THE VALUE OF EMPHASIS IN ELIMINATING ERRORS

A CONTROLLED STUDY IN TEACHING

BY

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Every teacher knows that in his field there are a number of errors which a proportion of students make with varying frequency year after year. The sources of these errors are not usually known, though one may suspect outdated or misleading textbooks, or defective communication between teachers and students. Examples of errors of this kind which arise in pharmacology and therapeutics are that folic acid is an effective treatment in pernicious anaemia, that atropine relaxes skeletal muscle, or that suxamethonium is a ganglion-blocking agent. Whatever the origin of such errors, it is better that they should be dispelled, and at this point two extreme approaches are possible. One is to waste no opportunity of warning students of these errors, and to draw their attention specifically to them. The other is to note the risks of putting misconceptions before a not always critical or fully receptive audience, and to aim to avoid these errors by never even hinting at their possibility.

Different teachers probably adopt intermediate practices according to their temperaments and experiences, but it is desirable and possible to obtain objective evidence on the relative merits of the two procedures by a properly designed controlled experiment. Such experiments are not original. For example, an experiment designed to find a way of eliminating typing mistakes (Holsopple and Vanouse, 1929) indicated that emphasis on the errors was more efficient than emphasis on the correct spelling. On the other hand, Peak, Brooks, and Hobson (1941) could find no difference between two groups of students making spelling mistakes when one group had received practice in the correct spelling and the other group in an incorrect version. But a proper investigation of this sort appears not to have been made in medical teaching and we have therefore studied the matter as follows. A number of misconceptions were selected and the extent to which they were held by a class of students was tested by a suitable examination. The misconceptions were then divided into two groups of equal average popularity. For the next four months each misconception in one group was deliberately discredited whenever it was relevant to mention it, while misconceptions in the other group received no special attention. At the end the prevalence of the misconceptions in each group was estimated by means of further examinations.

Method

The investigation was carried out during a course in pharmacology, which was interdigitated with other

subjects over six months during the first clinical year. The 53 students concerned had already received some teaching in pharmacology in their preclinical course. They had also at this time taken part in an experiment in teaching methods (Joyce and Weatherall, 1959), and may have expected further experiments during the part of the course now being discussed. But the present experiment was not mentioned to the students until it had been completed. The students were taught by lectures, seminars—that is, meetings of not more than 15 students for discussion with a teacher—and practical work, which was mainly clinical and arranged on a project system. The course was given by four teachers, who participated equally.

Before the course began, the teachers jointly prepared a list of 24 items all of which were believed to be commonly a source of confusion, misconception, or error among students. Some of the items related to what the students had been taught in their preclinical course and the rest to what they were going to be taught. An open-ended short-answer test was prepared containing these 24 items in random order and was given to the students at the first session of the course. The questions are shown in Table I, but the order in which they were presented to the students was different and the material was not at that stage subdivided. The test required that the students should write their own answers; it did not put the possible misconceptions before them. The misconceptions were a heterogeneous collection of varying importance. Some, such as the use of folic acid in pernicious anaemia (item A 8) and the effect of underdosing with an antibiotic (B 10), were directly relevant to clinical practice. Others were mainly useful to test understanding of pharmacological mechanisms—for example, A 4, B 2. It is possible that some of the answers which are here being called misconceptions are considered acceptable by other teachers. This possibility does not affect the validity of the present experiment, which was concerned with what the students learnt from what they were taught. However, we have no reason to think that the students concerned were receiving other teaching which conflicted with the present experimental material.

The replies to the short-answer test showed that some of the expected misconceptions were in fact widespread while others appeared rarely or not at all (Table I, column 3). In the light of these replies the 24 items were paired, mainly with reference to the frequency with which they had revealed misconceptions and to some extent with regard to subject-matter, and each pair was divided at random (by tossing a coin) into an item to be emphasized and a control item. For the benefit of the teachers on the course, the 12 treated items were listed in a way which emphasized the misconception to be avoided, and the 12 control items were listed with minimal attention to possible misconceptions. A copy of this list was given to each of the four teachers and to no one else. Throughout the course the treated items were commented on by the teachers with warnings about possible errors, while the control items were mentioned with no more reference to the misconceptions than seemed essential for sound teaching. It was recognized by all the teachers that their first duty was the proper education of the students, and the restraints required by the experiment were held second in importance to this principle.

Record forms were provided to the four teachers so that the success or otherwise with which these directions

were carried out was recorded after each session. The record forms were arranged to show the time and date of the teaching sessions, the time and date of the entries about these sessions, the number of students present, and the items mentioned and how they were mentioned at the session. It was therefore possible at the end of the experiment to discover the extent to which the various items had been presented to students, and how far stress had after all been laid on misconceptions which it had been planned not to emphasize.

At the end of the course a second test was given to all the students. It consisted of three parts. The first part was identical with that given at the beginning of the course—that is, it consisted of 24 questions to which the students had to provide the answers—and this test was completed and handed in before the second was issued. The second part consisted of a further 24 questions, closely similar in substance, though not all worded exactly as before, and to each of these questions four answers were attached, from which the student had to select and mark the one which he thought most nearly correct. These answers in each case included one consistent with departmental teaching, and one, or occasionally more, popular misconceptions; the remaining answer or answers were designed to look plausible while being appreciably different from either the accepted or the selected misconceived replies. This four-way choice test, like the open-ended test, was completed and handed in before the third was issued. The third test was mainly concerned with collecting students' opinions on the course, and is not wholly relevant to the present experiment. It included certain questions, such as whether the students were aware of any experiments being conducted during the course, to which further reference is made below.

After the course and these tests, and before the professional examinations, defects in knowledge revealed by the tests were discussed with the students and further teaching was given by those methods which appeared most likely to be effective in eliminating errors.

Results

Test Scores

Forty-two students took the initial test and 52 took the final tests. One of the original 42 was absent on the second occasion, and the analysis which follows is based on the 41 complete sets of tests.

The frequency with which the individual specified misconceptions occurred in the open-ended tests given before and after the course and in the four-way choice test given after the course is shown in Table I. The items in the table are divided into two groups—those to which attention was specially drawn and the control items. The total frequency of misconceptions in each group for each test is shown in Table II. It will be seen that the questions were successfully chosen in that expected errors appeared in as many as 352 out of 984 possible answers. This rate is, of course, not typical of the students' performance. The matching of the two groups was reasonably satisfactory, with misconception rates of 36.6% and 35.0% respectively; close correspondence was to be expected from the method of pairing adopted.

The outcome of the experiment is seen in Table III. At the end of the course misconceptions in both groups were less frequent, but the rate decreased much more

for those misconceptions which were emphasized than for those which were not. In the open-ended tests the reduction in rate in the control group does not reach conventional levels of significance ($\chi^2=2.03$, $n=1$, $0.2>P>0.1$), but the reduction in the treated group is highly significant not only when the initial rate is used as a standard but also when the results achieved in the control group are compared ($\chi^2=15.1$, $n=1$, $P<0.001$). It is clear that misconceptions became much less frequent when students were deliberately warned against them, whereas little improvement occurred when no special measures were adopted. The results with the 4-way choice test, which was administered only at the end of the course to avoid introducing the

TABLE I.—Questions, Misconceived Answers, and Frequency of Their Occurrence Before and After the Course

	Misconceived Answer	Frequency		
		Before Course, Open	After Course Open	4-way
<i>Items Emphasized</i>				
A 1. What is the action of therapeutic doses of oxytocin on smooth muscle?	Contraction (unqualified)	34	27	9
A 2. What is the effect of therapeutic doses of atropine on autonomic ganglia?	Blocks transmission	28	15	12
A 3. To what class of purgatives does castor oil belong?	Lubricant	27	4	8
A 4. How does morphine cause constipation?	Relaxing intestine	22	8	14
A 5. How serious is the danger of addiction to pethidine?	Unimportant	21	3	10
A 6. By what mechanism does digitalis slow the heart?	Slows conduction. Lengthens refractory period	13	18	27
A 7. Is adrenaline a safe agent for treatment of cardiac asthma?	Yes	12	2	5
A 8. What is the effect of folic acid in pernicious (Addisonian) anaemia?	Beneficial (unqualified)	9	5	13
A 9. What action does ethyl alcohol have on the cerebral cortex?	Stimulant	8	2	4
A 10. For what therapeutic effect is aspirin most used?	Antipyretic	5	12	12
A 11. How does mersalyl cause diuresis?	Irritates renal tubules	0	0	2
A 12. How does an overdose of adrenaline cause death?	Systolic arrest. Atrial fibrillation	1	2	0
Total		180	98	116
<i>Control Items</i>				
B 1. What is the effect of therapeutic doses of suxamethonium on autonomic ganglia?	Blocks transmission	21	27	24
B 2. At what site is atropine acting when it blocks parasympathetic activity?	Ganglia. Nerve endings	31	22	31
B 3. What causes death after overdosage with chloroform?	Respiratory failure	23	12	17
B 4. How does vasopressin inhibit diuresis?	By constricting renal blood-vessels	24	19	18
B 5. What is the effect of mepyrmine on gastric secretion?	Prevention	21	17	24
B 6. How does cascara sagrada purge?	Direct action	11	20	11
B 7. What is the mechanism of death in mammals after an overdose of digitalis?	Systolic arrest. Heart-block. Atrial fibrillation	12	17	27
B 8. How does noradrenaline slow the heart in man?	Direct action on pacemaker	9	5	2
B 9. What is the effect of therapeutic doses of atropine on transmission of impulses from motor nerve to voluntary muscle?	Blocks transmission	9	8	9
B 10. What effect do small repeated doses of an antibiotic have on the development of drug resistance?	Prevents resistance developing	4	0	0
B 11. What effect does physostigmine (eserine) have on cholinesterase?	Destruction	5	2	4
B 12. What causes death after overdosage with ether?	Cardiac failure	2	2	2
Total ..		172	151	169

students to the misconceptions to a greater extent than had occurred anyway, agreed quite closely with the results of the open test. Since the students acted on the instruction in the choice test and answered all questions, by guesswork if necessary, the slightly

TABLE II.—Total Frequencies in Emphasized and Control Groups

	Before Course. Open	After Course	
		Open	4-way
Frequency of misconceptions—emphasized group	180	98	116
Frequency of misconceptions—control group	172	151	169
Maximum possible frequency	492	492	492
Expected frequency with random choice of answers	—	—	123
Difference between emphasized and control group	χ^2 0.28 P > 0.5	15.10 < 0.001	13.87 < 0.001

TABLE III.—Improvement on Individual Questions Related to Frequency of Teaching of Item

Treated Group				Control Group			
Question No.	Initial Score	Frequency Taught	Improvement	Question No.	Initial Score	Frequency Taught	Improvement
(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
A 1	12	34	0	B 1	8	21	75
A 2	6	28	25	B 2	20	31	54
A 3	23	27	38	B 3	24	23	73
A 4	7	22	65	B 4	1	24	0
A 5	2	21	58	B 5	21	21	38
A 6	22	13	8	B 6	18	11	30
A 7	4	12	0	B 7	17	12	8
A 8	5	9	15	B 8	13	9	31
A 9	10	8	52	B 9	16	9	8*
A 10	19	5	58	B 10	14	4	20*
A 11	11	0	8	B 11	15	5	42
A 12	3	1	47	B 12	9	2	73
Total	180	374	+82		172	452	+21

(a) As in Table I

(b) Order of presentation to students.

(c) Sum of number of students present on each occasion when item was discussed.

(d) Difference between initial and final frequency observed in open-end test.

* These two items were presented explicitly enough to make their inclusion in the control group questionable.

greater frequency of misconceived answers was to be expected: the number of right answers in this test was also higher, by about the same proportion, than in the open test. The "right" and "misconceived" answers between them attracted nearly all (64.1% and 28.6% respectively) the choices made in the 4-way test.

Relation to Individual Students' Performance

It is also interesting to analyse the results of individual students according to their behaviour during the course. Attendance at lectures and seminars was not formally recorded, but a rough grading was made by asking the teachers to classify their students into frequent, moderate, and poor attenders. The teachers made this classification on two occasions, and were consistent in 32 instances. In the remaining nine the estimates differed by one grade, and these students have therefore been classed intermediately (Table IV). This table shows some notable trends. One is that the students who attended best had, quite unexpectedly, the highest incidence of misconceptions at the beginning of the course. There was, moreover, a moderate but significant correlation ($r = +0.38$, $n = 41$, $0.02 > P > 0.01$) between attendance (scored from 5 to 1 for most to least frequency) and initial number of misconceptions. The second is that the best attenders showed substantial improvement during the course, both on treated and

on control items: the moderate attenders improved only on the treated items, and the poor attenders showed little improvement, such as there was being mainly in the treated items.

The difference in improvement in the different groups is highly significant, even without reference to the experimental separation of control and treated items ($\chi^2 = 33.4$, $n = 4$, $P < 0.001$). This large χ^2 is largely due to the extreme groups, with excessive reduction in the most frequent attenders and considerably less than expected from the null hypothesis in the two least frequent groups. When the division between emphasized and unemphasized items is taken into account the very uneven partition in the moderate attenders also contributes heavily to the total ($\chi^2 = 95.7$, $n = 9$, $P < 0.001$). In interpreting these results it must be remembered that attendance is probably correlated with other qualities, such as intelligence and with private study. No estimates of the amount of private study were made on this occasion, but two estimates of the intellectual performance of the groups are included in Table IV. One estimate is based on the number of right answers given by each student in the final examination of this course; the other is based on a composite mark obtained from examinations held earlier in the course in pharmacology, physiology, and anatomy.

The students who attended most often also had the highest scores on both these assessments of performance, but correlation of the initial score for misconceptions with these measures of intellectual performance is quite insignificant for the whole set of 41 students ($r = +0.138$ with previous mark and $r = -0.003$ with the final exam. mark). That the "best" students improved on both emphasized and control items is not surprising; it is reasonable to regard them as more receptive, or more sensitive, and as responsive to unemphatic teaching as to emphatic. That the "worst" showed least change is corroborative evidence that the experimental procedure is sound: considerable problems would be raised if non-attenders had been much influenced by what happened in teaching sessions. It is the moderate group who are most affected by the form of teaching adopted, and for these students the evidence shows clearly that emphatic pointing out of misconceptions produces much more reduction (55%) in their incidence than does not drawing attention to them (3%).

Students' Attitudes

When tests were given at the end of the course, each student was asked also to award a mark (out of 10) to express (a) the use and (b) the enjoyment he had derived from various parts of the course. He was also invited to express his own comments, and he was asked whether he was aware of any experiments conducted during the course. Most of the information collected in this way is irrelevant to the present study and will be put forward elsewhere in due course. But two points have immediate relevance. One is that no student reported any awareness of the experiment actually in progress, although several mentioned aspects of the course which differed from those of previous years as possibly experimental. It therefore appears that the methods of teaching adopted in order to emphasize, or avoid emphasizing, misconceptions were not unusual enough to attract attention to any detectable extent. The other

point is that these students had already taken part, during their preclinical course, in an experiment on teaching (Joyce and Weatherall, 1959), and the questionnaire on use and enjoyment of the course was of the same pattern as the one used in the earlier experiment. The marks awarded in the present course (combined mean=5.0) were consistently lower than those given in its predecessor (mean=7.4), so the results have been obtained with students attending a course about which they were comparatively unenthusiastic.

Many factors could account for the lower ratings given to this course. The outlook of students on the teaching they receive probably changes as their experience grows. The demands of clinical work and of clinical teachers differ from those of the preclinical course, and it was impossible to arrange the course so that students could attend all sessions readily and without distraction. The teachers in this course were with one exception different from those in the preclinical course, and two were new to this medical school and may therefore have evoked different reactions from some students. The students were not aware that an experiment was in progress, whereas their active co-operation had been invited in the preclinical study, and it is possible that disappointment or apathy may have depressed the scores just as enthusiasm about experimentation improves performance (Whitehead, 1938; Houston, 1956; Joyce and Weatherall, 1957). Further experiments are needed to discover whether the students' attitudes are relevant in interpreting the present findings.

Discussion

This paper illustrates a number of points. The first, and perhaps the most important, is that this sort of research is possible. In spite of the large amount of published matter on the subject of medical education very little is based on controlled experiment and nearly all consists of well-considered opinions based on dubiously selected facts (cf. Malleon, 1959). Procedures based on subjective impression may work successfully, but those demonstrated to work by a properly controlled trial are more often reliable, especially if the circumstances of the trial are regarded intelligently and invalid inferences are not applied blindly (Hill, 1960). The same principles can be applied profitably to the critical study of medical teaching as to therapeutic methods; and this study, like its predecessors (Joyce and Weatherall, 1957, 1959), shows that there is no serious obstacle to doing so, at least in a modest way.

Perhaps the most interesting point which emerges from this study is the fact that those students who were the most frequent attenders entered this experiment with the highest incidence of misconceptions and finished with the lowest—that is, the best learners went

through a phase of putting forward the selected misconceptions unusually readily. The mechanisms by which students learn are largely unknown and a source of much controversy (Osgood, 1953; Hebb, 1958), and the present observations can perhaps be interpreted in a variety of ways. It is none the less tempting to suggest that these findings point to a trial-and-error mechanism of learning, and lend support to the saying, "If you don't make mistakes, you won't make anything."

The results obtained show a correlation between emphatic warning of possible misconceptions and reduction in the frequency of these misconceptions, mainly in less outstanding students. The results lend no support to the opposite hypothesis that mentioning inaccurate statements leads to their perpetuation. In the circumstances of this experiment, the correlation probably indicates a causal connexion, but it is not certain what part of the process of emphatic warning had the observed effect. The performance of control procedures in an experiment of this sort is difficult, in much the same way as it is difficult to devise a controlled evaluation of psychotherapy (Cole, 1959), and the teachers were at times doubtful whether their method of treating a topic properly belonged to the emphasized rather than the control category of treatments. As the teaching sessions were not recorded verbatim to permit later analysis, the classification has remained with the subjective judgment of the teachers concerned. Possibly emphasis on a misconception led to longer time being spent on the topic than on control items, and the effectiveness of the method depended simply on the extra duration of teaching and not on putting the point negatively. At least the negative presentation has no obvious harmful consequence.

At first sight this knowledge can be applied directly and profitably in improving the technique of a teacher. But there are some pointers towards further knowledge which may go against this simple interpretation. It is notable that those misconceptions which were emphasized early in the course were least affected when tested at the end of the course, and the extent to which emphasis modifies the rate of forgetting facts as well as initial retention has yet to be tested. It is also possible that emphatic teaching, especially of misconceptions, discourages students from hazarding answers of their own when they are unsure of themselves. As Table IV shows, the expression of a large number of misconceptions is in at least some circumstances correlated with learning and assiduousness, and reasons have been put forward why this may be not only a correlate but a cause or means by which skill is obtained. Emphatic teaching may easily slip into dogmatic teaching and discourage students from voicing opinions: it may be better to create opportunities where as many students as possible speculate and discover which of

TABLE IV.—Frequency of Errors per Student Related to Attendance at Teaching Sessions

Group	Attendance	No. of Students	Right Answers, Final Score	Previous Examination Results, Composite Mark	Initial Score of Misconceptions	Reduction in Score of Misconceptions		Final Score of Misconceptions
						Emphasized Items	Control Items	
Maximum score			24	268	24	12	12	24
A	Frequent	5	16.0	163	10.8	+2.8	+3.2	4.8
B	Fairly frequent	5	10.2	146	8.8	+1.4	+0.6	6.8
C	Moderate	15	13.1	145	8.7	+2.7	+0.1	5.9
D	Rather infrequent	4	15.0	145	7.3	+1.8	-0.8	6.3
E	Infrequent	12	12.7	143	7.9	+1.2	+0.3	6.4

their ideas are practical and which are not. These concepts of teaching are themselves susceptible to experimental evaluation, though a larger scale of operations may be necessary than in the present study.

Summary

The value of emphasizing common errors has been examined by a controlled experiment. A short-answer test, containing 24 questions each believed to concern a common source of confusion, was set to a group of students who were part-way through their pharmacology course. From the answers obtained, the topics of the 24 questions were paired according to the frequency with which misconceptions appeared in the students' answers. One topic of each pair was allotted to a treated and one to a control group. For the next four months all teachers emphasized the desirability of avoiding errors in the treated group, while drawing no special attention to those in the control group. The approximate number of student exposures to each topic was recorded. At the end of the course the short-answer test was issued again. On this second occasion the number of misconceptions in both groups was reduced, but significantly ($P < 0.001$) more so in the treated group where the errors had been emphasized. Some reasons are discussed for caution in applying these results to the practice of teaching medical students.

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FIFTH INTERNATIONAL CONGRESS ON NUTRITION

[FROM A SPECIAL CORRESPONDENT]

The Fifth International Congress on Nutrition was held in Washington D.C. from September 1 to 7. Judging by the increase in participants compared with the previous congress three years earlier, nutritional research seems to be regaining some of its lost popularity. Press reporters were present in strength, apparently hoping to learn about the treatment of over-nutrition, which they believed was the only local nutritional problem. However, they were disappointed, and what to your correspondent seems as important—namely, under-nutrition—received an adequate coverage in the many discussions.

Lipid Metabolism

Needless to say, lipid metabolism and with it the implication, often unspoken, of a link with arterial (especially coronary) disease has been subjected to a fair amount of investigation. B. BRONTE-STEWART (South Africa) warned, however, of the dangers of a too easy assumption of the hypothesis dietary lipid = lipid in atheromatous plaques =

ischaemic heart disease. Though alterations in the serum lipids could be brought about by the dietary fat, it had yet to be shown that such alterations had any bearing on the disease. He pointed out that if the hypothesis were proved then there would be wide implications in the fields of food processing, in health education of the young, and in animal husbandry. Nevertheless, of all the environmental variables of our present-day mode of life only dietary lipid intake could be so closely related to the pathological, metabolic, and epidemiological features of arteriosclerosis. W. S. HARTROFT (U.S.A.) sounded a similar word of caution and advised that the established principles of good nutrition should prevail until the day—far off—when every reasonable doubt of the truth of the dietary fat and arteriosclerosis concept had been removed. He did, however, point out a relationship between the Sippy diet and arteriosclerosis in man. The role of the gut in lipid biochemistry might not be insignificant, according to A. C. FRAZER (Birmingham). Fatty acids could be produced by the intestinal flora and fatty acids could modify intestinal flora. Also pancreatic enzymes could be inhibited by antibiotics with possible effects on lipid absorption.

It is obvious that lipid metabolism must be influenced by the presence or absence of non-lipid substances in the diet. For instance, it was reported by R. E. OLSON (U.S.A.) that the restriction of dietary protein in undernourished populations might play a part in reducing the incidence of atherosclerosis by reducing the concentration of cholesterol and β -lipoproteins in the serum. Evidence is also accumulating of the possibly useful part played by unsaturated fatty acids in the diet, and many consider it desirable that a certain minimum level be maintained in the serum. J. F. MUELLER (U.S.A.) reported that vitamin B₆ (pyridoxine) was essential for maintaining these serum levels.

Evaluation of Nutritional Status

This is a problem which faces not only the individual clinician but also the public health administrator. A panel of experts discussed various methods which included a team recording clinical and biochemical data of large numbers of persons; the study of health, morbidity, and mortality records of a town or country; studying the diet of a community; and the clinical evaluation of an individual with or without supporting biochemical analyses. Improvements in these various techniques were reported, but, as might be expected, no revolutionary methods of assessment were forthcoming.

Nutrition of Mother and Infant

A lively panel discussion on this aspect of nutrition was largely directed to the important problem of mal- and under-nutrition in the tropics. The general view seemed to be that the behaviour of the infant at birth and not its weight should be the index of immaturity (not prematurity). D. B. JELLIFFE (Uganda) pointed out that the failure of lactation was not due to bad nutrition, as witness the high incidence of lactation in Africa compared with the United Kingdom or U.S.A.—“more sophistication, less lactation.” The question of the value of breast milk as opposed to milk powder in Western countries was discussed at some length with divided views. P. GYORGY (U.S.A.) took a teleological standpoint, and, though admitting that antibiotics could replace the immune bodies, felt that breast milk was at no disadvantage as compared with artificial mixtures. For the undernourished there was no alternative to breast-feeding. Supplementary feeding was stated not to be detrimental at any age, but did it do any good in the very young?

Food Needs and Resources

A symposium on this subject revealed one of the great challenges to nutritional and socio-economic sciences. J. BONNER (U.S.A.) stated that every day 100,000 more persons were present on earth and at the present rate of