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M J Tebbutt

It may be argued that the adoption and implementation of a course such as Nuffield A-level physics (NAP) has at least two critical stages. The first one occurs when the course is first published and teachers are becoming acquainted with it, its philosophy, changed teaching methods, content and experimental work. They have to decide whether to adopt the course and if so, how to implement it. A questionnaire survey conducted soon after the publication of NAP some eight years ago showed high degrees of satisfaction with the course among teachers who had attended in-service courses on it. The entries for the special NAP examination now amount to about 20% of all A-level physics entries (Tebbutt 1978) and there is also evidence of substantial amounts of informal adoption (Nicodemus 1975). For all these reasons it seems that NAP passed the first of the critical stages successfully.

At the second stage the course has been in operation for some time and its features have been tried, tested and perhaps found wanting. At this stage the teachers may decide to continue with the course, or they may change to another course either because the original course is out of date or because rival courses have appeared which have greater appeal, or fewer demands. NAP has reached the second stage, at which revision is being considered, and this account gives a summary of the reactions to NAP of 116 teachers, representing a 60% return on a questionnaire survey of half the NAP schools, conducted in the summer of 1979.

As would be expected from a randomly chosen sample the teachers' experience with NAP varied from before 1971 to 1978 in a fairly even distribution. This has been a period of reorganisation and the schools had changed from grammar to comprehensive or sixth-form college, direct grant to independent, and a number of boys schools had become coeducational. In spite of a substantial amount of change there had apparently been little change in the motivation, average ability, spread of ability or maturity of the pupils taking the course. Most of the schools (55) had one set of pupils, and a further 34 had two sets. The sizes of individual groups varied between 7 and 81 but the mean of 19.6 was consistent with these figures. In 16 of the schools pupils were entered for physics or engineering sciences examinations as well as NAP. Overall these data suggest that the sample was a reasonably representative one.

Organisation of teaching

A minority of schools (10) were allocated seven 35 min periods per week throughout the course, while rather more (17) had eight 40 min periods. These were the extreme values and though they were not apparently too dissimilar there was overall a 30% difference in the total time allocation. Most schools (63) had an intermediate allocation of 280 min per week (either 7 × 40 or 8 × 35) while the reminder (17) had 300 min per week, usually made up of five 1 h periods, or seven periods of 40 min in one year of the course and eight periods in the other.

The course is arranged in 10 units, each devoted to a theme. Progression is built into the course from unit 1 to unit 10 but there is a substantial measure of freedom to deviate from this order. Well over half the sets (126) were taught the course in numerical order. For 38 sets one change, and for 22 sets two changes were made to the numerical order. Only 17 sets experienced an order which was changed more than this. There was some evidence that these changes were produced by the need to teach the course to many sets of pupils and yet to economise on apparatus demands, particularly at the beginning of the course. Occasionally the order was changed for other reasons; for example, in order to produce an allegedly more challenging start than that provided by most of unit 1.

On the face of it NAP is more difficult to divide between teachers than is a more traditional course, yet the need to share A-level teaching may demand a solution to this problem. In fact some kind of sharing was used for about half the sets in the sample. Of these, half the sets were taught throughout their sixth-form course by one teacher and the teachers

Maurice John Tebbutt *is a lecturer in education (physics) at Birmingham University, and is involved in science education courses for PGCE, B Phil(Ed) and M Ed, and in-service training. He graduated from Nottingham University and has previously taught in schools and a college of education. He is interested in the development and take-up of courses.*

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took turns to teach the NAP course. The sharing was accomplished for almost all the remaining sets by splitting the course so that each teacher took a number of specified units. Only a handful of sets were taught by one teacher carrying on where the other left off.

The course also recommends that two periods of about two weeks are devoted to pupils conducting investigations, the first of which is a trial exercise and the second is written up as part of the final assessment. It was clear that the vast majority of schools made use of both investigations in spite of the demands it places on apparatus and space. There was considerable spread in the placing of both investigations. The trial investigation was done variously from between units 3 and 4 to between units 7 and 8, but most were done between units 5 and 6, or in the summer of the lower-sixth year which probably amounts to the same thing. The assessed investigation's placing spread from between units 6 to 7 to immediately after unit 10, with most between units 8 and 9, or in the spring term of the upper-sixth year. Schools with multiple sets particularly needed to use this flexibility in order to spread the investigations over a suitably long period of time.

Teachers' reactions to the course

While questionnaires can sample the views of large numbers of people about a wide range of topics, the need for clarity requires that there are many individual questions. However the effect of the large numbers of both questions and respondents can be to produce a large degree of fragmentation together with a tendency for the responses to regress towards the mean. Reports based on such data may be bland and lack the 'colour' and 'life' which characterise the spontaneous responses often produced in interviews.

To attempt to counter this, one of the questions asked the teachers to select the two features of NAP which were the most successful and the two which were the least successful. Content analysis of the responses showed which features were mentioned and enabled these to be grouped under a number of broad headings as shown in table 1. The responses to this question reflected an intensity of feeling which was not necessarily apparent in the responses to other questions and the grouped responses were also useful in organising the reporting of the other questions in order to avoid too much repetiton. In addition the responses were a rich source of comments, some of which have been quoted below to provide some of the flavour of the answers.

Table 1 *Teachers' choices of most and least successful features*

Feature of the course	*Numbers selecting it as one of the Most successful*	*Least successful*
1 Method	(52)	(69)
(a) General	7	1
(b) Practical work	13	13
(c) Investigations	14	4
(d) Long experiments	6	29
(e) Numerical methods	5	5
(f) Reading and reporting back	4	17
(g) Discussion	3	0
2 Content	(27)	(32)
(a) General	9	5
(b) Style	17	9
(c) Size	1	2
(d) Omissions	0	16
3 Philosophy	35	12
4 Effects	11	8
5 Examinations	1	14
6 Individual units	(85)	(59)
(a) 1	3	7
(b) 2	4	0
(c) 3	2	7
(d) 4	5	3
(e) 5	7	7
(f) 6	33	2
(g) 7	5	5
(h) 8	9	9
(i) 9	9	9
(j) 10	8	10
Total	(211)	(194)

Method

Although the overall balance of this, the largest category, was slightly unfavourable, examination of table 1 shows that such global figures are misleading and that the balance of responses to the different elements in this category varied widely. Thus the general comments about the teaching methods (1a) usually referred to their varied nature and were predominantly favourable.

The strong emphasis on experimental work in one form or another in this section (1b) was not surprising given the emphasis which Nuffield courses usually place on such work. The range or amount of practical work attracted nine comments of which six were favourable, e.g.

'The variety of experiments and apparatus handled by pupils. Both are about *real* physics and not *applied mathematics*'.

The lack of practical work at both the beginning and end of the course was commented upon unfavourably. At the early stage it was the lack of *individual* practical work which was seen to cause problems when the students came to the trial investigation. Units 9 and 10 are usually done towards the end of the course and their nature makes it rather difficult to provide more practical work, but extra experiments at this stage would clearly be welcomed by some teachers. Five respondents highlighted the course's success in developing practical skills and confidence but three regretted the tendency for experiments to be qualitative and relatively informal in terms such as:

'Experiments tend to be qualitative. Additional, more straightforward experiments involving simple measurements and formal reporting could be added'.

The amount of favourable reaction to investigations (1c) reinforced the impression reported above, that schools were committed to running investigations as recommended in spite of the considerable disruption they can cause. The favourable reaction was evident too in the tone of the responses, of which the following were typical:

'Often brings out qualities in students not seen in other parts of the course, with the result that they work better afterwards'; and

'They bring out real physics, meaningful measurements and help the students (and the teacher) to understand himself'.

Even the negative comments expressed support for investigations, but various problems seemed to outweigh the positive feelings. The alleged lack of time devoted to the investigations and the difficulty of motivating some pupils were problems which were mentioned:

'I feel that it should be included somehow but our girls find it difficult. Choosing the topic in the first place is a problem; doing it with limited practical skills is another. They don't like it'.

Long experiments were, as the name suggests, more substantial and took longer to complete than those usually included in the remainder of the course, though it was not intended that students should do every one. They were clearly regarded as the most unsuccessful single feature of the course (1d) and although most of the unfavourable comments were directed at particular experiments—notably those designed to measure G, and the velocity of light and microwaves—five teachers thought that the experiments were generally too hard and seven specifically mentioned difficulties associated with time or organisation. Another question explored the extent to which various aspects of the course, including long experiments, were taught according to the guides, or with various amounts of modification; and also the extent to which the teacher would wish to retain, revise or replace these elements if the course were to be revised. While some experiments, such as measuring ε_0, or e/m for electrons, were obviously done by most schools, most of the long experiments were omitted by one-fifth of the respondents and some, like those mentioned above, were omitted by half. Furthermore, comments indicated that many of the experiments may have been done only 'in theory' and not as was intended. Somewhat paradoxically, however, about 100 respondents recommended that most experiments be retained as they stood or with some revision (the kind of revision desired was not specified, but neither had it been requested).

Divisions of view about mathematical techniques were evident in table 1 (1e) and elsewhere in the questionnaire. Rather more than half the teachers used the graph plotting techniques for modelling changing quantities as recommended, but substantial numbers used the more usual mathematical techniques and nearly half recommended that the NAP methods be revised or replaced. While some thought it was:

'A good thing for those doing mathematics to see a different approach—biologists enjoy it too'; others thought the technique was

'. . . usually dismissed as lengthy and roundabout because most candidates do mathematics and can use calculus methods (even if they don't understand them)'.

This last comment illustrates the tension which was often apparent, sometimes within the same person, between the wish to operate the NAP scheme as was intended and the pressure to use techniques which might produce results without necessarily producing understanding.

About half the schools offered a supplementary mathematics course, and they appeared to be reasonably satisfied with them. Of these half used the NAP course and the teaching was about evenly split between physics and mathematics departments. As would be expected, these courses were usually provided for those not doing A-level mathematics, apparently one-third of the entry on average.

At the time the course was published the extensive use of discussion, directed reading and 'reporting back' on reading and experiments were relatively unfamiliar techniques, and table 1 (1f, 1g) shows that some of the techniques attracted unfavourable reactions.

Table 2 provides information on the extent to which the features were used, and may enable conclusions to be drawn about some of the reasons for the unfavourable comments. The single texts which were made available were not generally those featured in the original book list but were almost entirely books which have been published relatively recently to cater for NAP as well as other A-level courses. In any case whether schools used a library or a single text 'pupil use' fell short of 'availability'.

If the use of class texts was not a feature of the original project then the use of students' books containing questions, reading materials and some structured teaching material was a considerable feature. Table 2 shows how much use was made of these books as a basis for discussion, and other questions explored further aspects of their use. In general there is one book for each unit and the flexibility with which the books could therefore be

Table 2 *Use of course features*

Feature	*Extent of use or availability*				
	Extensive	Consider-able	Some	Little	None
Reading					
Availability of library of physics texts	17	59	36	6	0
Pupil use of library of physics texts	5	38	57	19	0
Availability of one or two *single* texts for all or most pupils to use	47	34	11	13	8
Pupil use of this/these texts	11	50	37	7	0
Reporting back					
Reporting back on directed student reading	3	22	57	35	3
Reporting back on group experiments	14	39	46	17	3
Discussion					
Discussion as a teaching technique	32	45	35	5	1
Discussion using students' book questions	18	38	47	13	2

issued and used was regarded favourably. This format was not thought to be unduly expensive, but replacement costs may not have been considered. The actual size of the books was not regarded as being influential. Of a number of possible revision strategies, leaving the students' books as they are was, perhaps predictably, the clear preference over the alternatives of binding all the books into one volume or incorporating some of the material with extra material into an NAP textbook.

Content

The 'general' comments (2a) about content mentioned its breadth and the fact that it was modern. 'Style' (2b) covered the *kind* of *physics* which was included and also the *organisation* of the *content* which was used. Ten respondents commented favourably on the inclusion of 'relevant' or 'applied' physics, e.g.

'The way in which the course can be biased to engineering because most pupils do *not* do physics'.

Opinion was equally divided about the success of the organisation of the content.

Comments on 'omissions' (2d) could hardly be other than unfavourable ones. Most of these (9) related to mathematics and were consistent with the comments made above about numerical methods:

'Laboured avoidance of mathematics which makes it *more* difficult to follow and a lack of detailed equations—why keep them in the dark?' and

'Mathematical approach: not that NAP is wrong but it should "somehow" end up with more links to the A-level mathematics'.

There was a general lack of comment about the size of the content, which may suggest that the size of the course is about right.

Philosophy

There were almost as many comments on the philosophy of the course as on content. One-third of these (16) were about the integration of theoretical and practical work and almost all of them were favourable. Nine comments, eight of them favourable, mentioned the emphasis in the course on thinking and understanding. This emphasis, particularly when concerned with the processes of physics, could lead to the course being more tentative in its approach. It is clearly a matter of judgment about what balance there should be between tentativeness and precision. Seven respondents felt that the balance was towards too little precision:

'Tendency to make pupils think about a topic but never sufficiently to reach firm conclusions or answers'.

The philosophy of the course was perhaps expressed most overtly in the aims which were listed in the *Teachers' Handbook*. These seemed to be presented as main, overarching aims, together with varying numbers of contributory aims. Thus, 'learning in the future' was one main aim, and contributing to it were eight others such as acquaintance with and use of the language of physics; learning new ideas; reading, arguing, mathematical and communication skills and independence.

The teachers were asked to rate the main and contributory aims on scales ranging from 1 (extremely important), through 3 (important) to 5 (unimportant) according to their perceptions of the ideal emphasis on the aims, the emphasis placed on them in the NAP course and the emphasis which was possible in practice. Since the patterns of the responses were almost entirely consistent only the mean ratings for the main aims are given in table 3.

Once again patterns will be readily apparent, notably the high rating (low numbers) given to all the aims; and the fairly steady reduction in emphasis in going from the ideal situation to that perceived in NAP and finally to the situation in practice. These differences may reflect the realities of curriculum design and implementation or they may provide evidence, albeit of a different kind, of the mismatch

Table 3 *Ratings of aims*

Major aim	*Mean rating (rank order)* Ideal	NAP	Practice
Learning in the future	1.74 (4)	2.23 (5)	2.49 (5)
Understanding physics	1.40 (1)	1.57 (1)	1.86 (1)
Understanding the nature of physics	1.85 (5)	1.96 (3)	2.45 (4)
Learning to enquire	1.61 (2)	1.93 (2)	2.16 (3)
Enjoyment	1.66 (3)	2.08 (4)	2.13 (2)

between intentions and their realisation described by Hughes (1978). The order of priority accorded to the aims was similar, but not identical, in each situation.

Effects of the course

There were 19 comments about the effects of the course (table 1) but they were generally wide ranging and few effects attracted more than one or two comments. The effects which were mentioned were the production of 'good scientists', the problems produced for some pupils in higher education, the lack of confidence produced in some students but the interest and open minded attitude produced in others, the course's suitability or otherwise for pupils of different abilities.

Examination

It is arguable whether the examination occupies as central a position in a course like NAP as it does in a 'traditional' course, but since the examination is the most public feature of most school courses it is a feature which is likely to be most influential in forming a judgment, whether by those who teach the course or by those who do not but who have a variety of interests in it. While accepting the broader audience this survey could only examine relatively simply the views of the teachers of the course.

Table 4 summarises the teachers' assessment of the value and difficulty of the various elements of the examination. There seemed to be most doubt about the value of the long answer paper, the comprehension paper and the practical problems paper, and it was these papers which were responsible for most of the negative comments about examinations in table 1. The difficulty of the examinations seemed to be about right or a little on the hard side, and this was consistent with the results of another question which indicated that the examination results were very largely in argreement with the teachers' expectations.

It is sometimes said that the price of a particular curriculum is the curriculum it replaces and table 5 shows the teachers' views of NAP in comparison with the course they would have been teaching in the absence of NAP. Most of the views will be apparent fom the table, but there was substantial spread of opinion about the suitability of the course for Oxbridge candidates. There were, however, frequent annotations to the questionnaire suggesting that any unsuitability was more a criticism of the Oxbridge examinations than of NAP.

Individual units

About one-third of all the comments were linked with specific units. However examination of table 1 shows that most units attracted relatively few comments and these were often evenly split between support and criticism. Thus it is proposed to highlight only those comments which appear to show a clear pattern, though it is accepted that this carries the risk of ignoring pertinent observations.

About one-third of the comments about unit 1 concerned the section on x-ray diffraction which was generally regarded as being rather too difficult for this stage of the course, though there seemed to be little evidence of teachers exercising the option to teach this material later in the course.

Most of the comments about unit 2 were positive and related to the 'puzzle boxes' which are featured in it. On the other hand unit 3 attracted mainly negative comments, reflecting the problem of conceptual difficulty associated with this work in any physics

Table 4 *Assessment of value and difficulty of examination*

Examination component	*Number of responses*		*Value*					*Difficulty*		
	Great value	Considerable value	Some value	Little value	No value	Much too hard	Rather too hard	About right	Rather too easy	Much too easy
Coded answer	48	57	10	3	—	—	7	109	3	—
Short answer	49	60	8	—	—	—	35	83	1	—
Long answer	26	64	21	6	—	17	63	38	1	—
Comprehension	18	58	35	5	—	—	11	104	4	—
Practical problem	25	47	35	7	3	—	7	105	7	—
Investigation	45	49	18	4	—	1	7	104	1	—
Whole examination	34	70	7	2	—	—	25	93	1	—

Table 5 *Value of NAP course compared with A-level course which would otherwise be taken, for different groups of pupils*

	Number responding				
	Much better	Better	About the same	Worse	Much worse
Oxbridge candidates	12	26	35	33	3
University entrants doing physics	17	59	31	7	—
University entrants doing engineering or other sciences	20	47	35	13	1
As a general education	50	52	16	—	—
Higher ability pupils in general	40	22	52	3	
Lower ability pupils in general	11	33	25	45	4

course, and the work on gravitational fields was singled out for particular criticism. A novel feature of this unit was the self-teaching unit on ionic crystals in the *Students' Book.* It was used wholly as a self-teaching unit by 27 teachers, while 16 teachers taught the material themselves. The majority used a combination of individual student work and class discussion.

The radioactivity section of unit 5 was criticised as being slow, heavy and allegedly involving too much repetition of work done at O-level. Unit 6, however, was regarded as being very successful—in fact the most successful unit. It was seen to be relevant, well organised, capable of catering for pupils of all abilities, generating confidence and enjoyment. There were, however, comments about the need to update the content in view of the change from discrete components to integrated circuits, though whether this would be any more than a cosmetic change is arguable, in view of the use of a systems approach in any case.

Many of the comments on the later units mentioned the unit as a whole as being successful or not, and were not specific about the reasons for this; though where specific comments were made they mentioned the difficulty of the concepts involved and this could have been the reason for the nonspecific negative comments. The last two units have a number of possible finishing points so that teachers may opt for different end points depending on the requirements of the pupils individually or *en masse*, or the demands of time perhaps. It was suspected that much of the teaching was stopping at the first of the optional end points, and this was strongly supported by data from the questionnaire.

Conclusion

The overriding impression left by this survey was that the teachers were on the whole very satisfied with the NAP course. This was supported by the fact that 102 respondents were proposing to continue with NAP for the foreseeable future and a further seven were proposing to transfer to another course.

This report has indicated various areas where there was a degree of consensus about the need for change. In addition to these there were a number of indications that some of the teaching techniques were difficult, and there is perhaps a need to revise or modify the approaches in order to make them easier or clearer.

A number of reservations must be stated however. The relative lack of criticism could result from genuine satisfaction or a measure of conservatism. The satisfaction could be merely apparent since questionnaires are relatively inflexible, and though they can sample widely they may miss subtle yet important points which could be explored using other techniques. It must also be accepted that though teachers' views are important, view of others, such as the original course team, the publishers of the materials and the various consumers of the products of the course—university physics and engineering departments in this case—are also important.

References

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Modern optics course

A one-year postgraduate course in modern optics and semiconductor physics will commence in October 1981, offered jointly by the departments of physics at Heriot-Watt University and the University of St Andrews. The course leads to an MSc in opto-electronic and laser devices, and candidates will normally be expected to have a good honours degree or equivalent. A novel feature of the course is that the lecture programme is divided into four six-week blocks, to facilitate the retraining or continuing professional education of scientists in industry.

Further information can be obtained from Dr M J Colles, Department of Physics, Heriot-Watt University, Edinburgh EH14 4AS (tel. 031-449 5111 ext. 2335).