

Secondary learners' use of particle ideas to explain familiar phenomena

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The study reported here was carried out in the Cambridge area of England during a period of several months during spring and summer 2005. The study was designed to find out how secondary age students would explain a range of demonstrations relating to phenomena commonly met in school science.

Methodology

Data was collected study using semi-structured interviewing techniques with secondary students. The use of simple demonstrations (e.g. mixing two liquids) is an example of a well-established type of protocol used in science education research, known as 'interview-about-events'. A repertoire of demonstrations was developed, but as interviews typically lasted about 20-30 minutes (a reasonable time to maintain student interest and concentration), only a selection of demonstrations could be included in each interview. Audio recordings were made of the interviews, and these were later transcribed for analysis.

Sample

Data was collected from 46 secondary students, from 5 schools. The schools were co-educational state schools (three in the City of Cambridge and two in adjacent villages). Students were volunteers, nominated by their class teachers as being willing to spend time being interviewed, selected from across the ability range.

* <http://people.pwf.cam.ac.uk/kst24/index.html>

Data analysis

There were two stages in the analysis of data. The first stage used an iterative open-coding procedure to look for themes in students' explanations.

We then considered the specific question of the extent to which the student explanations drew upon the 'key idea' of particles, and whether particle-based explanations elicited matched the scientific models presented in the curriculum. The second stage of analysis involved classifying segments of our data into a number of categories:

N: no explanation offered

M: an explanation is offered, which does not call upon particle ideas (i.e. a 'macroscopic' or 'molar' level explanation)

P1: an explanation is offered in terms of particle ideas, but is not considered to offer a scientifically acceptable response (in terms of the models taught in the curriculum)

P2: an explanation is offered in terms of particle ideas, which is considered to be a scientifically acceptable response (in terms of the models taught in the curriculum)

We have analysed transcripts by episodes, where an episode reflects the recorded dialogue about a particular demonstration.

Findings

Intuitive ideas used by students

From the open-ended analysis of student comments we identified five types of intuitive ways of making sense of phenomena (sometimes called p-prims or 'phenomenological primitives' in the literature). These are summarised in table 1.

focus of p-prim	candidate p-prim	brief description	note
inherent property	P1: Component gives property	Substances' properties derive from <i>components</i> that have an inherent property	e.g. a blue substance has some component that is inherently blue
causation needs explaining:	P2: Changes require active agents	change requires cause (unless 'natural')	e.g. something external (heat, mixing) causes mixing
causation needs explaining:	P3: There is one active partner	a reaction involves an active partner acting on a passive partner	the active 'chemical' forces another chemical to <i>react</i>
inherent nature	P4: Substances that (naturally) react	reacting is the natural process when certain substances interact	it is in the nature of certain chemicals to react with suitable substrates
inherent nature	P5: Things have a (natural) predetermined configuration	certain configurations are natural	systems will spontaneously evolve towards certain 'natural' configurations

Table 1: Five candidate p-prim identified in the study

The so-called p-prim are not right or wrong in themselves, but when applied in inappropriate contexts, they lead to understandings at odds with scientific thinking.

Use of particle ideas

There were just over two hundred discrete episodes in the database, relating to five classes of phenomena: dissolving; changing state; mixing; chemical reactions; and immiscibility.

Considering all five classes of phenomena demonstrated, there are 202 episodes in the database (see Table 2), and students offered explanations in 190 episodes (i.e. 12 were categorised as N).

Class of Phenomena	No of episodes in database	N	M	P1	P2
Dissolving	79	7	22	36	14
Physical changes	41	2	5	10	24
Mixing	32	1	13	15	3
Chemical reactions	26	-	8	14	4
Immiscibility	24	2	13	8	1
Overall	202	12 (6%)	61 (30%)	83 (41%)	46 (22%)

Table 2: The overall classification of interview episodes

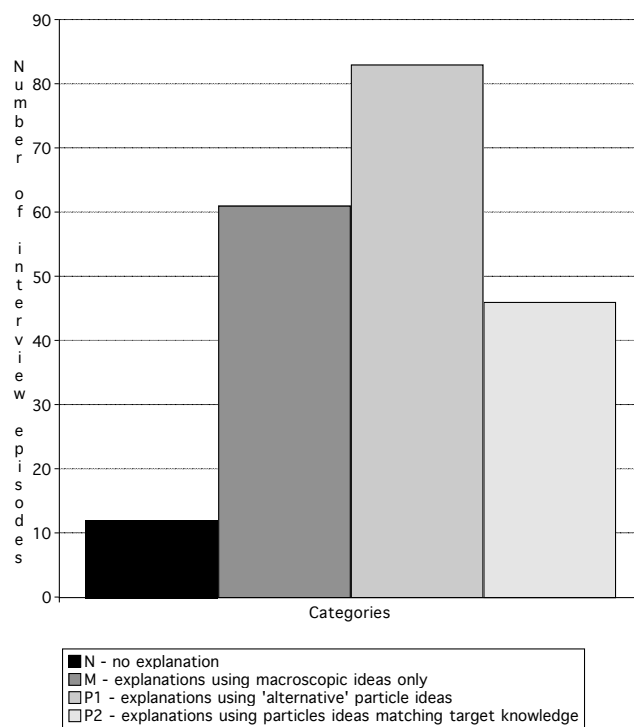


Figure 1: Distribution of student explanations across levels

Just under a third of the explanations (see figure 1) offered were framed purely in macroscopic terms (61 categorised as M). This means that in nearly two thirds of the episodes, students *did* offer explanations that drew upon the ‘key idea’ of particles. However, in most of these cases (83 categorised as P1) the explanations offered were not acceptable in terms of the scientific particle models taught in school science. So scientifically acceptable particle-based explanations were offered in just over one-fifth of the episodes recorded (46 categorised as P2).

The only class of phenomena where the students in our sample were generally able to offer acceptable responses was that of physical changes. This is not obviously the simplest class of phenomena to explain, and it may seem odd that students seemed to find mixing (for example) a more challenging class of phenomena to explain with particle ideas. However, the particle model is generally introduced and taught *in the context of* teaching about the states of matter – and then subsequently applied in various other contexts.

Although our sample is spread across the secondary age range (see Table 3), the nature of the sample does not allow us to make reliable comparisons between year groups.

year group	No of episodes in database	N	M	P1	P2
7 (KS3)	15	1	8	6	-
8 (KS3)	26	2	8	11	5
9 (KS3)	74	5	19	39	11
10 (KS4)	60	3	25	18	14
11 (KS4)	27	1	1	9	16
total	202	12	61	83	46

Table 3: Classification of interview episodes by year group

Conclusions

We have investigated the extent to which students could explain basic physical and chemical phenomena using particle ideas. This is an important focus because the particle concept is absolutely fundamental to understanding much of modern science, but previous studies have repeatedly demonstrated that this topic leads to such considerable learning difficulties that students frequently develop their own alternative conceptions inconsistent with the scientific models. This topic therefore offers a significant challenge to those designing science curricula and teaching schemes.

The present study found that most students in our sample were not able to use the particle model to provide explanations that matched scientific thinking. There already exists a good deal of research that indicates *why* this is a challenging topic, and *where* students commonly ‘go wrong’. It would seem guidance to teachers must be developed that is based on more sophisticated research-informed pedagogy.

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Note: This is a brief overview of the research prepared for the five schools which kindly supported the project. More detailed accounts are being prepared for publication, and details may be obtained from the authors (who may be contacted by email to kst24@cam.ac.uk or alegfranco@gmail.com)

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