Tirosh, 1996).
(3) over time students may relate activities and statements to theoretical knowledge explicitly: "It is always like this because in such cases always a …" (*explicit theory based*).

Referring to this distinction, a system of categories on students' development and usage of conceptual knowledge was set up and tested with data on physics instruction.

2. Method

This investigation is part of a series of five experimental studies in which pupils and physics students aged between 14 to 28 worked in small groups on tasks concerned with electrostatics and electrodynamics (cf., C. v. Aufschnaiter & S. v. Aufschnaiter, accepted). This paper focuses on the first two cohorts of this series: six groups of 8th graders, nine groups of 11th graders, and three groups repeating the investigation after an interval of two years. Over three weekly sessions, each lasting about 80 minutes, the students worked in groups of three on a variety of tasks based mainly on experiments and their explanations. The students had also access to a variety of materials to carry out the experiments. Furthermore, students were offered additional instructions which contained conceptual based explanations of the phenomena they were investigating. Tasks and instructions were written on cards to allow comparison of students' processes within and between the cohorts. Each session was recorded on video. The videos were used to create descriptions on students' activities and utterances. Although this procedure is similar to transcription, it does not contain every detail of the process, the resulting written material is therefore called "protocol" instead of "transcript". The protocols were then coded with a system of categories describing levels of (conceptual) understanding. The system comprises three categories each containing three sub domains:

Table 1. *Categories on Conceptual Development*

Area	Level	Description
explorative	**E**xperimen**T**	Students carry out an experiment (and/or describe what they observe).
	Mental **E**xperiment	Students "remember" a prior experiment (and/or describe what happened).
	DEscription	Students use linguistic elements (of any type) to describe observed/remembered phenomena or objects.
intuitive rule based	**E**xperience **B**ased	Students express an assumption about what will happen.
	Statement **B**ased	Students refer explicitly to a statement which is important from their point of view.
	ATtribution	Students make use of specific linguistic elements (physics terms) to describe observed/remembered phenomena and objects.
explicit rule based	**GE**neralisation	Students express a generalisation explicitly.
	EXplanation	Students develop a rule which is based on the connection between two or more aspects (one of which is a generalisation).
	HYpothesis	Students explicitly predict the result of an experiment on the basis of rule based connections.

The categorisation system was developed, tested, and modified using different sets of data. Once it had been shown to apply to events occurring across different groups it was used to investigate other material. Individual events (e.g., a single experiment or a coherent explanation), normally lasting no more than 30 seconds, were ascribed to different categories. Within the next few months, further data will be analysed and a test on observers' reliability will be carried out to evaluate the validity of the framework and method.

3. Results

The following table demonstrates the way categories were attributed to the events seen on the video (abbreviation of categories in brackets). In this example, three 8th graders (David, Norman, Jacob) were working on tasks about inducting an electroscope (3rd session, first two tasks):

Table 2. *Example of a Protocol and Ascribed Categories*

task 3.1:	**Hold rubbed material above the electroscope-plate. Do not touch the plate with the material. What do you observe?**
	Students hold different material above the electroscope-plate. (ET)
	Students discuss that the plate should not be touched with the material. (SB)
	Students find different deflection. (EXP)
David:	It does only depend on the rubbing. How heavily one is rubbing and an air balloon cannot be rubbed heavily. (GE)
David:	I always saw the same deflection. (ME)
David:	With the air balloon, the deflection was not very big because the balloon wasn't rubbed heavily. (AT)
	Students fix the results.
task 3.2:	**What do you observe if objects rubbed differently are used?**
David:	I've seen different deflection. (ME)
David:	The more you rub the more the needle deflects, the less you rub the less the needle

deflects. (EX)

Note. Descriptions and the student's comments have been shortened.

The analyses completed so far indicate that in more than 50% of individual events students follow an explorative approach. The instructions based on conceptual knowledge were used only once students had already reached a theoretical level on their own. However, they only used the parts of the instruction-cards which referred to the content that they had already developed. Furthermore, the results seem to demonstrate that the development of conceptual knowledge requires concrete experience. First, students grappled the problems with objects and words in an unsystematic fashion. With increasing experience students' activities seemed to be more systematic: rules which refer to experiences rather than to explicit theoretical considerations were developed. Statements that were explicitly based on theoretical frameworks (conceptual knowledge) mainly emerged following the completion of tasks. It should also be noted that there are indications that specific patterns in successive categories seem to accompany increasing stability of students intuitive and explicit rules.

4. Conclusions and Implications

Theoretical considerations and the results indicate that the stability of students' conceptions developed prior to teaching is a result of their experiences and may often relate to intuitive rather than to explicit theoretical understanding. This would suggest that teachers should not introduce a new concept unless students had had prior experiences in respect to the concept they should develop. Further research in this areas may reveal the nature of conceptual development and the factors that have an impact upon this development.

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5. Bibliography

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