STUDENT CONTRIBUTION

RADICAL APPROACHES TO LEARNING PHYSICS: SOME EXPERIENCES OF FIRST YEAR UNIVERSITY STUDENTS

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Introduction

The learning potential of first year physics students is largely untapped. Some first year physics students have important contributions to make in determining the structure of their courses. Do you agree with these statements? They are two conclusions reached as a result of activities in the Sydney University School of Physics in 1973. The two most important of these activities form the subject of this article. First, a group of first year students successfully participated in a course based on reading and studying published physics research papers. Second, some of the same group of students designed their own experimental physics course and upon its provisional acceptance by the School of Physics ably demonstrated its many advantages. We describe these happenings and discuss some of their implications.

The Research Study Course

In second term 1973 two separate groups of seven first year students each began a course based on reading and discussing a coherent series of research papers, called the Research Study Course. The topic of the papers in the course, "The use of trace substances in studying stratospheric dynamics", was an area of the research work being done by the instructor, postgraduate student Brian Martin. The course was based directly upon the teaching/learning method developed by Herman T. Epstein and described in his short book, *A Strategy for Education* [Oxford University Press, 1970]. To our knowledge the method had never been applied to physics previously. The course was advertised as being voluntary and non-credit, and furthermore the participants were asked to pay for xeroxing costs.

The first one hour meeting was spent discussing how a scientist chooses a research problem. At the end of this discussion each of the students was given the first research paper for the course and encouraged to read and study it. At the next meeting a week later, the discussion focussed on this research paper, and specifically on what the scientist who wrote the paper had been trying to do. When, after their reading, study and one or two one-hour meetings the students and instructor felt that a satisfactory understanding of the paper had been achieved, the next paper was distributed. The course continued in this manner for eleven weeks, seven papers being covered.

The classes were conducted primarily through student discussion and questioning. A student would ask a question or make a statement, which might be taken up or challenged by another student or presented by the instructor to someone else. The instructor's main duties were to answer technical points, to encourage balanced student participation, and to keep attention focussed on the paper at hand (that is, to keep digressions to a reasonable length). Some of the aspects of the papers which were discussed were factual details, the types of questions raised in the paper and the way in which the questions were asked, the way data was collected, the relevance of the data, the justifications for the method of collection of the data, the principal hypothesis presented, alternative hypotheses, and the validity of the arguments used to support a given hypothesis. An important area of discussion was methodology – the validity of the way in which the scientist attacked a certain problem, the justification for choosing one particular approach over various alternatives.

At all times the primary focus was on the actual work done by the researcher. Informational content was discussed only as it was required to understand the stated activities of the researcher.

After reading a given paper but before the discussion, many of the students did not feel that they understood the paper very well. It was the function of the group discussion to raise common problems and clear up areas of difficulty, and most importantly to emphasize aspects of the paper whose significance had not been fully appreciated. The discussions were helpful in aiding student understanding and comprehension of the papers for two particular reasons. First, because the instructor had done research in the area of the papers, he was able to explain with confidence the kind of fine points that often trouble students but which by necessity are slurred over in conventional presentations. Second, the students could efficiently help each other because, being at much the same level of understanding of the subject matter, they were able to understand each other's problems, difficulties, and ways of thinking. Often the students would remark that the paper made much more sense to them after the group discussions.

Even though the students were informed that they should ask the instructor elementary questions, at

first they were hesitant to talk and perhaps appear foolish or ignorant in front of their peers. Also most of the students were not used to stating their views openly. These difficulties disappeared naturally as the course progressed, and eventually all but a few reticent students capably offered useful contributions to the discussion.

The level of understanding demonstrated by the students showed two sides. First, areas of ignorance or basic misunderstanding were uncovered. In most conventional courses the students are afraid to appear ignorant before teachers or peers, while the same time normal methods of assessment usually only test recall or a surface level of understanding. Therefore areas of ignorance and misunderstanding can often persist undiagnosed for a long time. It is the advantage of the discussion format of the Research Study Course that to some extent the students were freed from their normal inhibitions, so that key shortcomings in knowledge and understanding could be quickly overcome. The students were highly motivated in this task, as it was prerequisite to a satisfactory understanding of the research papers.

While on one side demonstrating areas of lack of understanding, on the other side the students showed a remarkable talent in seeing into the heart of a paper, in asking the most important questions. The chance to develop and practise this ability in comprehension and critical evaluation appears to depend vitally on the reading of original research papers. In conventional courses using textbooks and lecture notes the emphasis is necessarily on knowledge and applications. Usually not until personal research work is begun is the student given the chance to develop his ability to comprehend and evaluate scientific work. But as demonstrated by the Research Study Course, this process can be begun much earlier, and at the same time used to motivate the learning of required background knowledge and applications.

The series of research papers has been called coherent: each paper reported work which in some way followed on from or built on work reported in the previous papers. Towards the end of each discussion the students were asked to infer, if possible, from the previous papers the next research effort that logically or practically should occur in the field. Usually numerous suggestions were offered, and at least one of these startlingly forecast the subject of the next paper. Furthermore, other suggestions were known by the instructor to have been the basis for other research efforts. Thus the students showed the ability to follow the thought processes of a scientist as presented in a research paper, and to think for themselves using these thought patterns as a guide.

Perhaps the most important achievement of the Research Study Course was the enthusiasm for learning which it engendered and sustained in the students. For a student, even one interested in physics, voluntarily to pay for a copy of a paper and then come in at 5 p.m. after classes to discuss what is to most first years an uninteresting subject (stratospheric physics) says a lot about motivation. Where did it come from? Mostly the motivation came from the excitement of trying to discover what a researcher is trying to do and how he is going about it, of following the mental path blazed by a scientist.

Some of the enthusiasm flowing from the course led to related individual and group activities. Some students did extra reading and looked up pertinent references. To aid in this work, through student initiative the group was able to obtain passes to the research library and be instructed on how to find research articles. After the completion of the course a long seminar was held to explain the course to Physics School staff, with the attendance of almost every student who had been in the course. Indeed, one problem that arose for about half the group might be called over-motivation, since time spent on physics resulted in some lack of attention to other subjects.

What are the criteria for success in a course like the Research Study Course? We may answer by describing what a student learns. He learns how scientists think and reason when working on a particular problem. He learns how the efforts of successive scientific workers can contribute to scientific knowledge, and about some of the pitfalls along the path to this knowledge. He learns a considerable amount of factual material related to the papers studied. Finally he learns that he is capable of understanding the important aspects of published scientific material, of analysing and criticising scientific work, and of validly thinking for himself about scientific matters. As a result of his learning the student becomes more confident in his study of physics. The course is successful if the student learns these things voluntarily, if his interest in science is increased by his tudies. The Research Study Course was a success for most of its participants when judged according to these criteria by the students, the instructor, and the numerous visitors to the discussions.

The Trial Experimental Physics Course

During one of the Research Study Course discussions one of the students mentioned how unsatisfactory their laboratory work was. This comment struck a resonant chord, and a lively discussion ensued. After another such discussion at the next meeting, the group members decided to meet and plan an alternative to the first year physics laboratory course. Although no one in the group at that stage believed there was much chance that an alternative would be accepted by the Physics School as a real option, the planning of an 'ideal' experimental course for themselves was thought to be a useful exercise in itself.

In designing their course, the students were guided by two principal aims. First, the student should have the opportunity to learn through direct experience the working of the experimental method: for example, how one asks a scientific question, how one designs an experiment to answer a specific question, how one conducts, analyses, and draws conclusions from an

experiment, and how one can learn from failure at any stage of an experiment. The opportunity to learn these things is basically the freedom to do as one likes in the laboratory (within the practical limitations which apply to every researcher), with no pressure for results or penalty for failure.

The second principal aim was that the students should have the chance to develop an understanding of the relationship of experimental physics and its techniques to theoretical physics and to the attainment of scientific knowledge: broadly, to place experimental physics in the context of our culture. This goal suggests a study of philosophy and methodology of science and of experimental method, and how these relate to the actual experiences of a researcher in the laboratory.

The students in designing their course were in general (if implicit) agreement about the aims just described. However there was considerable disagreement about how to design the course to achieve the aims, each student having his or her own individual set of ideas and opinions. The small amount of staff and postgraduate help in the planning mostly consisted of emphasizing the need for specific agreed-upon proposals. The one central idea accepted by everyone was that the course should be flexible and accommodate individual initiative and study preferences.

We now outline the sections of the proposed course, together with the suggested number of hours during the term to be spent in each area.

(1) Research Study Course (nine hours). This would be like the course described earlier but on a different topic.

(2) Visits to laboratories (six hours). The laboratories visited would ideally be related to the topic of the Research Study Course or to experimental work being done by the students.

(3) Statistics (four hours). The material studied should be applicable to data obtained in the student experiments, as well as facilitating an understanding of the role of measurement, accuracy and precision in the attainment of scientific knowledge.

(4) Computing (eight hours). This would be a course in simple programming for use in statistical analysis and the design of mathematical models.

(5) Philosophy of science (two hours). This would involve studying from a philosophical point of view the ways in which a physicist looks at a scientific problem.

(6) Experimental work (six hours). This work would be done individually, in groups, or by assisting a postgraduate student in his research. A resource list was requested to help the students in deciding on and planning their experiments. It was suggested that many students would wish to spend extra time in working at their experiments. Also planned were optional reports on the work carried out, and seminars at which results and experiences could be communicated to the other students in the group.

(7) Report (one hour). This would be an appraisal of all aspects of the trial course from the individual student's point of view.

Surprisingly to the students, acceptance of the course plan followed quickly after its submission to Dr. Brian McInnes, Director of First Year Physics.

Let us now consider the course as executed in terms of the planned course.

(1) Research Study Course. A series of papers on shock waves in plasmas were studied under the supervision of Dr. Brian James. There were some differences between this course and the earlier one covering stratospheric dynamics. First, the students were experienced in the method and so discussion developed more easily and freely. Second, some of the subject material had been covered in lectures. Third, Brian James purposely allowed the conversation to stray from the paper at hand and dwell on basic understanding of subject matter. It was found that material covered in lectures often was just not understood by students at an elementary level. Discussion in the Research Study Course allowed this to come out and for fundamental questions to be cleared up, in the process of relating the relevant concepts to the research paper at hand.

(2) Visits to laboratories. Due mainly to lack of time, the only visit was to the plasma physics laboratories at Sydney University. This was quite fruitful, since the Research Study Course had prepared the students for understanding the apparatus and for the asking of intelligent questions.

(3,4) Statistics and computing become especially worthy of note to the physics student when serving as tools for experimental work: running computer programs related to an experiment, and making statistical tests of data obtained. However the lectures on computing and statistics were not very successful. We feel this was mainly due to the lecture format used, and to the fact that the students did not know or agree on what material should be covered. Especially in computing, the students had widely varying backgrounds and requirements. The lecturers advertised their availability for consultation but little advantage was taken of this by the students. Nevertheless, we feel that staff support would most beneficially be in the form of persons available for consultation. By removing the time and pressure of the formal lectures and emphasising the availability of a consultant, and perhaps by organising student self-help sessions, more interest and learning might be achieved.

(5) Philosophy of science. It is important for the student entering a lifetime study of science to realise that there are different views of science,

and that a scientist's perception of his own view of reality may not be accurate. In this respect the three lectures on the philosophy of science were useful, in that the students were able to apply this philosophy to the scientific approaches they found in their lectures – not only in physics, but in applied mathematics and psychology as well. However its application to the philosophy of science lectures themselves suggests that discussion among the group would have been more fruitful in presenting the philosophy of science from more than one approach, rather than simply the lecturer's view.

(6) Experimental work. Although only six hours minimum were specified for the whole term for this area, most students ended up doing at least three hours per week. Each student had the opportunity to choose an experimental project, to try various methods of investigation, to run up against various dead ends, to evaluate equipment in terms of its possibilities for an experiment, and to make conclusions that were not anticipated from the beginning. To the student the experimental work gave the chance to do an experiment on one's own, rather than the necessity to follow instructions or to guess what someone else would like to see done.

It may be of interest to note some of the experiments done by the students. In one case a pair of students used equipment which served for a set of exercises in the Physics I Laboratory on the special distributions of black body radiation, but developed their own approach. Other groups of students worked in the following areas not related to the normal first year laboratory: the motion of a gyroscope, for example the variations in precession period with spin speed; the properties of a microwave absorption band as a function of the temperature of the absorbing medium; and the transmission of stereo sound via a polarised laser beam. In some of the experiments the students reached a successful conclusion to their work, in others progress was not particularly marked. In most cases the students encountered both failure and success in choosing a valid project, determining its feasibility, and working towards understanding of a physical phenomenon. Because of this, the students felt that they had learned a great deal about experimental physics.

Unfortunately there developed a subtle pressure from the staff on the students to spend time on experimental work in laboratory. Some students willingly spent large amounts of time on their experiments, but others would have preferred that more time be free for study in other aspects of the course. Near the end of term the students were unexpectedly asked to submit reports on their experimental projects. Although some students would willingly have prepared a report, to have the requirements imposed at such short notice appeared to be a manifestation of the underlying pressure to spend time on experimental work. Of course from the staff point of view work in a laboratory may seem the only valid way to learn experimental physics – certainly this is reflected in the existing course. But the student group had felt otherwise, and expressly designed the course to permit an approach to the understanding of experimental physics from a number of aspects.

(7) Report. Three students submitted reports on the Trial Course as a whole. Numerous suggestions were offered in these reports, and specifically comments about implementation of the course for more students in later first year classes.

The course both as planned and executed required a lot of student work. However all of the students fulfilled the minimum requirements of the plan and most did a significant amount of extra work: a total effort of eight hours per week on the Trial Course was not unusual. This compares with three hours per week that would have been spent in the Physics I Laboratory course; the theory covered in three lectures per week was in addition to each of these courses. In spite of the time spend by the students, one of the main problems in each aspect of the course was lack of time to follow up what was started or touched on. The reason for this problem is the large amount of time needed to study four subjects (the more formal course work) which leaves little time for private research. Naturally the effect of this problem varies from person to person. Some students will make time, or take time (at the expense of studying examinable material) for study of non-examinable subject matter. Others feel caught up in the formal courses to such a degree that they are afraid to do outside work, or feel guilty if they do. This problem of time was present in each component of the course.

The students were directly involved in much of the detailed planning and organising of the course as it progressed, such as arranging lecture meeting times, discussing material that should be covered, and locating equipment. Some of the time spent in these sorts of activities may have been at the expense of other aspects of the course. On the other hand, the involvement of the students in organising and running the course also fostered interaction of the students with many staff in a stimulating manner that would not have been normal in a smoothly running course.

In terms of content, a most important feature of the Trial Course was the breadth of material covered. Most of the specific areas, such as philosophy of science, statistics and computing, are normally covered as part of separate specialised conventional courses. But a given student might not be able to take each of these courses, especially since faculty requirements are sometimes rather restrictive. And even taking a course in a subject is not always desirable from the student's point of view, since the depth required or the emphasis made in the formal course might not suit his requirements. The advantage of the Trial Course here is its flexibility. The student is exposed to each subject area in the course, but does not have to follow up each topic to a predetermined depth. On the other hand if the area intrigues him, he has the option to study it in more depth on his own or to take a conventional course.

Another important aspect of the content of the course was the potential for integration of the subject areas covered. Although the areas were not formally integrated, the weekly study in areas such as the Research Study Course, the philosophy of science lectures and the experimental work emphasized the interlinking of theory and practice in experimental science.

The motivation for designing the Trial Course came from the students' overwhelming rejection of the Physics I Laboratory course which forms part of the first year syllabus. This rejection may seem surprising, since from the point of view of most staff and post-graduates of the present generation, the Sydney University Physics I Laboratory is one of the most modern, well-designed and enlightened one would be likely to see. For example, the experimental exercises, carefully designed using modern equipment, are "open-ended", in that there is more possible work available than any student can complete, and the procedural details are not spelled out cookbook-style. In fact, the stated aims which guided the designing of the Physics I Laboratory were much the same as those which led to the Trial Course. Here we do not attempt to diagnose in detail the reasons for the practical shortcomings of the conventional course. Rather we plan to describe some aspects of the average student's perception of the laboratory.

From the student point of view there is little if any perceived response to student desires. The laboratory course (indeed the University itself) seems from below monolithic and unresponsive, hence the unreality of the possibility of fruitfulness of student initiative. Mostly coming from rigid and authoritarian high school structures, students do not expect that opportunities for personal initiative exist, nor believe in them when they are presented. So although the official laboratory course potentially may be flexible in theory, it just does not seem so to the students, which is in many ways equivalent to it not being flexible at all.

So we may say that the failure of the Physics I Laboratory is not that students are not given choices. Rather it is that students are not encouraged to develop their ability to make their own choices, to use their initiative. That this does not occur in the laboratory is supported by simple observation. The task for teachers and course planners who seriously care to develop the critical abilities of physics students is that of designing a course structure which allows for a maximum of useful student contribution to that very structure.

These comments on student perception of the Physics I Laboratory throw some light on the success of the Trial Course. The very fact that it was designed by the students themselves greatly increased their motivation, and as a result their work improved in quality and quantity. If a course like the Trial Course were forced on another group of students, the same degree of success would be far less likely. The enthusiasm for work and learning which marked the Trial Course came not only from its scope and flexibility, but also from the fact that the students were to a significant degree in control of their own education.

Conclusion

At the beginning of this article we stated that the learning potential of first year physics students is largely untapped and that some first year students have important contributions to make in determining the structure of their courses. Let us consider these statements further in the light of the experiences we have described.

Normally first year students are not thought to be ready to read published research papers in physics, and in any case few people ever imagine that such an activity could be a useful way to promote learning. But experiences such as the Research Study Course indicate that students are capable of reading and ready to read research papers, and indeed eager to do so. And in this eagerness lie the reasons for the success of this teaching/learning method: the students are motivated to learn a mass of material, factual and conceptual, as a means to understanding the research papers. From an educational point of view, the method may be considered to stand conventional teaching on its head. Instead of first learning 'facts' so that later principles may be understood as correlating them, the activities of scientists are the main object of understanding; the students' desire to understand these activities motivates the learning of the necessary background facts and organising principles in a *highly efficient manner.*

Few educators demonstrate in practice a belief that first year university students can take any real control of their learning. Student suggestions and attitudes are sometimes noted with attention, but usually so that the educator may redesign the course for them. This attitude that the learning environment of the student must be completely structured for him leads to actions which can only appear to support that belief: given little or no responsibility for his education, the student never develops the ability to handle responsibility and often comes to believe he has no right to any responsibility. We believe this attitude is misguided.

The example of the Trial Course as an experience in student capabilities and initiative suggests that apparent student apathy and inability may be explained in terms of a lack of involvement in the designing of their courses. Some students can design a plan for their own education and show in the process considerable sensitivity to the problems involved in the enterprise. But the real importance of students having an active role in designing their education is the enthusiasm for work which this role engenders. Normally it is thought the students must be pushed into study by attendance at lectures, assignments, examinations, or other pressures; spontaneous extra work by students is though to be unusual and something to be 'absorbed' by making the course more difficult. From our experience with the Trial Course, we believe that given a group of students taking a course because they want to, a successful course will be marked by the fact that extra work is the rule

rather than the exception. The Trial Course was spectacularly successful in this sense, not only because it was open-ended and flexible, but also because it was designed by the students themselves, and therefore especially suited to their particular needs.

To conclude, we believe the student is much underrated by those who administer his educational experiences. The few occasions on which students show their true potential belie the assumptions of the conventional approaches to teaching. Although we believe that the method of the Research Study Course and the structure of the Trial Course are in themselves of considerable significance, their real import lies in their demonstration of the hitherto unrealised or repressed capabilities of first year university students.

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THE REGISTER

CHANGES IN MEMBERSHIP FROM 23 APRIL 1974 TO 2 JULY 1974

Fellowship

Transfer

Thomas, B.W.	Western Australian Institute of Technology

Membership

(a) New Elections

Barber, M.H.	University of New South Wales.
Chan, D. M–H.	Department of Primary Industry, ACT.
Dewar, R.L.	Australian National University, ACT.

(b) Transfers

Doughty, C.J.	South Australian College of External Studies.
LeMarshall, J.F.	Bureau of Meteorology, Vic.
Willett, P.R.	The Olympic Tyre & Rubber Co. Pty Ltd, Vic.

(c) Removals from Register under Clause 13 of Articles of Association

Bailey, J.E.	(NSW)	Crinean, G.B.	(Vic.)
Fenton, R.S.	(Vic.)	Gordon, C.J.	(NSW)
Gupta, R.K.	(O/S)	Hands, P.E.	(WA)
Lokan, K.H.	(O/S)	Shamsi, S.K.	(O/S)
Simons, R.G.	(NSW)	Webb, J.P.	(Qld)

(d) Removals from Register, Address Unknown

LeMarne, A.E.

(e) Resignations

Belin, R.E.	(Vic.)	Towson, J.E. (Mrs)	(NSW)

Graduateship

(a) New Elections

Antonopoulos, W.G.	Department of Education, NSW.
Harridge, G.W.	Monash University, Vic.
Rigutto, G. (Ms)	Monash University, Vic.
Zybert, J.J.	Monash University, Vic.

(b) Transfers

Campbell, M. (Mrs)	Wollongong University College, NSW.
Coles, B.D.	AFMECO Pty Ltd, SA.
Hayes, F.K.	Department of Education, Vic.
Kennedy, G.D.M.	Department of Education, NSW
Whyte, L.C.F.	Australian National University, ACT.

(c) Removals from Register under Clause 13 of Articles of Association

Bhathal, R.S.	(O/S)	Borejdo, J.	(O/S)
Dingle, R.E.	(Vic.)	Hagan, P.J.	(O/S)
Harwood, K.	(Vic.)	Isaak, G.R.	(O/S)
Kiewiet, C.W.	(O/S)	Miller, D.J.	(NSW)
Nolan, S.J.	(SA)	Waite, P.J.	(SA)
Wallace, W.J.	(NSW)	Wilson, V.C.	(NSW)

(d) Removals from Register, Address Unknown

Falvelle, A.J.	Fowler, D.K.
Molde, T.A.	

(e) Resignations

Barker, P.S. (Mrs)	(Vic.)	Bolton, T.M.	(O/S)
		Holt, J.N.	(Qld)
Brown, K.	(NSW)	Stewart, R.T.	(NSW)

Students

(a) New Elections

Bartlett, W.P.	(Vic.)	Clark, P.R.	(Qld)
Khanarian, G.	(NSW)	McKay, P.A. (Miss)	(Qld)
Porter, S.E.	(Qld)		
Willmott, M.C.	(Vic.)	Soar, R.G.	(Vic.)

(b) Removals from Register under Clause 13 of Articles of Association

Bradford, B.D.	(WA)	Carter, R.J.	(Vic.)
Curtin, P.C.	(Qld)	Fletcher, G.	(NSW)
Powell, D.L.	(ACT)	Stirzaker, L.R.	(NSW)
Whitehouse, T.J.	(Vic.)	Zalcman, L.B.	(Vic.)