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This progress report provides information about the Nuffield Science Teaching Project activities related to the development of a physical science course. Included is information concerning the schools involved in the project, student enrollment figures, and certain student characteristics. Sections are devoted to discussions of teaching the course, the cost of the course, the A-level examination, and final publication form of the teachers' guide and pupils' materials. Two essays entitled "Is Physical Science Teachable" and "University Reactions to Physical Science" are also presented. (BC)

NUFFIELD SCIENCE TEACHING PROJECT

PHYSICAL SCIENCE COURSE

PROGRESS REPORT

Two hundred pupils will take the first A-level examination in physical science this month. There will be nearly eight hundred A-level candidates in 1969, and present indications are that the number of schools offering the subject will continue to increase.

The physical science group will cease to exist in its present form next year, and its various publications are due to appear in the summer of 1970.

The statement in PR 2: '.....we now intend to issue progress reports two or three times a year.....' was wildly over-optimistic; there just has not been the time to write them. However, at least one more progress report will appear, probably in the autumn of 1969.

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12 Kingsgate Street,
Winchester

J.E. Spice,
Organiser,
Nuffield Physical Science Group

1st June, 1968

The Physical Science Group

The present membership is as follows:

Dr. J.E. Spice (Organiser)	-	Senior Chemistry Master, Winchester College	- part-time
Dr. B.E. Dawson	-	Lecturer in the Department of Education, King's College, London	- spare-time
Dr. H. Derbyshire	-	previously Senior Science Master, Wyndham School, Egremont, Cumberland	- full-time
Mr. D.G.F. Eastwood	-	Physics Master, Fettes College, Edinburgh (seconded)	- full-time
Mr. A.W. Gammage	-	previously Senior Physics Master, Liverpool Institute High School	- full-time
Dr. A.D.C. Grassie	-	Lecturer in the School of Mathematical and Physical Sciences, University of Sussex	- spare-time
Mr. S.W. Hockey	-	Senior Physics Master, Marlborough College	- part-time
Mr. D.E.P. Hughes	-	Senior Science Master, Shrewsbury School	- part-time
Dr. F.R. McKim	-	Senior Science Master, Marlborough College	- part-time

Physical Science Schools

When the second progress report was written in October, 1966, sixteen schools had just begun to teach physical science. During the spring of 1967 interested schools were invited, through the bulletin of the Association for Science Education ('Education in Science') to write for particulars of the course. As a result of this general approach and of various talks to teachers, a considerable number of schools was sent details of its content, of university reactions to it, and of apparatus requirements. Thirty-nine of these schools, together with three technical colleges, evenutally decided to join the trials. Consequently, the second generation of physical science pupils began the course in fifty-eight centres (including the sixteen original ones) in September, 1967. The schools and technical colleges in which physical science is at present being taught are as follows:

School	Type		Number of PS Pupils A-level '68	A-level '69
Abbs Cross T.H.S., Essex	L	M		15
Aldridge G.S., Staffs	L	M		10 (2)
Arnold S., Blackpool	D	B		12
Atlantic C., Glamorgan	I	M	11	19 (1)
Beckenham and Penge G.S.	L	B		13
Bedford S.	I	B		25
* Bletchley G.S.	L	M	7 (2)	18
Brighton, Hove and Sussex G.S.	L	B	8	13
Broxbourne G.S., Herts	L	M		2
Canon Slade G.S., Bolton	D	M		10 (2)
* Cardinal Hinsley G.S., Bradford	L	M	14 (3)	15 (3)
Cavendish S., Hemel Hempstead	L	M		16 (3)
Charterhouse, Godalming	I	B		9
Christ's Hospital, Horsham	I	B	15	12
* City of London Girls' S., E.C.4	I	G	7 (7)	3 (3)
* Cleveland G.S., Redcar	L	G	11 (11)	12 (12)
* Dartington Hall S., Totnes	I	M		4
Dauntsey's S., Wilts	D	B	6	3
* Dudley H.S.	L	G	7 (7)	6 (6)
Eastbourne G.S.	L	B	9	15
* Elizabeth C., Guernsey	I	B	13	23
Ewell C.T.C.	Tech. Coll.			12 (2)
Falmouth G.S.	L	B		7
Farnham G.S.	L	B		13
Gateway S., Leicester	L	B		11
Gordonstoun S., Elgin	I	B	9	9
Hall Park C.T.G.S., Notts	L	M		11 (2)
Handsworth G.S., Birmingham	L	B		10
Haywards Heath G.S.	L	M		15 (4)
Highgate S., N.6	I	B		16
Hurstpierpoint C., Sussex	I	B		13
King Edward VI S., Southampton	L	B		12
Marlborough C.	I	B	16	17

School	Type		Number of PS Pupils A-level '68	A-level '69
* Merchant Taylors' S., Middlesex	I	B		53
Mid-Essex T.C., Chelmsford	Tech.	Coll.		10 (2)
* Notre Dame H.S., Norwich	D	G		3 (3)
Nottingham H.S.	I	B		17
Poole T.C.	Tech.	Coll.		7 (1)
* Queen Eleanor's S., Dunstable	L	G		9 (9)
St. Edward's S., Oxford	I	B		16
St. Mary's C., Lancs	D	B		26
St. Paul's S., W.14	I	B		7
Seaford C., Sussex	I	B	16	6
* Shire Oak G.S., Staffs	L	M		19 (5)
Shrewsbury S.	I	B		13
Sir Walter St. John's S., S.W.11	L	B		10
Stowe S., Bucks	I	B		11
Taunton's S., Southampton	L	B		12
Uppingham S., Rutland	I	B		17
Watford G.S.	L	B	34	27
Wellington C., Berks	I	B		12
Westminster City S., S.W.1	L	B		6
William Ellis S., N.W.5	L	B		14
Winchester C.	I	B	17	30
* Winchester C.H.S.	L	G		20 (20)
Wolstanton C.G.S., Staffs	L	B		20
Wymondham C., Norfolk	L	M		8 (3)
Wyndham S., Cumberland	L	M		9 (2)
			(30)	(85)
		Total	200	783

Schools are here classified as independent (I), direct grant (D) and L.E.A. (L), the latter including voluntary aided and voluntary controlled schools. They are also classified as boys' (B), girls' (G) and mixed (M). The number of girls included in each physical science set is shown in brackets.

Excluding the three technical colleges, the breakdown by types of school is:

	Boys'	Girls'	Mixed	Total
Independent	18	1	2	21
Direct-Grant	3	1	1	5
L.E.A.	14	4	11	29
Total:	35	6	14	55

Schools marked * have now completely replaced physics and chemistry in their first-year VIth by physical science. Some of these schools have made this change as a matter of deliberate policy; others do not normally have more than one physics and one chemistry set, and so could not in any case offer physical science as an alternative.

The small number of girls' schools is a matter for regret. The reason is probably that very few girls' schools have a large enough science VIth to warrant parallel physics and chemistry sets. Consequently, a girls' school wishing to teach physical science cannot usually offer the subject as an alternative, but has to make the difficult decision to replace the separate subjects by it. It is not surprising that few have so far felt able to do this. Most existing comprehensive schools are in the same position of having very small A-level physics and chemistry sets, and this is doubtless why only one such school (Wyndham) is at present teaching physical science. However, there will be two more from next September.

Many schools who wish to introduce physical science have been unable to do so immediately, for various reasons. Some are about to undergo reorganisation from grammar to comprehensive; others are beset with staffing difficulties; many have begun to introduce Nuffield O-level courses, and have decided to wait until pupils who have taken these courses reach the VIth form; some L.E.A. schools are unable to obtain grants for necessary apparatus in this time of financial stringency; one or two schools are awaiting the building of new laboratories. All these schools are being kept in touch with the progress of the trials, and many will probably introduce the subject at a later date.

Thirty-five of the present fifty-eight centres lie south and east of a line drawn through Poole, Devizes, Bedford and Chelmsford. Atlantic College is at present the only physical science school in Wales, and there are only seven schools north of a line through Liverpool and Lincoln. It must be emphasised that this distribution of physical science schools is in no way due to a policy of concentration in the south-east on the part of the physical

science group; with only one or two exceptions, every school which has so far wanted to teach physical science has been enabled to do so. Nor can the apparent lack of interest in some parts of the country be due to ignorance. Reports appear from time to time in 'Education in Science', and Nuffield news-letters are widely circulated. Moreover, members of the physical science group have spoken at a great many meetings in all parts of the country - about thirty during the session 1966-7.

It may be that some northern and midlands schools who might have been attracted to physical science have decided to change their VIth form science curriculum in a different direction by introducing the new N.U.J.M.B. engineering science syllabus; others may be waiting for the N.U.J.M.B.'s own physical science syllabus. And some of the above reasons for delay may apply more in the north than in the south; for instance, 'reorganisation' is probably furthest advanced in some large northern cities.

For a number of reasons, no general invitation to interested schools was issued this spring, and only about fifteen new schools will begin the course next September. Thus, there are likely to be about a thousand A-level candidates in 1970. It is hoped that a large number of schools will begin physical science in 1969, and that the number will increase very rapidly when the various publications appear in 1970.

Subject Combinations

The intended A-level subject combinationsof pupils at present taking physical science may be summarised as follows:

		A-level in '68		A-level in '69		Both Years	
		Total	%ge	Total	%ge	Total	%ge
One other Subject	Mathematics	10	5	68[1]	9	78[1]	8
	Biology	7	4	11	1	18	2
	Other subjects	5	3	8	1	13	1
Two or more other Subjects[2]	'Double' Mathematics[3]	29	15	138	18	167	17
	Maths + Biology[4]	63	32	296	38	359	36
	Maths + Geography[5]	19	10	31	4	50	5
	Maths + Metalwork etc.[6]	5	3	31	4	36	4
	Maths + Economics	11	6	79	10	90	9
	Maths + other Arts	30	15	57	7	87	9
	Biology + any other	19	10	35	4	54	5
	Two 'miscellaneous'[7]	-	-	15	2	15	2
	Two Arts	2	1	14	2	16	1

Notes

1. These numbers include 48 boys from Merchant Taylors', all of whom will have three full years in the VIth. What they will do in 1969-70 has yet to be decided.

2. In most cases only the two subjects stated are to be offered at A-level. Occasionally, additional subjects are being taken. For instance, 'double' mathematics + biology is entered in the M + B column.

3. This includes all combinations of two mathematics A-levels, and also statistics and computer science.

4. Mostly biology, but occasionally zoology.

5. Includes a few candidates offering maths + geology and one taking maths + domestic science.

6. Includes metalwork, woodwork, technical drawing and engineering science.

7. Includes a few pupils intending to offer geology + geography and a few taking botany + zoology.

Comments As might be expected, most schools concentrate on a few combinations - such as M + B and M + Ec. A few schools, however, include pupils taking a much larger number of the above combinations.

Subjects being taken, apart from those already mentioned, are: art, music, divinity, history, Latin, Greek, English, French, German, Spanish, Russian.

The following percentages of all those studying physical science at present are noteworthy:

Also taking:	mathematics	89%
	mathematics + biology	36%
	'double' mathematics	17%
	mathematics + economics	9%
	mathematics + some other arts subject	9%

Contacts With and Between Schools

The part-time membership of the physical science group has changed slightly since PR 2 was written, but the most important development has been the appointment of three full-time members (see p. 2 of this report) all of whom have been working in Winchester since September, 1967. Two of these teachers (Messrs. Derbyshire and Gammage) are to continue with the project until it closes down in its present form in the summer of 1969. A second secretary has been engaged, and this concentration of strength at Winchester has made possible a considerably increased output of literature.

Teachers from the original sixteen schools have formed a close-knit extension of the physical science group. This larger group has continued to meet for two or three days every term, and all important decisions have been taken during these discussions. It was clearly impossible to have this kind of consultation with the hundred or so teachers who have been teaching the subject since September, 1967. Accordingly, nine area groups have been formed. For each a teacher from one of the trials schools organises meetings, usually once a term but sometimes more often, for the schools in the area. At these meetings matters of common interest, including criticisms of the course and suggestions for its improvement, are discussed. A full-time member of the physical science group from Winchester attends each meeting, and often visits one or more of the schools while he is in the district. Except for a very few outlying schools, all centres at present teaching physical science are involved in area meetings, and in this way are kept in close touch with the centre.

It is much to be hoped that these area meetings will continue for the next year or so, as a means of spreading knowledge of the physical science course. Already, teachers from schools thinking of teaching the subject have been able to learn something of the course from their attendance at these meetings. Anyone who is interested in physical science may like to make enquiries of the nearest area organiser:

Lancs and North-West:	Mr. P. Manson, Arnold School, Blackpool
East Midlands:	Mr. T.C. Swinfen, Uppingham School, Rutland
West Midlands:	Mr. D.E.P. Hughes, Shrewsbury School
Herts and N.W. London:	Mr. J.J. Thompson, Watford Grammar School
Central and S. London:	Mrs. A. Bradshaw, City of London Girls' School, E.C.4
East Sussex:	Mr. D.W.H. Tripp, Brighton, Hove and Sussex Grammar School
W. Sussex and Surrey:	Mr. Glyn James, Christ's Hospital, Horsham
Hants and Dorset:	Dr. J.E. Spice, 12 Kingsgate Street, Winchester
Wilts and Oxon:	Dr. T.E. Rogers, Marlborough College

In addition to area meetings, all those teaching the new generation of physical science pupils are invited to a meeting held in London once a term. Detailed discussion is difficult at such a large meeting, but points of general interest are raised, and decisions are taken. Schools continue to submit weekly progress reports, and they also return annotated sections of the Teachers' Guide at suitable intervals, and questionnaires on reactions to pupils' materials.

Teaching the Course

Most of the schools teaching physical science have been able to arrange for both a physicist and a chemist to be timetabled jointly with the physical science set, at least for some of the periods each week. The pupils in such schools are left in no doubt about the course being regarded as a joint venture, and the subject as a unified one. Various possibilities of double-barrelled teaching have been exploited. Obviously, one teacher can greatly help another with demonstrations and class experiments. Also, when he is sitting by he can sometimes resolve a problem of communication, he can make useful contributions to the discussion from his particular experience; and in time a joint discussion - real 'team' teaching - can emerge. In addition, experience is showing that double-barrelled teaching is the best kind of 'in service' training by which the chemist can learn how to teach the more physical parts of the course and the physicist the more chemical parts.

Some teachers who have taught jointly for the past two years have already decided next year to teach physical science sets by themselves.

For all this, as the course is adopted in more and more schools, there will be a considerable need for training courses of all kinds, in order to prepare teachers to teach it. Steps are now being taken to provide such courses.

The Teachers' Guide: Pupils' Materials: Final Publications

The Teachers' Guide The original sixteen schools have been teaching the course since September, 1966, on the basis of papers written by members of the physical science group, which vary considerably in the amount of detail they contain. It has been possible to use these papers because there has been the opportunity of interpreting, expanding and modifying them at the termly discussions. The Teachers' Guide, intended for the use of a much larger number of second-generation trials schools, and which must be the basis of the published Teachers' Guide, naturally has to be considerably more detailed. It is divided into seventeen sections, which are not necessarily taught in the following order:

I Forces, Motion and Energy

II Chemistry of the Elements, Part 1
(The elements of the second short period)

III Kinetic Theory and Phase Equilibria

IV Some Basic Chemistry
(Stoichiometry of acid-base, complexing and redox reactions)

V Electricity and Atomic Structure
(Electrostatics and simple aspects of electromagnetism, leading to the evidence for the 'Rutherford' atom)

VI Chemical Equilibrium

VII Thermodynamic Ideas

VIII Bonding, Structure and Properties of Materials, Part 1
(A general account, in terms of ionic and covalent bonds, and intermolecular forces)

IX Organic Chemistry, Part 1
(Properties and reactions of compounds containing C-H, C-Halogen and C=C bonds, and of benzene)

X Circular Motion, Simple Harmonic Motion and Wave Motion

XI Chemistry of the Elements, Part 2
(The elements of either group IV or group V)

XII Chemical Kinetics

XIII Electrical Oscillations
(Including preliminary work on electromagnetic induction)

XIV Electromagnetic Radiation

XV Organic Chemistry, Part 2
(Properties and reactions of compounds containing C-OH, C-NH_2 and C=O bonds, and of carboxylic acids and their derivatives)

XVI Chemistry of the Elements, Part 3
(The elements of the first transition series)

XVII Bonding, Structure and Properties of Materials, Part 2
(An introduction, in terms of either metals, or glasses and ceramics, or macromolecules)

Nine of these sections are now complete, and the remainder (except probably for section XVII) will have been finished by the autumn of this year.

Except for minor differences, the work contained in these Teachers' Guide sections corresponds to what is summarised on pp. 6-12 of the second progress report, PR 2. Each section is divided into three parts, of which the first comprises the main approach. In it, the work of the section is summarised, the key concepts and the less essential topics are listed, and a general method of treatment is recommended. The treatment is detailed where the subject-matter is likely to be unfamiliar to teachers, and much less detailed where it will be familiar. In the second part the practical details of suggested experiments and demonstrations are given, with an apparatus list. The third part contains data whose inclusion in the first part would unduly disturb the flow of the main development, notes on aspects which may cause difficulty and which would probably be used only with an exceptionally good class, and certain pieces of background information specifically for the teacher.

The Teachers' Guide has been written so as to make plain the essential backbone of the course, while including enough material for the teacher who has to stimulate and satisfy better-than-average pupils. There is no wish on the part of the physical science group to impose a particular order or method of treatment; instead, it is hoped that teachers will arrange matters according to their own ideas. This is particularly true of the experiments and demonstrations, far more of which are included than any one school could do.

Pupils' Materials Pupils' materials are being written, to correspond with the Teachers' Guide sections, in four main categories:

1. Sheets for Experiments Pupils read the sheet for a given experiment before coming to do it, and insert the sheet in their own notes. They do not then have to write routine descriptions of experimental procedures, but need only enter numerical results, calculations, answers to questions, and general comments.

2. Questions for Homework These are graded in difficulty, and arranged so as to carry pupils forward from one idea to the next. The physical science group and the sixteen schools have several times debated whether a pupils' textbook should be produced. There is the very natural wish of pupils to have such a book, and textbooks for physical science will certainly appear as the subject grows in popularity. On the other hand, a textbook written

as part of the Nuffield physical science project would tend to be regarded as a 'bible' for the course, and the subject might then develop less freely than is desired. Teachers have therefore given their pupils various existing physics and chemistry textbooks. The P.S.S.C. textbook 'Physics' is much used, as is either 'Modern College Physics' or 'Modern University Physics', by Richards, Sears, Wehr and Zemansky. 'Chemistry: a Structural View' by Stranks, Heffernan, Dow, McTigue and Withers is a favourite choice, and various American college texts (e.g. 'Chemistry', by Sienko and Plane) are also used. None of these are wholly satisfactory, so as a partial step towards the provision of a pupils' guide, the questions for each section are set in the context of a general statement of where that section stands in the whole course (what work it arises from and why it is being done) together with a brief summary of the main results which should be known. In addition, expositions of certain topics and ideas which, from the physical science point of view, are not treated adequately in any otherwise suitable texts, are also being written.

3. Source Material Teachers must of necessity concentrate on the central principles of the course; they naturally mention the implications of these principles for science and technology generally, but there is no time in the main course to do justice to these important aspects. In order partially to remedy this situation, each pupil is being supplied with accounts of particular applications, all short enough to be read at a sitting. Each begins from a particular principle or topic which will have been discussed at some length in the course, and goes on to deal with some of its consequences for science or technology. It is hoped that the provision of such source material will help to prevent pupils regarding physical science merely as an academic discipline, and that they will be stimulated to read further. To the latter end, one or two suitable references are given at the end of each article.

Titles of some articles already issued are:

The Control and Guidance of Rocket Vehicles

Protection in Car Crashes

The Silver Method for the Accurate Determination of Atomic Weights

Pumping Systems and Pressure Measurement

Zone Refining

Applications of Conductance Measurements in Industry

Uses of Complexing Agents

Atmospheric Electricity

The Application and Manufacture of Capacitors

Magnets and their Uses

4. Data Sheets Learning how to use a data book forms part of the physical science course. Pending the publication of a Nuffield A-level data book, pupils are using the 'Chemical Data Book' by Aylward and Findlay. Separate data sheets are issued, to supplement it.

Final Publications Present intentions are to publish the following:

1. Introduction to the General Philosopny of the Course
2. Teachers' Guide
3. Experiment Sheets for Pupils
4. Pupils' 'Workbook', consisting of questions linked by short descriptive and explanatory passages and summaries.
5. Book of Source Material
6. Data Book, compiled for use with the A-level chemistry and physics courses, as well as the physical science course.
7. Possibly a Project Book, written in collaboration with the A-level biology group.

The various manuscripts are to be delivered to the publishers in May, 1969, so that the various books may be available in the summer of 1970.

Apparatus: the Cost of the Course

Work continues on the development of suitable experiments for the course. Relatively little apparatus has needed to be developed specially, but steps have been taken to make equipment cheaply available to schools where it was not already on the market at a reasonable price.

It is impossible to quote a figure for the cost of introducing the physical science course into a school. In the first place, schools vary very widely in the apparatus they already have. Many schools now possess such items as one-pan balances, gas syringes, pH meters, linear air tracks, xenon flashers, oscilloscopes, power packs and d.c. amplifiers, microwave apparatus, and so on, and such schools find that comparatively little extra expenditure is needed. In the second place, very few of the experiments suggested could be described as absolutely vital and essential; most can be either replaced by others or modified in some way. Consequently, a school can begin to teach physical science with little or no additional outlay, and then gradually add to the range of experiments and demonstrations as money becomes available.

Every effort is being made to keep the cost of apparatus to a minimum, and where possible equipment is selected in such a way that it can serve more than one purpose. (For instance, an inexpensive 0-50 microammeter has been made available, whose zero can be at the left of the scale or in the centre; it has both linear and logarithmic scales. It is used (i) as a microammeter; (ii) as a null indicator for potentiometric measurements; (iii) as the meter for a photoelectric colorimeter).

Most schools starting physical science have spent a few hundred pounds for the whole two-year course; a median figure might lie in the range £300-£500, but this is naturally subject to the above qualifications.

The Project

All those doing physical science have to spend about forty teaching periods (thirty hours) on a practical project; some, naturally, spend longer from choice. Schools make their own arrangements for project work; some begin it almost at the start of the course, while most make plans during the third term, and start work at the beginning of the second year. Most schools allot a small amount of time each week, but at least one school has devoted almost half a term exclusively to project work. Some pupils have their own ideas for projects, but more need to have suggested subjects to choose from. Some projects comprise a more intensive study of particular practical aspects than there is time for in the main course; others are small research problems; others involve the design and construction of a machine or of a piece of apparatus. The idea is that pupils should learn a little of what is involved in an extended piece of practical work, and thus come to appreciate something of the flavour of actual scientific or technological enterprise, where - unlike experiments in the artificial school situation - practical work is often apparently unsuccessful, and seldom gives a clear-cut answer. Each pupil writes a short report (not more than about five thousand words) which is submitted to the examiners. The intention is to arrive at a mark for the project, (i) on the basis of a report from each pupil's teacher; (ii) from the examiner's reading of the report. In these assessments, the success or otherwise of the project is of small importance. What counts is the attitude of the pupil, how he has organised himself, how he has attempted to overcome difficulties, what initiative he has shown, and so on.

This year, the examiners are interviewing each candidate, so as to 'calibrate' the assessment procedure. It seems already that the results of these interviews usually confirm the mark arrived at from (i) and (ii) above. If this is indeed found to be so, the examiners will be able to rely with confidence on (i) and (ii) in the future, when the number of candidates is too large for individual interviews to be possible.

This year a good project mark will be able to improve a candidate's A-level grade, whereas a poor mark will not be able to depress it. What will happen in the future has yet to be decided by the trials schools.

Titles of some of the year's projects are:

A Study of the Amino-Acids in Cheese of Various Types

Breathalyser Systems - an Experimental Study

The Construction and Use of a Gas Chromatograph

An Investigation of 'Jetex' Model Aircraft Fuel

Properties of Rubber Bands

A Study of the Viscosity of Engine Oil

The Physics of Wind Instruments

The Accurate Measurement of the Acceleration due to Gravity

The Design and Construction of a Linear Induction Motor

The A-level Examination

The examination is designed on a two-dimensional plan. The elements of one dimension comprise the subject-matter of the course, and the examination marks are divided among subject-matter areas in much the same ratio as the course time is divided. The elements of the second dimension are the activities or qualities which are relevant to the practice of science: (i) the ability to recall; (ii) the ability to solve a routine problem; (iii) the ability to solve a novel problem; (iv) the ability to produce a plan or summary; (v) (to be tested through the project - see above) the ability to carry out an experimental investigation. Three written papers are being set this year, and also a 'special' paper of conventional design, for the comparatively small number of schools who wish to enter candidates for it. The design of the 'A-level' papers this year is as follows; it has been arrived at through discussion between the examiners, the physical science group and the original sixteen schools, carried out in the light of experience with the tests periodically set by the examiners for physical science pupils. A number of teachers have helped by setting multiple choice questions. Those which are not used in the above tests are added to a 'bank' for possible use in future tests and A-level examinations. The design may be changed in the future, after discussion by the schools concerned.

Paper I $1\frac{1}{2}$ hours. Fifty multiple choice questions, set on the 'core' of the course and all compulsory.

In order to see physical science in its true perspective it is essential to cover all the main topics of the course, but schools vary widely in the detailed coverage given to each. About two-thirds of the course, involving the essential ideas of all the main topics, has therefore been designated the 'core'. It seems desirable that the pupils' grasp of this core should be tested compulsorily, and this can be done both efficiently and quickly with multiple choice questions. These have the additional advantage that they can be pre-tested in order to ensure that the paper is of the right standard and discrimination.

Paper II $2\frac{1}{2}$ hours.

Section A About a dozen questions requiring short verbal answers or short calculations, set on the 'core' and all compulsory.

Experiments suggests that multiple choice questions are unsatisfactory if too many logical steps are involved. More complex reasoning is therefore tested in this section, where questions are highly structured, and a response has to be made at each stage.

Section B A comprehension passage to be read, commented on, and summarised.

The proper study of a scientific subject involves much reading, and pupils should learn to pick out the important points from books and articles. The passage is of a 'semi-popular' standard, and on a topic on the fringes of the course.

Section C A data analysis question.

This question requires translation either way between numerical, graphical and verbal data. Candidates will also be asked to suggest a hypothesis as a result of studying the data, and then to design an experiment to test it. Schools are told the general subject-area of this question, three months before the examination.

Paper III $2\frac{1}{2}$ hours. Five questions to be selected from fifteen set on the whole course. Section A contains three questions on purely chemical topics, and either one or two must be answered; section B contains three questions on purely physical topics, and either one or two must be answered. The remaining one, two or three questions must be chosen from nine in section C, dealing with neither specifically chemical nor specifically physical topics.

Different schools cover slightly different material, sometimes because a definite choice has to be made (e.g. in section XVII), and sometimes because the school decides to cover one section in greater detail than another. This paper therefore contains a wide variety of questions, ranging from the highly structured type used in section A of paper II, to more traditional essay-type questions which require the candidate to use material from many parts of the course and to synthesise it into a piece of clear, logical and continuous prose. The paper is divided into sections in such a way that each candidate must answer at least one question on a specifically chemical and one on a specifically physical topic, but may - if his interests lie in either direction - answer two.

A more detailed account of the rationale of the A-level examination, together with specimen papers, is available from Winchester. Supplies are strictly limited, but can be sent to those with a direct interest in the examination. Later this year the actual A-level papers will be on sale, and a detailed report will have been prepared on the first A-level examination.

Is Physical Science Teachable? Is it a Stimulating Course?

There has never been any doubt that the idea of physical science is a worthwhile one, among those teaching it in the original sixteen schools. Indeed, enthusiasm for the course among these teachers has increased rather than diminished. There has been much more discussion about whether it is feasible to teach physical science within the time allowance of one A-level subject, and whether the course as it stands is overloaded.

Initial reactions are sometimes unfavourable; it seems to the pupils that the course involves a great many new ideas, which crowd hard and fast upon one another, allowing no time for them to be properly digested. To some extent this may be inevitable with a course planned in a roughly linear manner.

If the professed ideal of giving a unified account of the principles which govern the structure and properties of matter is to be carried out, it is inevitable that these principles will be introduced as early as possible, so that maximum use can be made of them. On the other hand, it is regrettable if pupils, at the very outset of their VIth form careers, when they have hardly begun to attune themselves to the new pace of work, are to be confronted in rapid succession with a number of new principles. A certain amount of rearrangement of the early part of the course will certainly help, but it may be inevitable that for the first term pupils will find physical science harder going than either physics or chemistry. In a sense, it does deal with the more difficult parts of each subject. The sixteen schools, however, all agree that as the course progresses the pupils acquire an increasingly firm touch. They begin to see how the physical and the chemical aspects cohere, and they become accustomed to the method of working - by experiment, discussion, use of the data book, etc. It is most certainly not true that individual ideas, principles, applications, etc. are any more difficult than those which appear in conventional chemistry and physics A-level courses. Nor is a higher level of mathematical knowledge required than for the separate subjects.

As for the question whether the course is overfull, the sixteen schools have concluded that no substantial parts of it should or need be removed, although they have made various minor changes. On the other hand, it has been recognised that it would not be useful to produce a course the whole of which could be covered to an equal extent by pupils of every level of ability, since with such a course the better-than-average pupils would certainly feel frustrated and insufficiently extended. Probably no conventional science A-level course is covered in its entirety by all pupils. Teachers are ready to omit whole sections, having first assessed their importance for examination purposes. This may be quite satisfactory for conventional courses, which are not planned in a linear manner, but it would be disastrous for physical science, because of its rationale and method of construction. The sixteen schools have therefore decided that a distinction between 'core' and 'optional' topics should be made in the Teachers' Guide. The core comprises the most central ideas, with enough actual examples to place them in their proper context - about two-thirds of the whole course. Omission of the optional topics is not disastrous to the general development of the course, however interesting and important they may be. Every section of the course (as set out on p. 10) is divided into core and optional topics (except for section XVII) so that the core topics alone tell a connected story, which is complete in itself. The distinction between core and optional topics is reflected in the examination papers as at present arranged - see pp. 15-16 of this report - so that the non-core parts of the course are examined only in paper III, where there is a very wide choice of questions. It is hoped and believed that all pupils can obtain a feeling for physical science from their coverage of the core topics, and can spend sufficient time on some of the optional topics for them to make a fair showing in paper III. On the other hand, better-than-average pupils should find enough to interest and extend them in these optional topics.

The sixteen schools have all now completed the course as set out in t... report and in PR 2, though individual schools may not have covered particular sections as thoroughly as they might have wished. The teachers from these schools feel that the course is essentially teachable in its present form. They believe that difficulties about timing are to some extent inevitable at first, but that they can be overcome in the light of experience. This applies, for instance, to the presentation of unfamiliar ideas, experiments and demonstrations, and to knowing the correct level at which to present topics, and how much it is possible to leave out when time runs short. Also, it has to be remembered that the present course devotes a substantial proportion of the total time to matters which are covered in the Nuffield O-level physics and chemistry courses. In the future, when pupils come to physical science after having done these courses, time will be available for a fuller treatment of topics which at present have to be covered rather quickly.

The physical science sets who started in September, 1967, are now further behind schedule than the first sixteen schools were this time last year. This is mainly because the Teachers' Guide in its present form is insufficiently explicit about such matters as the level to which certain topics should be taken, the amount of detail to be given, and the extent to which omissions should be made. Further, it has not been possible to keep in close and continuous touch with this much larger group of schools. Suitable amendments are being made to the Teachers' Guide, and special short 'briefing' conferences are being held for schools beginning to teach the subject next September.

It is too early to report fully on the reactions of the larger group of schools. In general, teachers seem happy with the way the course is developing, although they mostly wish they had more time. Certainly, no general feeling has emerged among them that the course is unteachable, and with one exception (due to local staffing difficulties) all the present fifty-eight schools are starting new physical science sets next September.

The pupils themselves, although some feel overwhelmed at first, also seem happy about the course. Perhaps the surest index lies in the numbers of pupils opting for physical science in those of the sixteen schools which allowed a choice between physical science and conventional courses <u>both</u> in 1966 <u>and</u> in 1967:

	<u>A-level in 1968</u>	<u>A-level in 1969</u>
Atlantic College	11	19
Brighton, Hove and Sussex	8	13
Christ's Hospital	15	12
Dauntsey's	6	3
Eastbourne	9	15
Gordonstoun	9	9
Marlborough	16	17
Watford	34	27
Winchester	17	30

Too much should not be deduced from these figures, but there is certainly no reason to suppose that the 'grape-vine' operated so as to deter pupils in these schools from choosing physical science.

There is also evidence to show - though not yet with any certainty - that in some schools the numbers of pupils entering the science rather than the arts VIth has increased, because of the availability of physical science.

University Reactions to Physical Science

The organiser spends much of his time talking to and corresponding with university teachers about physical science. For instance, during 1966-7 he addressed more than twenty gatherings, large and small, in various university departments.

University reactions have now crystallised to the extent that, at any rate during the next few years, virtually every department which requires A-level passes in physics and/or in chemistry as a condition of entry, will accept an A-level pass in physical science as the equivalent. A small minority of departments are not particularly happy about the subject, and one or two of these have said they may require a higher grade in physical science than in physics and chemistry separately. The vast majority of departments are prepared to defer judgment until some of the physical science candidates have completed their degree courses. Naturally, with the present shortage of candidates for science and technology, physical science candidates are most unlikely to fail to secure places of some kind. On the other hand, a substantial number of departments of all kinds have given physical science a very positive welcome, and the following have said they will admit such candidates as a matter of definite policy, partly because in any case they welcome the subject and partly because they would like to have a 'control' group of 'physical science' undergraduates for comparative purposes. There would be no difficulty in extending this list considerably.

Bangor:	School of Engineering Science
Birmingham:	Department of Electronic and Electrical Engineering
Bristol:	Department of Physics
	Department of Chemistry
Exeter:	Department of Physics
Hull:	Department of Chemistry
Keele:	Department of Physics
Leicester:	School of Engineering
Sussex:	School of Physical Sciences (for Mathematics and Physics)
	School of Molecular Sciences (for Chemistry, Chemical Physics and Biochemistry)
	School of Biological Sciences
	School of Applied Sciences
University College	Department of Chemistry

Some of the first group of physical science candidates made their UCCA applications last autumn, and it is perfectly clear from their experience that their background has helped rather than hindered them in securing interviews and conditional offers. A candidate from one school, with the useful facility of being able to read writing upside-down, reported that the interviewer had written: '....doing physical science..... get her if possible....'! Various pupils have also been accepted by technical colleges, and for other forms of further and higher education. (It should be emphasised that virtually all physical science pupils are offering three subjects at A-level, just like those doing the conventional subjects).

The future of the VIth form curriculum is so uncertain that it is difficult to see what effect any changes are likely to have on physical science. The 'two A-level' pattern suggested by the Schools' Council would naturally have given a considerable impetus to the subject. The 'Dainton' pattern would weaken its appeal to those who wish to combine arts with science, since everyone would in any case have to do this. On the other hand, its appeal would be just as great as at present to those who wish to gain the broadest possible foundation in mathematics and in science.

Those who have been concerned to make physical science a viable A-level subject which can be taught in eight or nine periods a week, sometimes wonder how the subject could possibly be compressed into the five or six periods which a 'sub-A-level' science subject might expect to receive in a Dainton world. What needs to be remembered, of course, is that university departments would then, of necessity, have to ask for a smaller level of knowledge and attainment than at present in the individual sciences, and in these circumstances it would be quite possible to produce a satisfactory physical science course.
