Using concept maps with trainee physics teachers

Peter Adamczyk and Mike Willson *University of Sussex, Brighton, UK*

The technique of Concept Mapping described here is useful for identifying gaps in trainee teachers' knowledge, which may then be addressed to help those who must nowadays teach Science outside their own specialism.

The introduction of Broad and Balanced Science for All in schools, coupled with 9/92 teacher competency requirements with respect to subject knowledge [1], has given Higher Education Institutions and others considerable logistic problems in preparing Secondary PGCE trainees to teach outside their own specialism at National Curriculum Key Stages 3 and 4. As Jennison [2] notes: 'the demand on the subject knowledge of Science students is greater than for any other students, and the time available [to address this] is getting less'. In addition, if one accepts the premise of Harrison and Pritchard [3] that A-level standards in separate sciences are required to teach effectively across the three main specialisms, at the higher levels of Key Stage 4, and that in reality nearly two thirds of PGCE students teach in areas where they have O-level equivalents or less, then the task becomes indeed a considerable one.

The problem may even be evident where teachers are teaching their *own* specialism. In looking at the shortage of physics teachers nationally, Brenda Jennison points out that many schools do not have sufficiently well qualified physicists to sort out misconceptions that trainee teachers have in that subject. As she pointedly remarks: 'A first-class honours degree in Physics does not guarantee an accurate knowledge of the subject good enough to teach with'.

With the move towards school-based teacher training, future trainee teachers may spend as little as 80 hours on curriculum studies within their HEI and as a consequence it becomes imperative that students identify as quickly as possible gaps in their knowledge base needed to teach a particular area of Science and address misconceptions accrued throughout their own education. It should be emphasized at this stage that a single year of initial training, predominantly school-based, can only be expected to equip trainees with a mechanism for starting this process, and that if there is to be a serious attempt to address the problems outlined above, the PGCE year must form part of an ongoing professional development programme with a corresponding entitlement to relevant in-service training, particularly in the early years of teaching.

In considering the knowledge base problem encountered by PGCE trainees and Newly Qualified Teachers, an approach we have found promising in facilitating the identification of individual needs is the use of Concept Mapping. Its use as an 'active learning' tool enables gaps in knowledge and misunderstandings, which later might lead to misconceptions, to be targeted and then rectified through a series of planned activities, supported by suitable 'remedial' work where necessary. We have used this technique successfully in the diagnosis of practising teachers' misconceptions, and the subsequent evaluation of the effects of INSET activities on their knowledge and understanding [4]. In light of this we therefore considered that it would be an appropriate tool to use with our Secondary PGCE Science cohort.

As we have indicated elsewhere [5], the technique of Concept Mapping provides a flexible, multi-purpose tool with several models of mapping available to the user. In the context of the need described in this article we opted for the free-range mapping technique, since it enables the more able and/or older student to form complex links and develop sophisticated concepts. This type of map also allows both gaps in knowledge and misconceptions to be easily accessed, giving an 'open' opportunity for trainees to show what they know. The main disadvantage with this type of map is that detailed analysis can take a relatively long time and may not yield all the information needed for summative assessment purposes – not a problem in this situation. It was decided in this instance that the Physics tutor provide a list of prime descriptors (key words), which were taken from Attainment Target 4 across Key Stages 3 & 4 of Science in the National Curriculum. However, time permitting, prime descriptors may also be provided by an initial brainstorming session with the students.

Trainees were introduced to free-range concept mapping in a morning workshop during the Induction Week of their PGCE Course, building upon the idea in stages. We begin with our definition of a concept as the smallest unit of thought that can be totally abstract [5]. From this starting point we contend that as concept acquisition becomes more

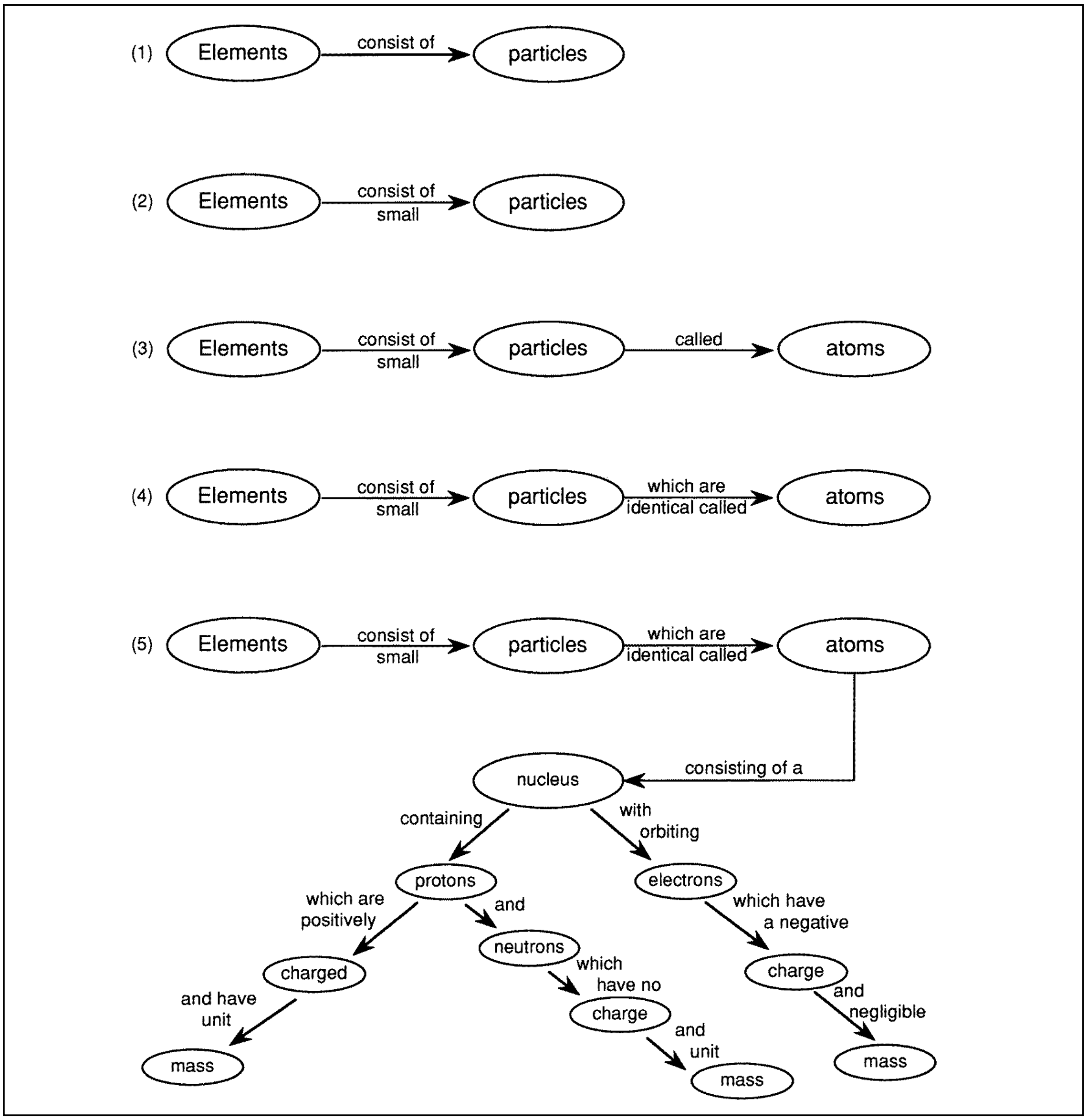

Figure 1. *Trial concept map.*

sophisticated, the learner gains the ability to apply the concept(s) in a wider range of contexts, bridging to different areas of knowledge, and in doing so ensuring that what perhaps began as a concrete concept (little more than an idea) becomes increasingly abstract within the organization of the knowledge base, as shown in figure 1. It was stressed to trainees that the exemplar map shown as stage 5 in figure 1 is essentially hierarchical in nature and it may be that in their own attempts they would wish to link the prime descriptors in a different manner, as they felt was appropriate. However, it is the propositional statement and the direction of the arrow linking prime descriptors that are equally important in defining the understanding of a concept.

Trainees were then invited to construct their own maps using the prime descriptors provided for them. Figure 2 shows an example generated at the beginning of our PGCE course by a trainee with a first degree in Physics. The prime descriptors represent an area of the Physics component which previous experience indicated was 'conceptually difficult' for PGCE Science trainees. They are listed in the bottom right hand corner of figure 2. Trainees were given as long as necessary to complete their maps (some trainees spending coffee break and lunchtime refining them); the maps were then collected in for analysis by the Physics tutor.

Analysis of the completed maps was carried out at different levels: the first was to consider individual links in terms of the accuracy of the 'link' (propositional statement and direction of the arrow), i.e. was it a misconception? The next level of analysis considered the number of links made and whether all prime descriptors had been used, as this gives an indication of the extent of their knowledge base. After this the relevance of the 'links' is evaluated, not only for individual linkages but over a coherent number of linkages, as applicable. Thus the analysed maps had a number of markings on them indicating misconceptions and irrelevant 'links'. Also the tutor wrote comments on each map indicating the general level of the whole map and conceptual areas on which the trainee should concentrate. Another level of analysis, not applied in this situation, is to consider the source of the prime descriptor, i.e. the National Curriculum (Science), and the 'links' may

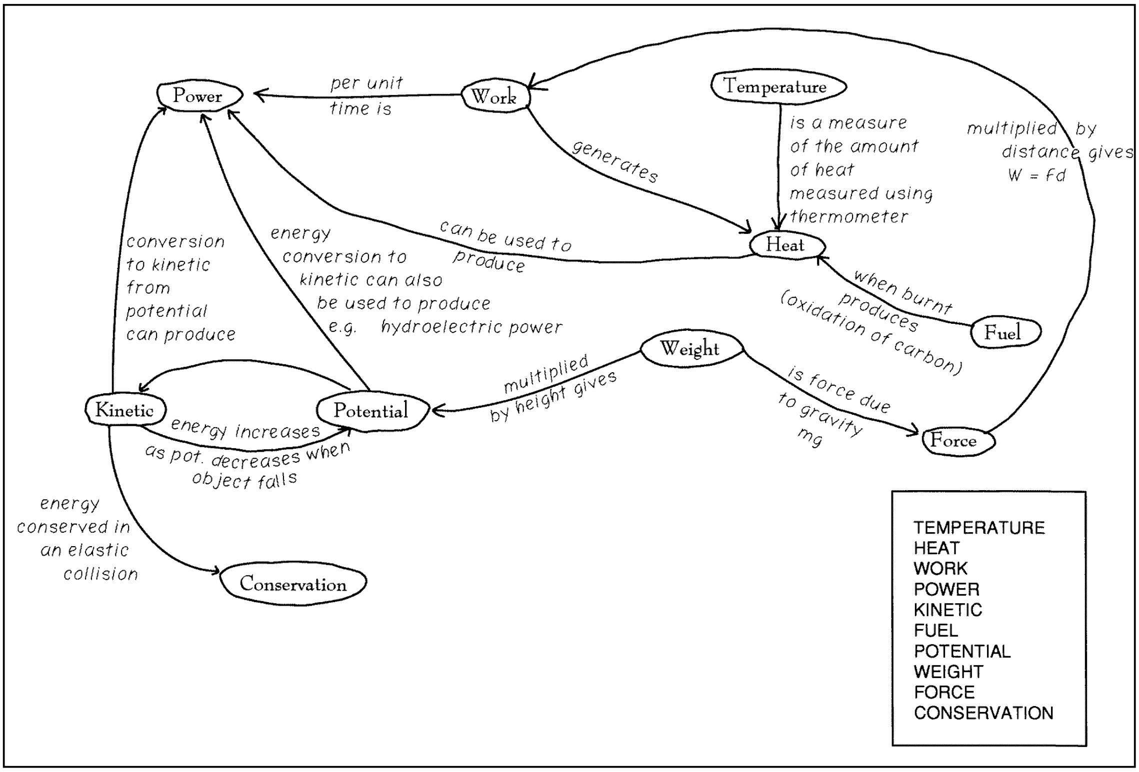

Figure 2. *A concept map 'pre-instruction' produced by a Physics graduate.*

be 'scored' using level statements as defined by the Attainment Targets/Examination syllabuses as we have illustrated elsewhere [4].

The validity of this technique in the diagnosis of trainee teachers' misunderstandings in science was tested in the area of Chemistry using 'blind interviews' with a representative sample of eight trainees, exploring both the problem area mapped and their understanding of concept mapping. The results of this triangulation are reported elsewhere [6].

The representative example chosen (figure 2) confirms Jennison's assertion that a graduate may have gaps in knowledge and understanding even within their own discipline, which may prove problematic when coming to teach their own subject. In this case the map indicates a basic understanding of the content chosen for inspection

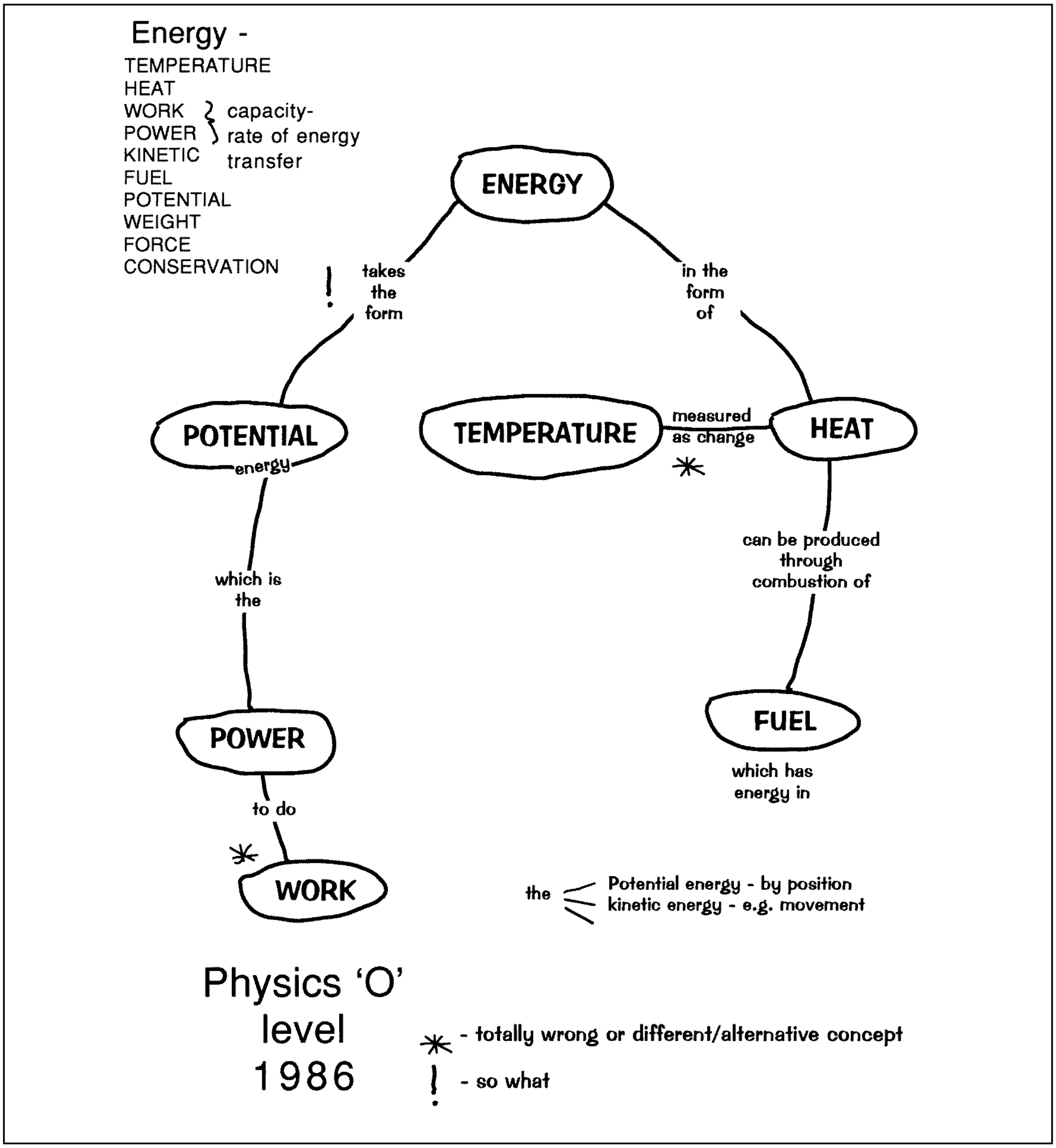

Figure 3. *An inaccurate map drawn by a Biology specialist.*

although several problem areas are evident. Foremost is the lack of understanding shown between heat and temperature as these are linked with the proposition: '[Temp] is a measure of the amount of heat, measured using a thermometer [Heat]'. Other potential problem areas are indicated by propositions such as: '[Work] generates [Heat]', and '[Heat] can be used to produce [Power]'. In general the one-to-one propositional links are limited and the overall structure of the map shows a need to refine the conceptual base of this area of content. Even with individuals relatively new to the mapping technique we would have expected an effective Physics teacher to demonstrate a more sophisticated hierarchical overview of this crucial area of energy and its transfer.

The situation can be worse when a student is required to teach outside their own discipline. Figure 3 shows a map drawn by a Biology specialist using the same prime descriptors. It contains no directional arrows, is largely inaccurate and not all the prime descriptors have been used, indicating

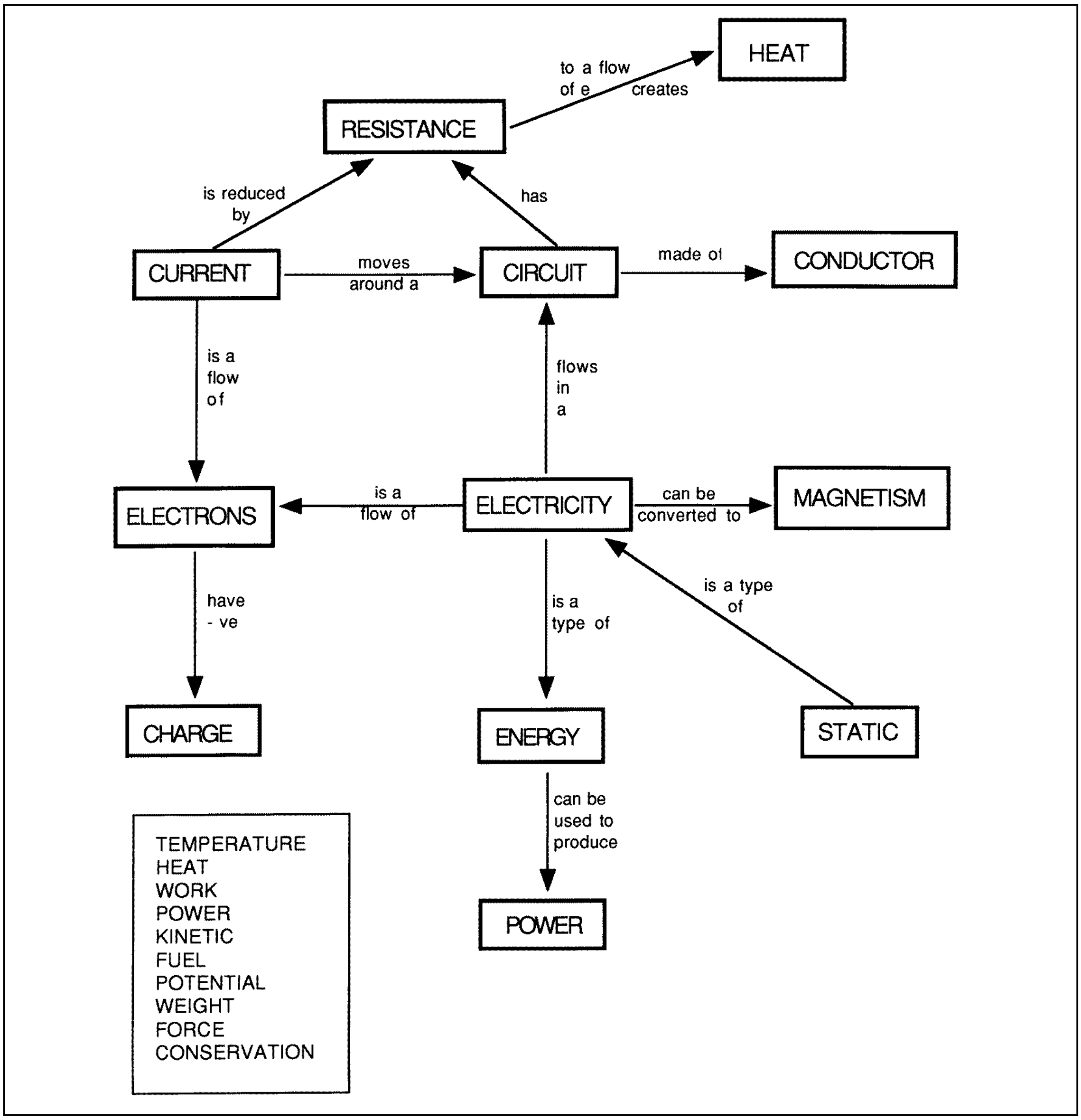

Figure 4. *A concept map of electricity and magnetism 'pre-instruction'.*

significant gaps in the trainee's knowledge base. There is little conceptual grasp of energy and its transfer and there is additionally confusion over energy and power. Using a different set of prime descriptors, one of our Chemistry PGCE students produced the map shown as figure 4. In this case the trainee shows a basic understanding of electrical phenomena but indicates problems, in that the inclusive concept electricity is simply equated with the *flow* of electrons, also that it can be **converted** into magnetism, and there is no indication of an understanding of the nature of static electricity.

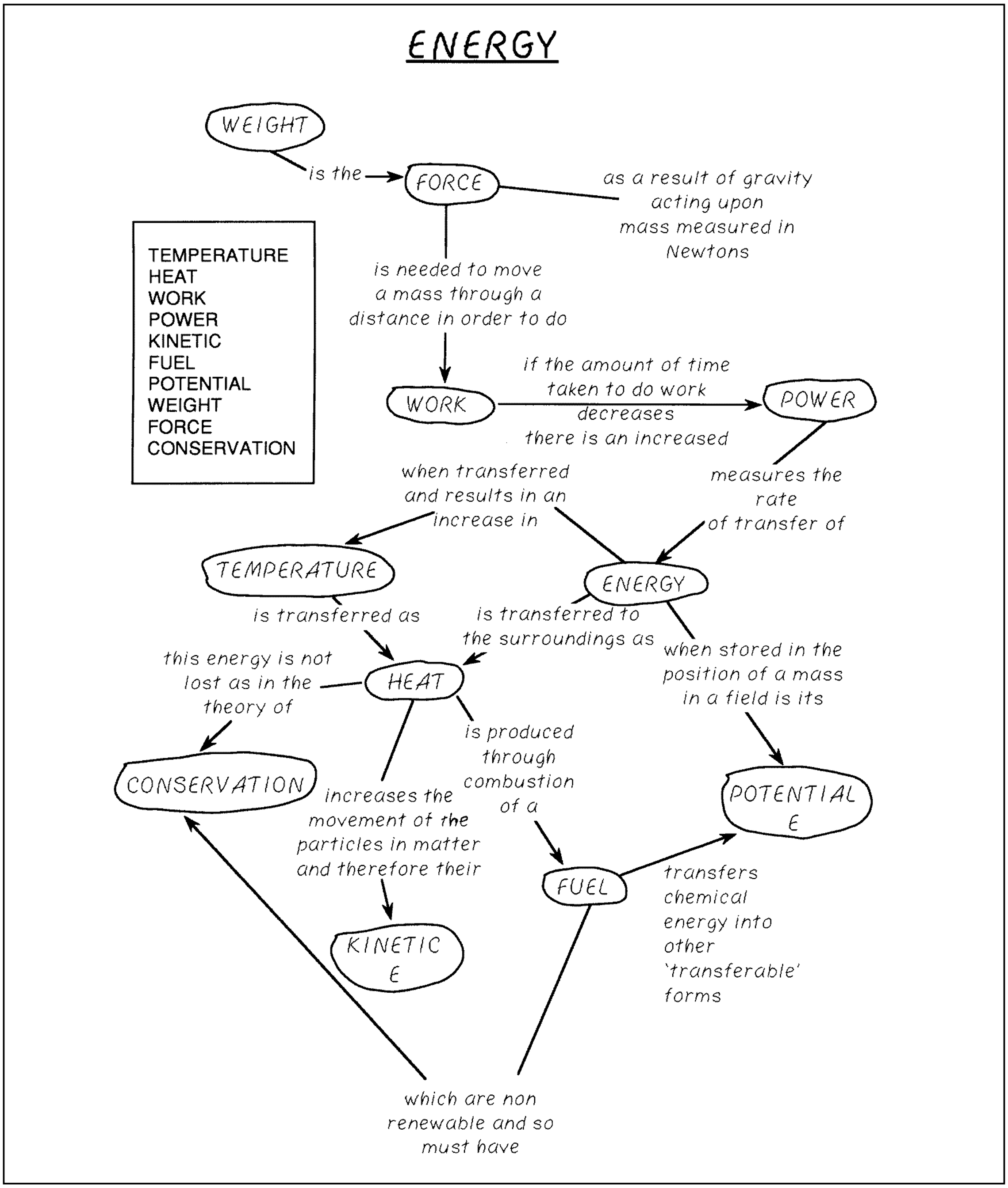

Figure 5. *A map produced by the Biology student at the end of the course.*

Following the analysis of the pre-course concept maps of last year's Science trainees, discussion with students regarding their maps allowed us to consider appropriate 'remedial' programmes to meet individual needs and develop these accordingly. Cross-specialism peer support groups were constructed and suggested as one avenue for addressing misconceptions, and common difficulties were made the focus of subsequent university-based science curriculum workshops. School-based Mentors were shown the maps and trainees were encouraged to undertake consultation with other school-based colleagues when preparing lessons in areas of Science with which they were not familiar, and in particular those areas indicated as needing attention by their maps. In addition, small groups of trainees were encouraged to consider the demands of the National Curriculum (Science), Key Stages 3 & 4, in terms of overarching concepts. They were asked to identify key words and construct their own maps for analysis/discussion with peers and tutors over the period of their course.

At the end of the PGCE course the trainees completed a post-programme concept map using the original prime descriptors. The results from the Biology student referred to above are shown as figure 5. The map here shows greater complexity and sophistication with respect to the propositional statements, and directional arrows are included so making it more meaningful. A detailed analysis indicates a refinement in the concept of energy transfer, work and power, but 'popularist' notions of energy conservation, heat being **produced**, along with confusion between the concepts of heat and temperature and their relation to kinetic energy still need attention. On interviewing this student it was revealed that attempts at remedial action in terms of knowledge and understanding had been primarily through the use of 'standard' school physics textbooks. The post-course map produced by the Chemistry trainee (figure 6) shows an increase in complexity, indicating that the student has addressed gaps in knowledge, but not enough attention has been paid to developing depth in

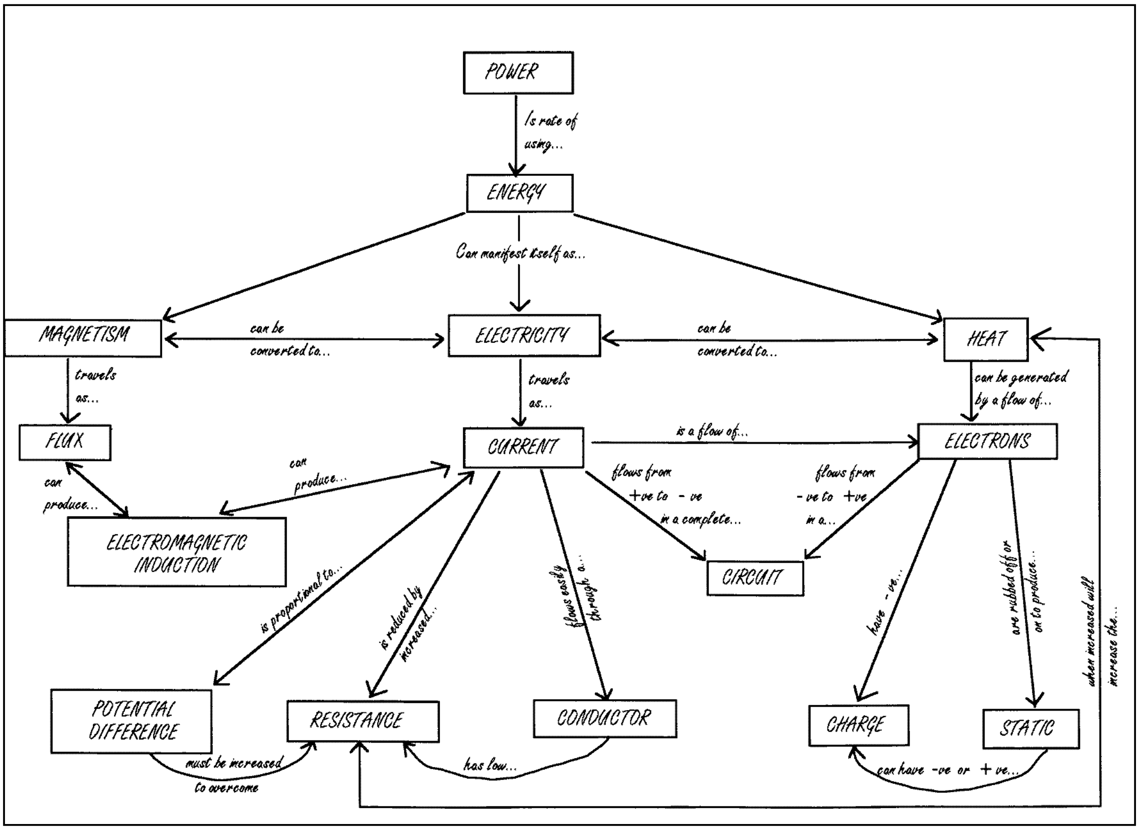

Figure 6. *A concept map of electricity and magnetism 'post-instruction'.*

conceptual understanding. Propositions such as power as the rate of **using** energy (rather than the rate of transfer) and electricity being **converted** into magnetism are still included.

The progress, or otherwise, of the trainees shown above is typical of last year's cohort in that an analysis of their maps shows an improvement in the broadening of their knowledge base but not always a corresponding deepening of their conceptual understanding. Common problems that emerged were misconceptions over:

- The nature of energy and its transfer.
- Energy availability from the fuel–oxygen system.
- The difference between heat and temperature (often regarded as synonymous).
- The relationship between weight and 'potential' energy.
- The relationship between work and power as well as that between force, work and energy.
- The similarities and differences between static and current electricity.
- General wave phenomena.

Our findings have implications not only for our PGCE course and the way in which trainees address gaps in their knowledge and understanding, but also for INSET courses designed to meet the needs of teachers during the induction period and on into Continuing Professional Development. Prospective teachers need to be encouraged to become 'active learners', taking responsibility for their own development in terms of improving their knowledge and understanding of physics. We submit that concept mapping offers an individualized diagnostic tool, enabling trainee teachers to embark upon this process.

Received 4 December 1995, in final form 29 March 1996

References

[1] DfE Circular 9/92 *Initial Teacher Training* (*Secondary Phase*)

[2] **Jennison B** 1993 *Report of the Fourth Meeting of the Institute of Physics Education Group* (dated 17th June)

[3] **Harrison J and Pritchard J** 1993 The demands on newly trained teachers of science at Key Stage 4 *Educ. Sci.* **150** 9–11

[4] **Willson M, Adamczyk P and Williams D** 1994 Evaluating science INSET through concept mapping *Br. J. In-Service Educ.* **20** 1

[5] **Adamczyk P, Willson M and Williams D** 1994 Concept mapping: a multi-level and multi-purpose tool *Sch. Sci. Rev.* **76** (275) 116–24

[6] **Willson M and Williams D** 1996 Trainee teacher's misunderstandings in chemistry: diagnosis and evaluation using concept mapping *Sch. Sci. Rev.* **77** (280) 107–13