Strategies for Conceptual Change in School Science

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Abstract

This study explores how experienced science teachers promote conceptual change. It examines how instructional strategies, learning tactics [1] and conceptual change interrelate. Pupils must construct new concepts while still having old ones [2]. Their evolving learning tactics are sometimes distorted by naïve techniques [3].

Three research methods (expert microteaching, verbal protocols and retrospective debriefing) were used. Data was video-recorded and managed using NVivo 9. Six 11 year-old pupils took part (three girls and three boys) in each expert microteaching interview, led by a science specialist (Advanced Skills Teacher). A ‘Concurrent Verbal Protocol and Retrospective Debriefing’ interview [4] happened with the teacher one month later. Six teachers participate altogether. All interviews were analysed using grounded theory methods [5]. The interpretivist theoretical perspective (symbolic interactionism) was underpinned by a social constructionist epistemology.

Initial findings show teachers use nine ‘teaching instruments’, ten ‘skill stratagems’ and six ‘deception stratagems’. Pupils demonstrate three learning tactics. Failure (strategic friction) is also explored.

What can be considered evidence is a function of the researcher’s methodological position [6]. So what constitutes reliable evidence can be contentious. Appropriate criteria for evaluating the grounded theory emerging from this study [7] were used. Interpretivist approaches for investigating conceptual change in school science are necessary to avoid unbalanced dominance by positivist literature. This approach, proved successful in other fields [4], is new to this context. The assumption that instructional strategy is straightforward [8] does not adequately explain the data collected here. However, abandoning attempts to unpick complicated interactions between pupils and teacher whilst learning takes place, leaves practitioners without guidance. Consensus exists among most conceptual change researchers that instructional strategies, learning tactics and conceptual change must be considered together where possible [9]. This present study proposes a grounded theory for how experienced science teachers promote conceptual change and questions how instructional strategy is understood in the literature.

1. Research questions

How do experienced science teachers promote conceptual change in children?

How are instructional strategy, learners’ reasoning tactics and conceptual change in school science related?

2. Methodology

The research questions arose from my concern, as an experienced science teacher, to understand how best to support children when they express naïve concepts. This is an emergent research problem [10], a characteristic of grounded theory, which is the methodology used in this study. A
second influence is the desire to address, from a teaching perspective, the rift between practice and research acknowledged in the literature [11]. ‘Naïve concept’ is common and not used pejoratively.

Here the distinction between qualitative and quantitative research arises at the level of research methods [12]. Underpinning the research methods are the theoretical perspective (interpretivism) and epistemology (constructivism). This present study is interpretivist in that it attempts to explain and understand [13] the variety of ways teachers promote conceptual change. Does knowledge of science classroom culture help or hinder this task of understanding and explaining complicated classroom dynamics? The interpretivist theoretical perspectives of symbolic interactionism and phenomenology respond in opposing ways to this question. An assumption behind this study is that some understanding of the meaning participants ascribe to incidents in the data is necessary, in order to understand what experienced teachers do when supporting students who express naïve concepts. Hence the theoretical perspective is symbolic interactionism. The approach taken here resembles that of Corbin and Strauss [5] who acknowledge symbolic interactionism and pragmatism as the philosophies underpinning their version of grounded theory.

As the theoretical perspective is a way of looking at, and making sense of, the world, it therefore involves knowledge. I see meaning in this study emerging from an engagement between participants (including myself) within this educational context. The underlying epistemology is therefore constructivist. But ‘constructivism’ can refer to epistemology, ontology, methodology or pedagogy [14]. Constructivism denotes epistemology in this study. The main types of constructivism [15] are personal construct psychology, radical constructivism and social constructionism. This study explores how individual science teachers use instructional strategy to influence conceptual change within groups of pupils both directly, and through guiding the pupils’ learning tactics. Therefore social constructionism underpins this work.

The constructivist and interpretivist approach adopted here could have led to either a qualitative, quantitative or mixed methods study. Educational researchers into conceptual change teaching strategies have already used various quantitative methodologies to test theories. One study [16] trained teachers to use specific teaching strategies, then compared pre and post test results for “treatment” groups of pupils with control groups. Such work can help practitioners, but should be balanced by the qualitative approach taken here, which seeks to construct a grounded theory from what experienced science teachers apparently do to promote conceptual change in a messy context which models, to some extent, what happens in science classrooms. That research concluded:

…it may be that an understanding of causal relationships between teaching strategies and student learning can best be advanced by studies relying on rich qualitative data from small numbers of classrooms. [16]

Here it is argued that rich qualitative data from whole classrooms can only be interpreted once a grounded theory for conceptual change is established, preferably by qualitative research.

An assumption behind this present study is that small scale, and often subtle, actions of the teacher and pupils are highly significant in promoting scientific conceptual change. Collecting evidence from a teacher with a whole class, during a normal school day, would not allow the context of conceptual change to be examined in sufficient detail for these small scale effects to be identified. Nevertheless, the context of conceptual change being investigated needs to resemble normal class life so that the grounded theory developed might eventually be used to interpret whole class interactions. Hence the research methods are a necessary compromise between naturalistic observation and laboratory conditions. The interpretation of whole class dynamics may depend on a satisfactory theory for these small effects. Consequently this study represents a first step, and the theory which emerges will need testing on whole classes. Whole class effects probably have significant influence on the strategies for conceptual change used by teachers.
Research methods used in this study are a combination of ‘expert microteaching’ (EMT), ‘verbal protocols’ (VP) and ‘retrospective debriefing’ (RD). A combination of concurrent verbal protocols and retrospective debriefing was used before and “research based guidelines” were followed [4]. All three types of interview were recorded using two video cameras filming from different angles so events could be seen from one camera, even if obscured in another. Microteaching [17], a method designed to train new teachers, is here adapted into an instrument for learning from experienced teachers. Six science teachers, all qualified Advanced Skills Teachers, were recruited. Every expert microteaching session was videoed and lasted one hour. Each session involved six pupils from year 7 (aged 11 or 12) and one teacher. 6 teachers and 36 students will take part. Participating teachers were asked to choose three boys and three girls from year 7. Sessions contained equal numbers of girls and boys where possible. Participant selection will be discussed further during the presentation. Discussion ranged over topics in chemistry, biology and physics. A questioning route was developed to direct the groups’ attention. Topics were identified from a review of ‘science misconceptions’ [18] and chosen as ones where students have many naïve ideas. Three resources were provided: a cup of tea and a bowl of ice cubes (‘heating and cooling’ topic), a card sort activity (‘living things’) and a teddy bear, torch and small whiteboards (‘light’). Key questions were:

1. Please tell me what is happening to the hot tea and the cold ice cubes.
2. Please sort these cards onto the spaces on the two mats: one for living things and the other for non-living things.
3. Please imagine you walk into a completely dark room with that torch on and you see teddy. Please make a sketch showing the torch, teddy and your eye which explains how you can see the bear.

Verbal protocols (VPs) involved the participating teacher watching, and commenting on, short clips from the EMT video, selected when a pupil expressed a naïve concept and/or where I had difficulty interpreting something or wished to compare interpretations. Each participating teacher ‘thought aloud’ for 30 minutes as they watched these video clips while being recorded on video. Immediately after the VP interview the teacher was interviewed for 30 minutes more (‘retrospective debriefing’ or RD) using open-ended questions and a questioning route. Questions were adapted in the light of previous interviews while the study progressed (the grounded theory process called ‘theoretical sampling’ [5]). There was a month’s delay between the EMT session and the other interviews (VP and RD). This allowed firstly the EMT video to be analysed using grounded theory techniques, secondly video excerpts from the EMT to be edited for use as prompts in the VP interview, and finally questions based on the analysis to be prepared for the RD interview.

3. Findings

“[A strategy is a] prudent idea or set of ideas for employing the instruments of … power in a synchronized and integrated fashion to achieve … objectives.” [19]

The objective explored in this study is conceptual change. Conceptual change research, which emerged from the “misconception movement” [2], catalogued many naïve concepts children express when studying science. 194 naïve concepts and 57 conceptual change events were identified in the first three EMT interviews.

Nine ‘teaching instruments’ identified in the data are described in table 1. Teaching instruments are plausible hypotheses for instructional methods that could have contributed to conceptual changes that appeared to have occurred:
### Table 1: Teaching instruments

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of teaching instrument</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Persuasion</td>
<td>Attempt to convince.</td>
</tr>
<tr>
<td>2</td>
<td>Redirection</td>
<td>Influence the direction of a discussion.</td>
</tr>
<tr>
<td>3</td>
<td>Clarification</td>
<td>Attempt to elucidate.</td>
</tr>
<tr>
<td>4</td>
<td>Support</td>
<td>Assist either personally, or by organizing other staff or students to help. May involve physical intervention, emotional and/or behavioral management. Additional or different resources could also be used.</td>
</tr>
<tr>
<td>5</td>
<td>Transfer</td>
<td>Tell, confirm or refute.</td>
</tr>
<tr>
<td>6</td>
<td>Condition</td>
<td>Make a response occur more frequently as a result of reinforcement.</td>
</tr>
<tr>
<td>7</td>
<td>Task</td>
<td>Use an activity (e.g. an experiment, worksheet, questions…).</td>
</tr>
<tr>
<td>8</td>
<td>Group</td>
<td>Use whole class, group, individual tuition or a combination of these.</td>
</tr>
<tr>
<td>9</td>
<td>Timing</td>
<td>Act now, later or never. Delay could involve changing the order of actions. Pace can sometimes be adjusted.</td>
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</table>

Three sorts of learning tactic were used by pupils (and sometimes influenced by teachers): tactics for producing new ideas, assessing ideas and anomaly resolution [1]. Students were also observed using learning tactics which professional scientists are unlikely to use.

The theoretical perspective underlying this present study acknowledges how prior knowledge influences our interpretation of other peoples’ actions. Thus teacher, pupils and researcher each have knowledge which moulds not only their understanding, but even what they see and hear [20]. Within the teachers’ knowledge, a set of ideas called stratagems has been identified from the data which guide the use of these teaching instruments. It proved useful to identify two kinds of stratagem: skill stratagems (table 2) involve intelligent use of teaching instruments, whereas deception stratagems entail a:

“distortion of perceived reality” [21]

Nine types of skill stratagem were found:

<table>
<thead>
<tr>
<th>No.</th>
<th>Skill stratagem</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Overlapping*</td>
<td>Attend to more than one thing simultaneously.</td>
</tr>
<tr>
<td>2</td>
<td>Preparedness#, Withitness* and reflection</td>
<td>Know what to expect, understand what is going on and learn from what happens.</td>
</tr>
<tr>
<td>3</td>
<td>Momentum*</td>
<td>Maintain flow.</td>
</tr>
<tr>
<td>4</td>
<td>Smoothness*</td>
<td>Avoid (and use) distractions and loss of focus during and between activities.</td>
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<tr>
<td>5</td>
<td>Group focus*</td>
<td>Control the itinerary.</td>
</tr>
<tr>
<td>6</td>
<td>Cognitive matching#</td>
<td>Skillfully choose who does what.</td>
</tr>
<tr>
<td>7</td>
<td>Detachment</td>
<td>Metaphorically ‘step back’.</td>
</tr>
<tr>
<td>8</td>
<td>Quality</td>
<td>Direct individuals along the most appropriate ‘route’ to a conceptual objective.</td>
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<tr>
<td>9</td>
<td>Capacity utilisation</td>
<td>Match teaching strategy to circumstance.</td>
</tr>
<tr>
<td>10</td>
<td>Ripple effect</td>
<td>Use an intervention with one person to influence others.</td>
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</tbody>
</table>

Table 2: Skill stratagems  
Key: Those marked * come from [22] and with # from [23]

Two kinds of deception are possible [21]: dissimulation (hiding the real) and simulation (showing the false); both can be further subdivided. The three types of dissimulation are masking (make invisible), repackaging (disguise) and dazzling (cause someone to lose clear vision). Three types of simulation are mimicking (through imitation), inventing (displaying a different reality) and decoying (diverting
Teachers and students appear to use all six types of deception stratagem. Many examples of strategy going wrong (‘strategic friction’) were identified in the data.

Nine teaching instruments, three learning tactics, ten skill stratagems, six deceptive stratagems and ‘strategic friction’ constitute the grounded theory. This study is on-going. Participant teachers used some techniques more than others (fig. 1 below):

![Graph showing number of references for most coded nodes for first 3 EMT interviews](image)

**Fig. 1:** Graph showing number of references for most coded nodes for first 3 EMT interviews

Positivist approaches to investigating conceptual change strategies have encountered several significant problems [16]. Interpretivist investigations of conceptual change strategies in school science like this present study have not been attempted, even though such an approach has been successful in exploring problem-solving in other fields. ‘Optimistic’ (for example [8]) and ‘pessimistic’ [20] views of conceptual change strategy both fail to adequately model classroom dynamics. This study shows that teachers can and do influence conceptual change and the learning tactics children use, and that instructional strategy is not a simple matter. This ‘middle way’ could be useful for teachers. An integrated approach to conceptual change research [9] is necessary. Conceptual change, learning tactics and instructional strategy should not be treated as isolated fields of study. However, current integrated approaches only incorporate positivist research and optimistic views of strategy. This paper argues that an interpretivist approach with a ‘middle way’ understanding of strategy can and should be incorporated into integrated conceptual change research.

**References**


