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ABSTRACT

For the past eight years postgraduate science teachers in training (approximately 50 each year) have been given Assessment of Performance Unit (APU) questions under strict test conditions as part of an initial learning experience in an education course. The APU questions were originally devised to explore the range of understanding of 15-year-old pupils in the United Kingdom of some key concepts in biology, chemistry, and physics. The key concepts probed included air pressure, oxidation, conservation of mass, photosynthesis, and reactivity series. Comparison of responses shows that beginning science teachers with a degree in biology, chemistry, or physics give more correct responses than 15-year-olds, as expected, but there remains a level of incorrect responses among the science graduates. The response patterns of the postgraduates remain similar from year to year. This study provides support for the view that alternative conceptions of scientific phenomena remain even in those who have experienced a high level of education in science. Implications for the training of preservice teachers are considered. Contains 23 references. (Author/WRM)

Science subject knowledge of pre-service postgraduate science teachers.

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Abstract
For the past eight years postgraduate science teachers in training (about 50 each year) have been given APU (Assessment of Performance Unit) questions under strict test conditions as part of an initial learning experience on the Southampton course. The APU questions were originally devised to explore the range of understanding of 15 year pupils in the UK of some key concepts in biology, chemistry and physics. The key concepts probed include: air pressure, oxidation, conservation of mass, photosynthesis, reactivity series. Comparison of responses shows that beginning science teachers with a degree in biology, chemistry or physics do give more scientifically correct responses than 15 year olds, as expected, but there remains a level of incorrect responses amongst the science graduates. The response patterns of the postgraduates remain similar from year to year. The study provides support for the view that alternative conceptions of scientific phenomena remain even in those who have experienced a high level of education in science. Implications for the training of pre-service teachers are considered.

Background

Teacher preparation in England and Wales is increasingly focusing on the science subject knowledge of new entrants to secondary science teaching. Entrants are usually graduates with a degree related to a main discipline of biology, chemistry or physics. They undertake a one year teacher training course in preparation to teach across the sciences in the 11-13 age range and their specialist science to ages 14-19. This focus on subject knowledge is a requirement of the Teacher Training Agency (TTA), the body in England which regulates national teacher training provision. From 1999/00 a statutory curriculum will be enforced for all those training to be science teachers.
This curriculum has three elements:
Pedagogical knowledge and understanding required by trainees to secure pupils' progression in science.
Use of effective teaching and assessment methods.
Trainees' knowledge and understanding of science.

Course providers have to audit trainees' subject knowledge against the content of the Science National Curriculum and the Advanced 'A' level core (16-19 syllabus) in the specialist science. "Where gaps in trainees subject knowledge are identified, providers must make arrangements to ensure that trainees gain that knowledge during the course and that, **by the end of the course**, they are competent in using their knowledge of science in their teaching." In addition, "trainees must demonstrate that they know and understand the nature of science" as part of the teacher training course. (DfEE, 1998 p118) The curriculum is intended to support the achievement of a long list of Standards, which trainees have to demonstrate in order to achieve Qualified Teacher Status:
Knowledge and Understanding; Planning, Teaching and Class Management; Monitoring, Assessment, Recording, Reporting and Accountability; Other Professional Requirements. (DfEE, 1998)

The interplay between different knowledge drawn upon and gained during initial teacher education is complex. A framework similar to that of Adams and Krockover (1997) is implicit in the TTA ITT curriculum and Standards for newly qualified teachers - with elements of knowledge as: PCK, subject matter, knowledge of self, general pedagogical knowledge, knowledge of the milieu. Of these elements, the main focus of initial teacher postgraduate education in the UK has traditionally been on development of pedagogical content knowledge, general pedagogical knowledge and associated teacher skills and attributes. The inclusion of a detailed prescription of a subject knowledge base creates additional demands on an already demanding course which consists of 12 weeks in the university and 24 weeks in school placements.

Although this national approach to teacher training gives a clear cut stance as to teaching requirements, there is controversy over what science subject knowledge is needed for beginning secondary science teachers (Ratcliffe, 1998). The TTA appear to have taken a pragmatic line by expecting the current pupils' National Curriculum and syllabuses to dictate the subject content audit and development.

Kennedy (1998) highlights five distinct ideas of conceptual understanding of science for science teaching:
A sense of proportion - a minimalist approach which few consider adequate
Understanding the central ideas - a focus on the big ideas of science
Seeing relationships among ideas - understanding of interrelationships is necessary in order to focus pupils' attention on big ideas
Elaborated knowledge - detailed specific knowledge within domains
Reasoning Ability - using understanding to reason, develop arguments, solve real problems and justify solutions.

As Kennedy points out, a focus on elaborated knowledge may not ensure an understanding of interrelationships - it may just be recitational knowledge unless an underlying organisational framework is present in the individual. The TTA ITT curriculum implies a view of teacher knowledge as elaborated knowledge rather than an overview of major concepts.
The focus of this study is on trainee science teachers' understanding of a few major ideas but with some detail (elaborated knowledge) in areas of chemistry.

Even elaborated or recitational knowledge by itself is not a secure base for teaching. Shulman's (1986) idea of pedagogical content knowledge is important in teacher education - the translation of complex subject knowledge into ideas, concepts and models which pupils can grasp. Development of good pedagogical content knowledge involves reconceptualising one's own content knowledge, recognising pre-conceptions pupils may have and devising 'strategies most likely to be fruitful in reorganising the understanding of learners' (Shulman, 1986 p10).

If we assume, for the moment, that there is consensus over the body of knowledge regarded as a pre-requisite for secondary science teaching, there enters a more problematic area - the evaluation of this knowledge base in trainee teachers. Trainee secondary teachers are mostly graduates with 50% or more of the degree content in one of the three sciences - their specialist discipline for teaching 14 year olds onwards. Traditionally this subject base, and the degree classification of the graduate, has been taken as a measure of specialist knowledge with little attention to updating knowledge. The auditing and development of subject knowledge calls into question the nature of the qualifications the science graduates already have. Yet it has been known for some time that scientists can graduate without a complete understanding of some fundamental science concepts and that they lack a coherent picture of the structure, function and development of their specialist scientific discipline (e.g. Anderson, Sheldon & Dubay, 1990; Lederman, 1992; Pomeroy, 1993; Abd-el-khalick & Boujade, 1997; Trumper & Gorsky, 1997). This study thus uses assessment items developed specifically for exploring the range of pupil understanding of fundamental topics.

Assessment of subject knowledge - actions of the APU

> "The Assessment of Performance Unit (APU) was set up in 1975 within the Department of Education and Science (DES) to promote the development of methods of assessing and monitoring the achievement of children at school, and to seek to identify the incidence of underachievement. The APU exists to provide objective information about national standards of children's performance at all levels of ability. Such information can help to inform decisions about where and how improvements to the educational system can be made." (DES, 1989)

The APU no longer exists but its actions were instrumental in bringing evaluation of pupils' conceptions to the attention of teachers and government alike. APU science work also led to the establishment of the *Childrens Learning in Science Project* under Rosalind Driver at Leeds and the *Open Ended Work in Science* at King's College, London. The APU science team was led at Kings College, London by Paul Black and at Leeds University by Fred Archenhold. An overview of the impact of APU Science on policy and practice is given by Black (1990).

The APU Science team devised, what were then, novel methods of exploring pupil understanding using the following domain- based framework:

Domain	Assessment method
Use of graphical and symbolic representation	written test
Use of apparatus and measuring instruments	group practical test
Making and interpreting observations	group practical test
Interpreting presented information	written test
Planning parts of investigations	written test
Performance of investigations	individual practical test
Applying biology concepts	written test
Applying chemistry concepts	written test
Applying physics concepts	written test

Tests were developed, trialled and then administered to large cohorts of pupils at ages 11, 13 and 15. Stratified random sampling from different types of schools across England, Wales and Northern Ireland enabled confidence that the results reflected the national picture.

Results of the APU work were made accessible to teachers as short reports showing examples of questions as well as major findings.

Methodology

APU items for 15 year olds are given to postgraduate trainee science teachers at the start of their course in this university. The information collected over 8 years from using these APU assessment items was not just conceived as an ongoing research study. Teaching intentions were at the forefront. The first day of the Southampton postgraduate course is devoted to placing trainee teachers as learners in a school context. The three science tutors each 'deliver' a lesson to the course cohort who are banded into three groups labelled as 'top', 'middle' and 'bottom'. Despite trainee teachers' random assignment to one of these three groups, tutors attempt to reinforce the labelling through their actions as teachers. Each group undertakes the three lessons in a different order. The lessons are: a open-ended practical with the tutor taking an uninterested and very relaxed stance; a structured practical session with clear intended learning outcomes with the tutor acting supportively; a written test with no prior warning with the tutor (myself) taking an authoritarian stance. Following these activities, tutors lead a de-briefing in which the implications of teacher action are discussed. The test also forms the basis of a later session on the advantages and disadvantages of different assessment methods. In this later session the trainees' achievements are compared with the original pupil cohort. Additionally, the test raises ongoing issues for trainee teachers about their subject knowledge.

As the procedure was kept the same from year to year it became evident that the data collected lent themselves to some analysis of different cohorts of trainee teachers' conceptions of some important science concepts. As a consequence the outcomes from administering the same test to each new cohort over a period of eight years are reported and analysed.

Although the main focus of this report is the outcomes from this written assessment, other methods are used during the course to explore and develop subject and pedagogical content knowledge. These are discussed later along with the implications from the study.

Assessment items.

Items were selected from the *Applying concepts* APU category only, on the basis that multiple methods are more necessary to ascertain levels of science skills and processes. Items were selected from the APU reports for 15 year olds. The level of conceptual demand of these seemed more appropriate for science graduates than questions aimed at 11 and 13 year olds. The items could be regarded as mainly an opportunity sample - i.e. they had to be taken from those items which were given in full, including pupil outcomes, in the available reports (DES/APU, 1984; DES/APU, 1988). There was a skew towards chemistry items as a result. Concepts examined are representative of those within the science curriculum rather than ensuring coverage.

Concepts explored were thus:

Concept	Item	Source
Air pressure	*Syringe*	DES/APU (1984)
Photosynthesis	*Sealed Tubes*	" "
Conservation of mass in chemical reaction	*Phosphorus*	" "
Combustion as oxidation	*Iron wool*	" "
Reactivity of different metals	*Metals*	DES/APU (1988)
Nature of displacement reaction	*Copper*	" "
Nature of reaction of metal with water	*Calcium*	" "
Periodicity	*Metal Region*	" "

The full items are shown in appendix 1.

Results

Science graduates' responses were compared with the original APU categorisation. Answers to APU questions were not marked correct or incorrect but different main responses were categorised, giving between 4 and 8 categories per questions. However, for each question there is one answer which could be regarded as a full and correct response. (Several of the other response categories can be regarded as partially correct rather than wrong.) The details of responses for all test items are shown in appendix 2.
[At the time of the original APU study of pupils, there was no National Curriculum in place. Pupils at age 14 could opt to do one, two or three sciences for the two year examination courses, according to the curriculum structure operating within the school. Hence the APU team recorded whether or not the pupil was still studying the relevant science.]

Three main areas for discussion arise from analysis of the test results:
1. Postgraduate trainee science teachers show a better understanding of the science concepts tested than 15 year olds, including those 15 year olds who were studying the specialist science.

2. There is a similar response pattern year on year for the cohorts of trainee science teachers.

3. Where 'misconceptions' are shown by trainee science teachers they are in line with those shown by 15 year olds.

1. Comparison between science graduates and 15 year olds

In total 392 science graduates answered all the test items. Their pattern of responses for each item was compared with those of the 15 year olds studying the specialist subject (Biology, Chemistry or Physics) using a chi-square test. It was felt more appropriate to use the data from the 15 year olds studying the subject than the whole 15 year old cohort to explore significant differences. If differences are present in comparison with the subject specialist at 15 they will be even more apparent for the whole population.

Table 1 shows the percentages of the populations giving different categories of response. A chi-square test was carried on the original frequency data. In all test items the relative proportion of responses in each category differs significantly between 15 year olds studying the subject and science graduates - in favour of scientifically more correct responses from science graduates. This is an expected result! However, it is worth exploring the responses in a little more detail. Although science graduates are significantly better than 15 year olds, there may be a number of interpretations of the evidence presented below, for each concept, in terms of science graduates' preparedness to teach.

Table 1 Comparison of responses of 15 year old pupils studying a specialist science with science graduates

Syringe		*Sealed tubes*		*Phosphorus*		*Iron Wool*		*Copper*		*Copper reasoning*		*Calcium*		*Metal Region*	
Phy 259	PG 392	Bio 355	PG 392	Che 224	PG 392	Che 224	PG 392	Che 210	PG 392	Che 210	PG 392	Che 50	PG 392	Che 50	PG 392
22	**39**	**46**	**87**	**41**	**84**	**42**	**67**	**44**	**43**	*6*	*18*	**20**	**37**	**40**	**59**
4	*16*	**48**	**77**	2	2	5	1	5	4	*11*	*11*	25	19	4	11
59	*40*	26	14	18	3	5	5	24	40	**25**	**26**	*23*	*18*	*12*	*12*
1	2	15	4	11	1	2	4	27	13	48	17	31	24	44	17
7	1	11	5	4	2	19	11			11	28				
5	2			4	3	10	2								
				20	5	10	5								
						7	5								
Chi prob 3.8E-13		Chi prob 3.6E-15		Chi prob 7.71E-28		Chi prob 7.5E-10		Chi prob 4.77E-6		Chi prob 1.31E-23		Chi prob 6.88E-5		Chi prob 1.29E-4	

Numbers in the table show **percentages** for each different category of response. Categories vary according to the individual item but **bold** indicates a full, scientifically correct response; *italics* indicates a partially correct response and normal text indicates an incorrect response.

2. Different cohorts of trainee teachers

Each year there were between 30 and 55 science graduates embarking on the one year teacher training course. Of these, about two-thirds each year have a biology based degree. Others have a chemistry or physics based degree (including geology and engineering). Unfortunately, records were not kept of responses according to degree discipline. However, inspection of each of the tables in appendix 2 shows a good degree of similarity in response from different trainee cohorts on most items. There is more variation amongst items exploring the detail of chemical reactions (*metal region*) than those testing fundamental concepts (*syringe, sealed tube, phosphorus).* The most extreme variation is between the 90/91 and 91/92 cohorts on the *metal region* item showing significant variation in responses (Chi-square probability of 0.003). This variation is smaller than comparisons between trainees and pupils for any items.

3. Nature of responses

Comments can be made about the nature of conceptions shown for each concept tested. Some fundamental physics, biology and chemistry concepts were explored along with a more detailed understanding (or possibly recall) of particular chemical reactions.
Salient features from different items are highlighted below

Air pressure (*Syringe*)

Considerably larger numbers of science graduates (39.3%) than 15 year olds (11%) explain water entering the barrel of a syringe using pressure changes inside **and** outside the syringe - a scientifically full answer. However, it would appear that many science graduates (39.8%), like 15 year olds (55%), conceptualise the action as a 'vacuum sucking'.

Photosynthesis (*Sealed Tubes*)
Far more science graduates (86.8%) than 15 year olds (37%) show “an appreciation of the need for light in the process of carbon dioxide uptake”. “27% of all pupils and 41% of those studying biology include in their answer the idea that plants take in carbon dioxide in the presence of light.” (DES/APU, 1984, p171). This compares with 77.3% of science graduates. The vast majority of science graduates recognise and explain the process of photosynthesis.

Conservation of mass in a chemical reaction (*Phosphorus*)
“Nearly 30% of all pupil responses indicated an awareness that mass is conserved in a chemical reaction. In some cases they argue in more concrete ways that nothing enters or leaves the container so the mass of the flask and contents will not change.” (DES/APU, 1984 p161). In contrast, 83.8% of science graduates recognise conservation of mass but with some ‘concrete’ responses as with pupils. For pupils, “the most common response (31%) was to predict a decrease in the weight or mass of the flask and contents. The kinds of reasons given included the idea that a gas or vapour weighs less than a solid, or that there is a loss in weight when a substance dissolves. Both these ideas suggest that pupils are considering weight as acting when a solid ‘presses down’ on a surface and does not therefore exist for a gas or for a substance in solution.” (DES/APU, 1984 p162). Six percent of science graduates still appear to hold this conception.

Combustion as oxidation (*Iron wool*)
“Overall 15% of pupils’ responses indicated an appreciation that the iron reacts with the oxygen thus producing an overall increase in mass. 42% of pupils studying chemistry gave this response compared with 4% of the others.“ (DES/APU, 1984 p157). In contrast, 66.8% of science graduates argued correctly. For pupils, the most popular result (54%) was to predict a decrease in mass. “The reasons given were either that ‘stuff’ is ‘driven off’ when a substance burns or that the ash left, in this case the powder, will weigh less than the original material. This idea of weight loss on burning is supported by everyday experiences. It is interesting to note that even the pupils studying chemistry made this prediction” (ibid). This appears to be a fairly persistent ‘misconception’ as 21.6% of science graduates reasoned in this way.

Reactivity of different metals (*Metals*)
The APU team interpreted results of the questions seeking recognition of specific metal reactions with water or steam, oxygen and dilute acid in terms of connection with the reactivity series. “In each case the frequency with which metals are thought to react roughly follows their reactivity series order.” (DES/APU, 1988 p24) The APU team suggest that variations may be to do with concrete and memorable experience of reactions. “It is possible that many of the observed anomalies are connected with specific teaching practices in this area, particularly where these involve vivid or reliable effects. This shows that pupils tend to base their understanding on specific instances rather than to link different ideas of experience, and suggests that more metals need to be demonstrated and the links between them made clear.” (ibid). It appears that this item is not just exploring understanding of a fundamental concept - different metals have different reactivity - but is also inviting recall of particular reactions (recitational knowledge). Science graduates’ responses reflect those of the 15 year olds studying chemistry but with better recognition of the lack of reactivity of gold. However, as with 15 year olds, one interpretation may be that concrete everyday experiences do not appear assimilated with formal chemical knowledge - 28.5% of science graduates consider that copper reacts with water or steam despite the common use of copper in water pipes etc. An

alternative interpretation of this response is that pupils and graduates try to respond in a 'school science' setting ignoring everyday experience.

Nature of displacement reaction (*Copper*)
As with the previous item, recitational knowledge (specific recall of reaction products) is explored as well as understanding a central idea (understanding of a displacement reaction). More science graduates than 15 year old pupils can give a very full (25.8% vs 10%) or partial (30% vs 15%) account which is a correct explanation of the nature of a displacement reaction. However, both pupils and science graduates appear to have difficulty in correctly identifying the reaction products and their properties. The majority of science graduates appear to recognise the reaction between iron and copper sulphate solution as forming copper and iron sulphate but with 42.9% correctly attributing the pink solid formed as copper and 39.6% considering it to be iron sulphate. This compares with 27% of all pupils (44% of those studying chemistry) and 13% of all pupils (24% of those studying chemistry), respectively.
For science graduates, the central idea may be more prominent in their understanding than recall or application to particular reactions.

Nature of reaction of metal with water (*Calcium*)
Lack of recitational knowledge is also apparent in the question asking for the products formed when calcium is added to water. In the margins of many science graduates' responses are the scribblings of equations - ie science graduates appear to have a procedure for tackling the question (reasoning ability). Most (76.4%) recognise the limited range of possible products but only 37% are able to provide the fully correct response. This contrasts with only 25% of all pupils (69% of those studying chemistry) recognising relevant possible products and 5% of all pupils (20% of those studying chemistry) providing the fully correct response.

Periodicity (*Metal Region*)
The APU team interpreted pupil responses to the question seeking them to shade in the region where metals are found on the Periodic Table as showing lack of understanding of groups in the periodic table. "Despite the generous criteria used for the metal region the knowledge even of the chemists was very sketchy. The largest single group of responses among chemists and non-chemists was not equivalent to any simple region of the Periodic Table. Single periods, single groups and even single elements were common and apparently random shading was frequent. About one-tenth of chemists associated only the transition metals with the metallic region, indicating perhaps a confused memory of some account of this area of the Periodic Table". (DES/APU, 1988 p30). In contrast, most science graduates (82.%) shaded the whole of an identifiable region, but a similar proportion to 15 year old chemists shaded the transition metal region. 59.4% of science graduates shaded all or most of the metal region.

<u>Discussion</u>
The results from this study, in terms of graduates' understanding of science, are open to a number of interpretations, as they rely on a single instrument. An important point Black (1990) emphasises in his overview of APU impact is the necessity to use a wide range of assessment methods to ensure reliability in evaluating pupil understanding and progress. This as true of evaluating trainee teachers' understanding as it is of pupils. Short tests cannot give fully reliable results. Hence there are limitations from extrapolating from the evidence presented in this study.

Given this caveat, should we be disturbed or pleased by the contrast between science trainee teachers and 15 year old pupils in answering test items?

Science graduates appear to have a good understanding of central ideas but have problems with recall of recitational knowledge when a test is sprung upon them. Many of the science graduates commented in the debriefing on their difficulty in remembering this 'school science'.

The cohorts are similar from year to year - ie there will always be some postgraduate trainee science teachers with 'inadequate' understanding of some science concepts. In this sense the TTA is maybe correct to insist on auditing and development of science knowledge. However, there is still not enough clear research evidence to guide teacher educators on two major issues:
- What is the best method(s) of evaluating trainee science teachers' subject knowledge?
- What is the relationship between subject knowledge and PCK?

Development of Praxis II subject assessment in the US has involved job analysis of newly licensed chemistry, physics and biology teachers, validated by teachers and teacher educators (Tannenbaum, 1992; Wesley, 1996). It is interesting that this has resulted in a conservative list of major science concepts for assessment - e.g. scientific methods, basic topics in physical sciences are rated as more important by teachers and teacher educators than biochemistry, modern physics, STS and pedagogy specific to physical sciences. This must raise questions about newly licensed and experienced teachers' preparedness to cope with curricula that draw upon contemporary science. Nonetheless, this work has identified major conceptual areas of importance. But it is not clear whether these concepts will be evaluated piecemeal (ie as recitational knowledge) or as exploration of interrelationships between fundamental concepts. As Kennedy (1998) implies the latter is necessary in teachers to provide adequate scaffolding for pupils in their conceptual development. Some of the same problems of attention to detail at the expense of key concepts and their interrelationships are evident in the pupils' curriculum. A recent seminar series funded by the Nuffield Foundation explored the aims, structure and implementional issues for science education for the 21st century. It identified that, among other important issues, the key concepts and interrelationships should be clearly articulated (Millar and Osborne, 1998). Currently there is too much emphasis on knowledge of the 'bricks' at the expense of appreciating the 'cathedral'.

This study did not set out to 'measure' subject knowledge of trainee teachers, rather it was an opportunity for trainee teachers to explore a particular approach to evaluating understanding of science concepts. Nonetheless, it has raised the importance of subject knowledge for trainee science teachers at the start of their course. For these intending science teachers there seems two slightly different cases in translating subject knowledge into PCK. For their specialist subject they often have detailed recitational knowledge which they reconceptualise appropriately as they develop PCK through their experience of planning and teaching. However, because they are expected to teach all three sciences in the 11-13 age range, most experience more uncertainty as to how to approach teaching and learning in the less familiar sciences. In both cases understanding of central ideas and their interrelationships are of major importance. At Southampton University we place trainee teachers in peer teaching groups, each containing specialists in each science, for part of their course in order to help them develop appropriate PCK. In these groups they are expected to consider and develop teaching and learning strategies for key areas they identify - i.e. there should be a mixture of

subject knowledge expertise for a particular concept within the group; this knowledge is pooled in developing some PCK for later implementation. We take the view that by doing this we are encouraging a process of development of PCK which can be built upon and adapted for whatever concepts there are asked to teach in future.
This approach is based on experience over the years and from using such crude baseline testing as the sample of APU test items outlined rather than any other research evidence. It appears there is limited research into the relationship between subject knowledge and PCK in science teachers. Magnusson *et al* (1994) studied the PCK of six teachers when teaching heat energy and temperature. Their study provides evidence that PCK is not necessarily stable - frameworks can change, not always becoming more accurate. Teaching strategies did not always follow from conceptual frameworks. Despite understanding the key misconception of confusing heat energy with temperature, "most of the teachers did NOT exhibit substantial knowledge of activities that emphasised the distinction between heat energy and temperature." Magnusson *et al* indicate that this demonstrates the complexity of how teacher knowledge translates into action and that further investigation of teacher knowledge is needed. Rahilly and Saroyan (1997) show that, for professors, who are regarded as exemplary higher education teachers, the following, ranked in order of importance, influenced their teaching approaches: PCK; current knowledge of learners; knowledge of content; knowledge of learners' background. Subject situated knowledge rather than general pedagogic or curricular knowledge is important. Rahilly and Saroyan indicate that knowledge of content is conceptualised as declarative and procedural - ie professors show an expert understanding of the *nature* of the discipline as well as detailed content. With this in mind, it is perhaps helpful that the TTA now have an expectation that intending science teachers will understand the nature of science - even though there is lack of consensus in this area (Alters, 1997; Smith *et al*, 1997).

Some recent studies have started to address the subject base of beginning teachers through a variety of methods e.g. concept mapping, interviews, tests of achievement (Goodwin, 1995; Bishop & Denley, 1997). It seems that explaining an idea, teaching others and devising appropriate learning activities are the routes by which understanding of scientific concepts become clearer - i.e. the translation of subject knowledge into pedagogical content knowledge through reconceptualising existing subject knowledge is a good method of ensuring a clear understanding (Goodwin, 1995). However, in a one year postgraduate course, the trainee teacher will only experience the teaching of a limited range of content.
Either consolidating subject knowledge through the development of PCK has to be regarded as taking longer than a one-year course or auditing and development of subject knowledge has to take place outside a teaching context. The latter stance has been taken by the TTA. It remains to be seen how effective this is in improving the initial training of science teachers.

References:

Abd-El-Khalick, F., & Boujade, S (1997) An exploratory study of the knowledge base for science teaching. *Journal of Research in Science Teaching* 34, 7, 673-699

Adams, P.E. & Krockover, G.H. (1997) Beginning teacher cognition and its origins in the preservice secondary science teacher program. *Journal of Research in Science Teaching* 34, 6, 633-653

Anderson, C., Sheldon, T., & Dubay, J. (1990) The effects of instruction on college non-majors' conceptions of respiration and photosynthesis *Journal of Research in Science Teaching* 27, 8, 761-776

Alters, B.J., 1997 Whose nature of science? *Journal of Research in Science Teaching*, 34, 39-55

Bishop, K & Denley, P (1997) The fundamental role of subject matter knowledge in the teaching of science *School Science Review* 79 (286) 65-71

Black, P (1990) APU Science - the past and the future *School Science Review* 72 (258) 13-28

DES/APU (1984) *Science in Schools Age 15: Report No.2* DES

DES/APU (1988) *Science report for teachers: 10 Metals at age 15* DES

Department of Education and Science DES (1989) *National Assessment: The APU Science Approach* London: HMSO

DfEE (Department for Education and Employment) *Teaching: High Status, High Standards Requirements for courses of initial teacher training.* Circular 4/98 DfEE

Goodwin, A. J. (1995) Understanding secondary school science: a perspective of the graduate scientist beginning teacher. *School Science Review* 76 (176) 100-109

Kennedy, M (1998) Education reform and subject matter knowledge. *Journal of Research in Science Teaching* 35, 3, 249-263

Lederman, N.G. (1992) Students' and teachers' conceptions about the nature of science: A review of the research. *Journal of Research in Science Teaching* 29, 331-359

Magnusson, S., Borko, H., and Krajcik, J.S. (1994) Teaching complex subject matter in science: Insights from an analysis of pedagogical content knowledge. *Paper presented at the NARST Annual Meeting, Anaheim, CA* EDRS ED390715

Millar, R. and Osborne, J. 1998 *Beyond 2000: Science Education for the future* (London: King's College London, School of Education)

Pomeroy, D (1993) Implications of teachers' beliefs about the nature of science: Comparison of the beliefs of scientists, secondary science teachers and elementary teachers. *Science Education* 77, 261-278

Rahilly, T.J. and Saroyan, A (1997) Memorable events in the classroom: types of knowledge influencing professors' classroom teaching. EDRS ED411719

Ratcliffe, M. (1998) Initial teacher education - another national curriculum! *Education in Science* April, 177, 8-9

11

Shulman, L.S. (1986) Those who understand: Knowledge growth in teaching. *Educational Researcher* 15, 2, 4-14

Smith, M.U., Lederman, N.G., Bell, R.L., McComas, W.F. and Clough, M.P. 1997 How great is the disagreement about the nature of science: A response to Alters. *Journal of Research in Science Teaching*, 34, 1101-1103

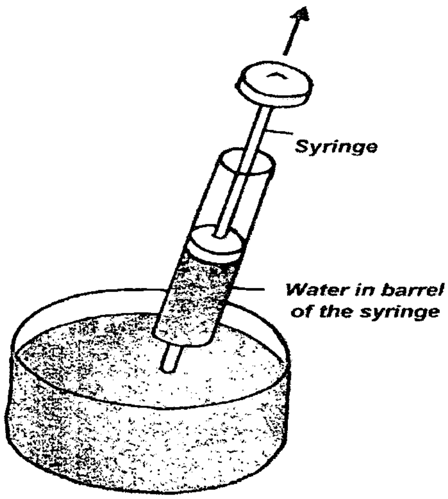
Tannenbaum, R.J. (1992) *Job analyses of the knowledge important for newly licensed (certified) chemistry and physics teachers. The Praxis Series: professional assessments for beginning teachers.* Report no. ETS-RR-92-78 Educational Testing Service, Princeton, NJ EDRS ED385586

Trumper, R & Gorsky, P (1997) A survey of biology students' conceptions of force in pre-service training for high school teachers. *Research in Science and Technological Education* 15, 2, 133-147

Wesley, S (1996) *Job analysis of the knowledge important for newly licensed biology teachers.* Report no. ETS-RR-96-19 Educational Testing Service, Princeton, NJ EDRS ED403278

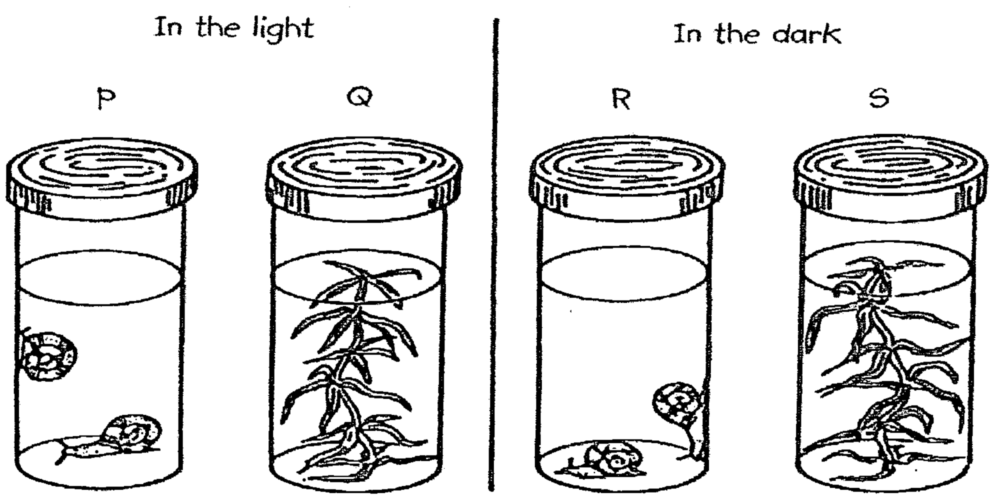
Syringe

When the plunger of this syringe is pulled up, water goes into the barrel of the syringe. What makes the water go into the syringe?
Explain your answer as fully as you can.



Sealed Tubes

Four sealed tubes were set up as shown below using water-living plants and animals. The experiment was left for twelve hours.



a) At the end of the experiment, in which of the following tubes would you expect there to be the least amount of carbon dioxide in the water?

Tick beside the letter:

.... A Tube P
.... B Tube Q
.... C Tube R
.... D Tube S
.... E All tubes the same

b) Give the reasons for your choice.

b) Which of the following metals will react with oxygen when heated?

Put a TICK beside any that WILL react
Put a CROSS beside any that WILL NOT react.
Make sure you put a tick or cross beside every answer.

.... A sodium .... B zinc .... C copper .... D iron .... E gold

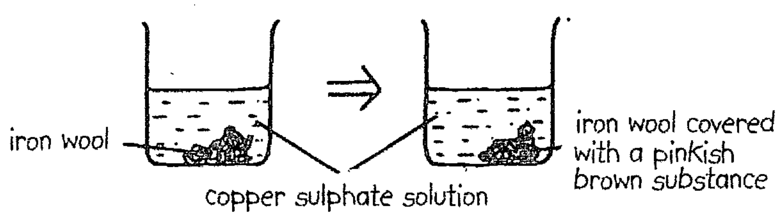
c) Which of the following metals will react with dilute hydrochloric acid?

Put a TICK beside any that WILL react
Put a CROSS beside any that WILL NOT react.
Make sure you put a tick or cross beside every answer.

.... A magnesium .... B zinc .... C calcium .... D copper .... E gold

Copper

A pupil puts some iron wool in copper sulphate solution. He notices that it becomes covered with a pinkish-brown substance.

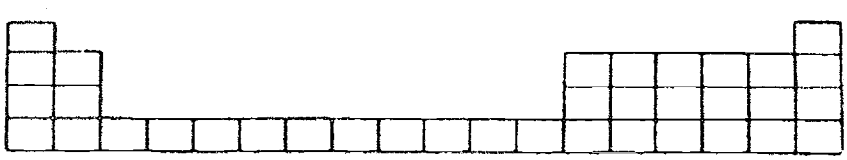


a) What is the pinkish-brown substance?

b) Give a reason for the appearance of this substance.

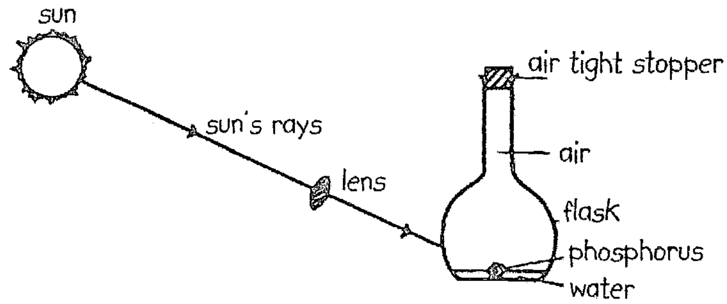
Metal Region

Here is an outline of the Periodic Table of Elements (first 4 periods).



Shade the area where you would expect to find METALS.

Phosphorus



A piece of phosphorus was held in a flask as shown in the diagram. The mass of the flask and contents equalled 205g. The sun's rays were focused on the phosphorus which then caught fire. The white smoke slowly dissolved in the water.
After cooling, the flask and contents were weighed again.

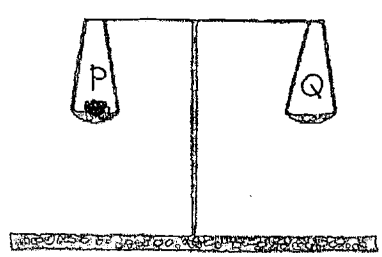
a) Would you expect the weight to be:

.... A More than 205g
.... B 205g
.... C Less than 205g
.... D Not enough information to answer

Tick next to the answer you choose.

b) Give the reason for your answer.

Iron Wool



A small amount of iron wool was placed on pan P, and weights were added to pan Q to balance the scales. The iron wool was then removed and heated in air.
It formed a black powder which was carefully collected and returned to pan P.

What do you expect to happen to pan P?
Explain the reason for your answer.

Metals

a) Which of the following metals will react with water or steam?

Put a TICK beside any that WILL react
Put a CROSS beside any that WILL NOT react.
Make sure you put a tick or cross beside every answer.

.... A sodium .... B magnesium .... C iron .... D copper .... E gold

What products are formed when CALCIUM reacts with water?

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Appendix 2

Responses to each APU item

Note: all references to subject specialism are for average and above average pupils

Syringe	APU original / %			Postgraduate trainee science teachers / %								
	Pupils	Phys	Non-Phys	90/91	91/92	92/3	93/4	94/5	95/6	96/7	97/8	
n	771	259	515	30	50	53	55	50	53	51	50	392
Pressure inside AND out	11	22	5	40	44	38	38	36	34	42	42	39.3
Pressure inside OR out	5	4	5	17	16	23	16	14	21	6	14	15.9
suction / vacuum	55	59	52	33	40	30	42	42	42	51	38	39.8
water pushes	2	1	3	10	0	0	2	2	0	0	2	2.0
air pressure inside sucks	16	7	21	0	0	2	2	4	0	2	0	1.3
Other	12	5	16	0	0	7	0	2	3	0	4	2.0

Sealed Tubes	APU original / %			Postgraduate trainee science teachers / %								
	Total	Bio	Non Bio	90/1	91/2	92/3	93/4	94/5	95/6	96/7	97/8	
n	759	355	406	30	50	53	55	50	53	51	50	392
Tube Q	37	46	30	87	82	75	89	90	89	94	88	86.8
response type												
CO2 taken in by plant	36	48	37	80	76	64	85	82	81	82	68	77.3
other responses with CO2	25	26	19	7	6	23	11	10	15	14	22	13.5
other responses gas exchange	17	15	18	10	16	6	0	0	2	0	2	4.5
Other	22	11	26	3	2	7	4	8	2	4	8	4.8

Conservation of mass	APU original / %			Postgraduate trainee science teachers / %								
	Total	Chem	Non-Chem	90/1	91/2	92/3	93/4	94/5	95/6	96/7	97/8	
n	759	224	541	30	50	53	55	50	53	51	50	392
same weight/mass matter conserved	29	41	21	80	92	79	91	82	74	84	88	83.8
same weight/ gases given off no weight	1	2	1	0	0	0	2	0	0	10	4	2.0
loses weight gases weigh less	16	18	15	7	2	2	0	4	8	2	0	3.1
loses weight less when gas dissolved	10	11	10	0	2	2	0	0	4	0	2	1.3
loses weight P uses up oxygen	5	4	8	0	0	2	0	2	5	0	4	1.6
gains weight gas produced	6	4	8	13	0	2	2	2	5	0	0	3.0
Other	33	20	39	0	4	13	5	10	4	4	2	5.3

oxidation	APU original / %			Postgraduate trainee science teachers / %								
	Total	Chem	Non Chem	90/1	91/2	92/3	93/4	94/5	95/6	96/7	97/8	
n	759	224	541	30	50	53	55	50	53	51	50	392
mass inc. combines oxygen	15	42	4	63	82	62	78	56	66	67	60	66.8
mass inc. physical props	6	5	4	0	0	4	2	2	2	0	2	1.5
mass same - same iron	8	5	8	10	0	2	4	4	2	6	10	4.8
mass dec. iron lost	4	2	5	3	2	4	0	4	0	2	16	3.9
mass dec. stuff burnt out	21	19	22	10	8	6	13	10	17	14	10	11.0
mass dec. iron oxide lost	7	10	3	0	0	11	0	2	0	0	0	1.6
mass dec. ash lighter	22	10	26	13	6	6	4	6	0	4	2	5.1
other	17	7	28	0	2	6	2	16	7	8	0	5.1

Reactivity	APU original / %			Postgraduate trainee science teachers / %								
	Total	Chem	Non Chem	90/1	91/2	92/3	93/4	94/5	95/6	96/7	97/8	
water	240	55	82	30	50	53	55	50	53	51	50	392
sodium	88	96	95	100	100	100	98	98	81	100	92	96.1
magnesium	70	82	69	87	84	81	78	86	77	84	70	80.9
iron	45	64	35	77	66	79	69	82	77	73	68	73.9
copper	29	16	26	33	32	36	27	26	23	25	26	28.5
gold	11	4	9	0	0	0	0	2	0	0	0	0.3
oxygen												
sodium	75	70	73	90	90	87	85	88	81	92	80	86.6
zinc	75	83	74	79	86	89	89	92	83	92	82	86.5
copper	60	73	57	86	86	72	64	82	74	69	74	75.9
iron	45	61	47	86	86	81	80	86	85	75	74	81.6
gold	18	13	11	3	0	2	5	4	2	2	6	3.0
dil acid												
magnesium	81	98	82	90	98	87	100	92	94	98	84	92.9
zinc	74	92	74	65	84	79	91	90	81	80	76	80.8
calcium	64	76	61	96	86	89	93	94	91	92	86	90.9
copper	58	42	62	59	54	47	53	56	49	55	42	51.9
gold	17	10	18	7	4	2	5	10	8	4	8	6.0

Displacement reaction	APU original / %			Postgraduate trainee science teachers / %								
	Total	Chem	Non Chem	90/1	91/2	92/3	93/4	94/5	95/6	96/7	97/8	
n	745	210	377	30	50	53	55	50	53	51	50	392
copper	27	44	26	38	52	49	38	50	47	37	32	42.9
rust	17	5	20	10	4	0	0	6	2	6	0	3.5
iron sulphate	13	24	7	28	40	43	49	30	34	45	48	39.6
copper sulphate	5	1	3	0	0	0	2	0	2	0	0	0.5
iron	3	1	1	0	0	0	0	2	0	0	0	0.3
other	35	25	42	24	4	8	6	12	15	14	20	12.9
Fe more reactive Cu	11	6	12	17	34	13	20	20	19	20	8	18.9
Fe displaces Cu	4	11	2	0	8	11	11	16	11	20	12	11.1
BOTH of above	10	25	9	27	12	34	24	12	26	33	38	25.8
Fe reacts CuSO4	43	48	42	10	26	11	18	26	26	10	16	17.9
Other	33	11	36	47	20	30	27	26	32	18	26	28.3

Reaction calcium & water	APU original / %			Postgraduate trainee science teachers / %								
	Total	Chem	Non Chem	90/1	91/2	92/3	93/4	94/5	95/6	96/7	97/8	
n	238	50	89	30	50	53	55	50	53	51	50	392
Ca(OH)2 + H2	5	20	0	31	42	38	42	32	40	45	26	37
CaO + H2	8	25	4	17	30	17	20	24	11	16	18	19.1
H2 only	<1	0	1	0	0	0	0	0	0	0	2	0.3
CaO only	2	2	5	7	2	4	0	2	4	0	2	2.6
Ca(OH)2 only	9	23	5	21	10	21	16	8	21	16	28	17.6
other	75	31	84	24	16	21	22	34	25	23	24	23.6

periodic table	APU original / %			APU original / %								
	Total	Chem	Non Chem	90/1	91/2	92/3	93/4	94/5	95/6	96/7	97/8	
n	243	50	89	30	50	53	55	50	53	51	50	392
within metal region	21	40	17	42	72	70	69	58	53	61	50	59.4
in non-metal region	5	4	6	19	2	2	9	12	13	20	12	11.1
transition metals	3	12	3	19	10	9	15	12	13	2	18	12.3
other	56	44	62	3	12	4	4	10	9	12	12	8.3
no response	12	0	11	16	4	15	4	8	11	6	8	9.0

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