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ABSTRACT

This report of an international conference deals with problems concerning the development and implementation of science curriculum, particularly physics. Papers and discussions of participants are included and are categorized into the following groups: (1) The Motivation and the structure of science curricula; (2) Strategies and dispositions for the construction of science curricula; (3) Methods of the implementation and of the instruction of specific subject matters; (4) The evaluation of science teaching; and (5) Experimental psychology and science instruction. (CP)

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Implementation of Curricula in Science Education

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Report of an International Seminar on "The Implementation of Curricula in Science Education with Special Regard to the Teaching of Physics", organized by the German Commission for UNESCO and the Institute for Science Education at the University of Kiel, Kiel, March 16–18, 1972

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Seminarbericht der Deutschen UNESCO-Kommission Nr. 22

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Vorwort

Veranstaltungen über aktuelle Probleme aus dem Bereich der Naturwissenschaften nehmen im Arbeitsprogramm der Deutschen UNESCO-Kommission einen sich ständig vergrößernden Platz ein. Das gilt nicht nur für Themen der Forschungsförderung im internationalen und interdisziplinären Zusammenhang, sondern auch für Fragen, die sich aus der Lehre der Naturwissenschaften und der Ausbildung hierzu ergeben. Vor diesem Hintergrund ist das internationale Seminar über die Einführung naturwissenschaftlicher Curricula in den Physikunterricht zu sehen, das von der Deutschen UNESCO-Kommission und dem Institut für die Pädagogik der Naturwissenschaften (IPN) an der Universität Kiel gemeinsam veranstaltet wurde.
Die hierbei angeschnittene Frage hat in den letzten Jahren zunehmend an Bedeutung gewonnen, wobei man versuchte - parallel zu einer sich immer schneller entwickelnden Technologie - auch im Physikunterricht die Entwicklung neuer Lehrmethoden und -materialien mit Nachdruck voranzutreiben. Die nach dem Erscheinen des Sputnik zuerst in Amerika und England begonnenen Projekte für Curriculumentwicklung in den Naturwissenschaften - jetzt beläuft sich die Anzahl von Projekten international auf einige hundert - und etwa die erhöhten Aktivitäten von Lehrplankommissionen sind Anzeichen für diesen Trend. Es ist nicht zuletzt deshalb notwendig, neue Wege zu gehen, weil die in jüngster Zeit angestrebten Reformen ihr Ziel nur in beschränktem Maße erreichten. Gangbare Wege zu finden heißt auch, den Informationsfluß zwischen den verschiedenen Techniken, Systemen und wissenschaftlichen Grundlagenforschungen auf dem Gebiet der Pädagogik anzubahnen und zu fördern. Diese Forderung zu erfüllen, sah die Deutsche UNESCO-Kommission in der Möglichkeit einer gemeinsamen Veranstaltung dieses Seminars mit dem Institut für die Pädagogik der Naturwissenschaften in Kiel, wobei eine schon seit langem bestehende gute Zusammenarbeit genutzt werden konnte. Es sei der Deutschen UNESCO-Kommission daher an dieser Stelle erlaubt, ihren besonderen Dank dem Institut für die Pädagogik der Naturwissenschaften und dabei speziell seinem früheren Institutsdirektor Prof. Dr. K. Hecht und dem heutigen Geschäftsführenden Direktor Prof. Dr. K. Frey auszusprechen.
Dank der internationalen Verbindungen der UNESCO in Paris gelang es der Deutschen UNESCO-Kommission, Teilnehmer aus drei Kontinenten zu diesem Erfahrungsaustausch zusammenzubringen. Das IPN besorgte die wissenschaftliche Ausrichtung; durch seine enge Verbindung mit dem Groupe International de Recherche sur l'Enseignement de la Physique (GIREP), einer internationalen Vereinigung von Physikern und Physiklehrern, konnte auch es eine Reihe ausländischer Experten für Beiträge zu diesem Seminar gewinnen. Diese internationale Zusammenarbeit in Referaten und Diskussionen - auch mit Beiträgen von Fachleuten südosteuropäischer Länder - unterstreicht die Bedeutung des Seminars und hat sicherlich nicht zuletzt zu seinem erfolgreichen Verlauf beigetragen.

Thomas Keller
Generalsekretär der
Deutschen UNESCO-Kommission

Preface

Proceedings connected with current problems in the sphere of the natural sciences occupy a continually larger place in the operational programme of the German Commission for UNESCO. This holds good not only for topics having a bearing on the promotion of research in the international and interdisciplinary connection, but also for pertinent questions arising out of the theory of, and instruction in, the natural sciences. It is against this background that is to be seen the international seminar on the introduction of natural science curricula in physics instruction that was organized jointly by the German Commission for UNESCO and the Institute for the Pedagogics of the Natural Sciences (IPN) at Kiel University.
Increasing importance had attached in recent years to questions cropping up in this connection, with the attempt being made - parallel to a technology that is advancing ever more rapidly - to press forward energetically with the development of new methods and materials in physics instruction as well. The projects for curricula development in the natural sciences, first initiated in America and Britain following the appearance of the Sputnik - the number of projects pursued on an international basis now amounts to something like a hundred - and, possibly, the increased activities of instructional plan commissions are indications of this trend. Not least is it necessary to adopt fresh approaches, because only to a limited extent have the reforms sought in recent times achieved their object. To find practicable ways also means embarking on and encouraging the flow of information among the various techniques, systems and axioms of science in the field of pedagogics. The German Commission for UNESCO saw the feasibility of meeting this demand by organizing this seminar jointly with the Institute for the Pedagogics of the Natural Sciences in Kiel, whereby it was possible to make use of the excellent co-operation that has been existing for a long time already. At this place, therefore, the German Commission for UNESCO may perhaps be permitted to tender its special thanks to the Institute for the Pedagogics of the Natural Sciences and particularly to the Institute's former Director, Prof. Dr. K. Hecht, and to the present Director of operations, Prof. Dr. K. Frey.
Thanks to the international connections of UNESCO in Paris, the German Commission for UNESCO succeeded in securing the attendance of people from three continents for participating in this exchange of experiences. The IPN was in charge of the scientific arrangements and, through its close connection with the Groupe International de Recherche sur l'Enseignement de la Physique (GIREP), an international association of physicists and physics instructors, it also succeeded in getting a number of foreign experts to make contributions to this seminar. This international co-operation in lectures and discussions - including contributions from experts in South-East European countries as well - underlines the significance of the seminar and certainly helped, not least, towards the success of its course.

Thomas Keller
Secretary-General
German Commission for UNESCO

Contents

I. Introduction

Karl Frey

The implementation problem of science curricula

The topic of the UNESCO-Seminar is "The implementation of science curricula with special regard to physics instruction". This topic has not only developed in recent years its own objectives for which experiences can be exchanged, but also has become, especially in the natural sciences, a question of primary concern. The priority of this question has its reason in practice, because in recent years it could be shown definitely in this area that reforms of education did not reach their goals, because the implementation did not lead to the desired products and because curriculum development was in danger of becoming an uneconomical enterprise. The first statement, that the finished curricula did not lead to the desired students' learning results, as well as the second, that curriculum projects become too expensive and relatively ineffective enterprises, have led to basic thoughts concerning the curriculum process.

One kind of reasoning led to the extreme position that no curricula should be constructed as such anymore but only broad and general topics, educational tendencies or "objectives with open ends" planned. The whole curriculum process is so to speak reduced to the instructional moment, when the teacher interacts with the student.

On the other side there were thoughts and experiments to plan the curriculum process in its phase of implementation totally by using the different kinds of knowledge and techniques from research in innovation, system engineering, socialization techniques, and administration theories. At the same time, problems of methodology and systems of science arose immediately. Curriculum implementation has been shown to be an utmost complex field, where system theoretical as well as ideographical statements are possible and necessary. In addition, traditional research designs controlling variables are not applicable for explaining and exploring implementation processes. There is also the interrelation of areas to be attacked experimentally, and the areas of policy and norms.

Some of these problems are intended to be dealt with in the contributions of the UNESCO-Seminar, e.g. the central point of teachers as implementators of curricula (contributions by Rogers, Thomsen, Baez, Sawicki, Balasubramaniam) and evaluation (contributions by Wood, Keeves and others).

Unfortunately, the general topic of implementation of curricula in the natural sciences could not be attacked systematically, but mainly from the viewpoint of single projects or authors. The expansion, concretization, and connections between the contributions happen in discussions and workshops.

As a consequence, in addition to the presentation of each paper, exchange of information and development of new concepts is possible, which is a major goal of this international seminar.

In addition, the UNESCO-Seminar, dealing with implementation and curricula in the natural sciences in the IPN, is a new model for cooperation between the German UNESCO-Commission and subject- or science-oriented institutions. In this model, UNESCO lays the necessary foundations for financial resources and external facilities and takes care of the public representation of the seminar. The IPN takes care of the planning of the topics, the structuring of questions, and the inner organization of the seminar. We hope that a fertile approach has been found, by this complete subjectfree planning of content and at the same time the assistance of the external organization, so that an international exchange of information and the collective development of new concepts will be possible.

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II. The motivation and the structure of science curricula

M.G. Ebison

The role of the history and philosophy of physics in the physics curriculum

1. Introduction

It is a formidable task to persuade some of the professional physicists who ultimately exercise considerable control over much of the physics taught in schools and colleges by their influence on the production of syllabuses and on the setting of examinations, of the value and importance of the history and philosophy of physics. Such physicists seem unwilling to see physics as anything other than the reduction of physical phenomena to mathematical representations which take the place of reality.
There are those who are simply destructive critics, arguing that history and philosophy of physics are nothing more than a complete waste of time for all kinds of students at every level. To this extreme position we may reply that science is essentially a process, stretching through time from the past, through the present to the future. In the second century B.C. the great Greek astronomer Hipparchus constructed the first accurate star map. Nearly two thousand years later, Bradley recorded precisely the positions of many stars. In 1818 his results were revised by Bessel and in 1886 again revised by Auwers. Since then fresh measurements have been made and in this way we discover that certain stars move extremely slowly in various directions. It is out of such patient endeavour that scientific knowledge emerges. Science may ignore its history, but if it does it runs the risk of failing. At the end of the nineteenth century, physicists were very concerned because it seemed impossible to discover whether or not the earth moved through the aether from an experiment performed in an earth-bound laboratory. The refined method upon which reliance was placed, depended upon a system of mechanics built on foundations laid by Galileo. But in 1630 Galileo himself had written: "I will endeavour to show that all experiments that can be made upon the Earth are insufficient means to conclude its mobility, and are indifferently applicable to the Earth movable or immovable"; and this was in fact an essential part of his theory. But no one remembered this and the paradox remained unresolved until Einstein said the same thing in different words.
Herbert Dingle writes:

> "... the history of science is science. Scientific workers may forget this, and, knowing little or nothing of the ground on which their edifice rests, may add to its structure and reach positions of the highest eminence in their profession, but they are not then educated men. To the true scientist they are as the artificer to the artist, the sleep-walker to the explorer, the instinctive cry to the pregnant phrase. Such a one may achieve much of value, but he is also a potential danger. At the moment he happens to be a profoundly disquieting menace to our civilization"(1).

It would not, I think, be equally valid to claim that the philosophy of science is science. Yet surely it is almost beyond contention that an important part in the process of learning about science must lie in trying to understand the nature of science. The scientist making the semi-serious charge that the task of the philosopher of science is to make difficult what everybody else finds perfectly easy, is misinterpreting, perhaps deliberately, what the philosopher of science is trying to do. Amongst those who express constructive doubts concerning the history and philosophy of science, it is possible to distinguish the following groups:

(a) Those who argue that since it is not possible to unearth accurately the whole historical truth about any past set of circumstances, the whole activity of looking at the history of science can lead only to frustration and misconceptions (2). This view is surely unduly pessimistic. Certainly, fallacies may arise from the use of bad or inadequate history of science (of which there is admittedly a good deal). A good history of science that is based upon some acquaintance on the part of the teacher with original rather than secondary sources, is able to provide illumination without necessarily claiming completeness for the story told. S. G. Brush, by using a number of case histories, has illustrated how over-reliance on secondary sources can lead to errors of fact being perpetuated (3).

In connection with the point of accuracy in history, G. Sarton has written:

"... those who know science - or are supposed to know it because they have made a special study in some narrow field - are often given to viewing history with contempt. They think that the study of history is hopelessly inaccurate and, according to their own definition of science, unscientific. This is a mistake, which, however, it would take too long to refute completely. Suffice it to say that historical studies, like all other studies, are approximate; the approximation obtained by historians may be looser, but the studies are none the less scientific for that. It is not so much its degree of approximation, as a definite knowledge of this degree, that gives to a study its scientific character" (4).

(b) Those who accept the value of the history of science for students who are not going to become specialists in the subject, but have doubts about its value for the future professional scientist. Thus, J. B. Conant, who has pioneered the use of historical case studies for non-science majors [see, for example, "Science and Common Sense and Harvard Case Histories in Experimental Science"] has written that while a knowledge of the history of science may help a scientist to function more effectively as a citizen outside the laboratory, it has nothing to teach him about the methods he should adopt in order to make new discoveries. R. B. Lindsay has effectively refuted this view by giving a number of instances in which scientists have been greatly helped by a knowledge of the work of their predecessors. Such instances include Galileo's reliance upon Archimedes in mechanics, Young and Fresnel's careful study of the work of Newton and Huygens in optics, and de Broglie's dependence on the speculations of Hamilton and Jacobi on the relationship between mechanics and optics (5). H. Dingle also takes a view contrary to that of Conant. He suggests that any scientific researcher will profit by returning to the great thinkers and investigators of the past within his own particular area of research. The results of such forays can be surprising, since the residuum of the work of such people which gets fossilised in textbooks often presents a distorted view of what they actually did and thought. Dingle feels that clues to the psychology of scientific discovery can often be gleaned from this kind of historical study (6).

(c) There are those who believe that a study of the history and philosophy of science, though very valuable, should essentially be confined to graduate study. O. Blüh, for example, has argued that

"... only if students have some background of the subject will it be possible to awaken their interest in the historical development seen as a search for knowledge. ... One might venture to put forward as an educational principle the proposition that the specialist will appreciate the wider aspects of his chosen field of study only when he sees them from his local standpoint, from the viewpoint of his specialization"(7).

This view may well be applicable to a detailed study of the technicalities of the history of science but it can be argued that much can be done at lower levels by presenting physics with a due regard to its historical and cultural setting. Even in an initial course the historical material does not have to be confined to anecdotes and simplifications of doubtful authenticity as Blüh contends. [See G. Holton's comment on Blüh's paper in the American Journal of Physics 23,389 (1955).]

In contrast to the doubters, many eminent scientists have written persuasive articles and given eloquent talks in an attempt to justify the importance of the history and philosophy of science. Six extracts have been chosen from a period covering more than forty years.

(a) In 1927 Charles Singer wrote:

"We cannot form a clear picture of the government of our country unless we know its political history, and we cannot attain to an educationally valuable knowledge of science unless we know also how that body of thought came to be what in fact it is. We must understand the judgements on which it came to be based. Long before the days of Comte, Goethe assured us that the history of science is science itself. If trained along historical lines from the first, the student will learn to recognise that science has grown in the past by the operation of forces similar to those which are promoting it in the present. And, moreover, that science has not only grown, but has also developed, and that this process of development has been so profound that the whole appearance of the body of scientific knowledge has been changed. This naturally leads to the attitude that what has happened repeatedly in the past may be expected to happen again, and that even what seem our most fundamental scientific conceptions are liable to revision. It is in this willingness to revise opinions that scientific attitude is found. Practical acquaintance with the methods of science is needed to help us live our lives. A survey of science that shall aid us in understanding our world is no less essential to make our lives worth living. For such a survey, historical considerations are not only necessary, but are implicit in the very attempt"(8).

(b) In 1952 I. Bernard Cohen wrote:

"From the point of view of General Education the purpose of teaching science is twofold: social and intellectual. This reflects the dual role played by science in our civilization. Science has come to occupy a foremost place among the factors affecting our health, wealth and security, and producing social change; whether we like it or not, the promotion of science must be a primary concern for all active citizens in a free society.

Yet to view the social context of science only in terms of the fruits of science, would be a cruel travesty. Since its very inception science has been the delight of the mind, one of the great creations of the human spirit, and its effect on every other branch of human thinking in every age is manifest to all who have eyes to see.

... Taken over the centuries, scientific ideas have exerted a force on our civilization fully as great as the more tangible practical applications of scientific research. And I would submit that to present science in purely abstract terms as a collection of information or as a system of knowledge, thereby ignoring the place of science in the drama of human history, is simply to rob the students of their own heritage as human beings and to reduce one of the most exciting chapters in the history of mankind to the bare bones of observed facts and the skeletons of dry theories built of them"(9).

(c) In 1966 S.I. Jaki wrote:

"Although physics has grown into a major force in history, its own history is little known and seldom reflected upon. Yet, like any other human creation, physics cannot be fully understood unless it is viewed in the perspective of its historical development. Indeed neglect of the study of the recent and remote past of physics is probably a principal cause of the cultural split that in our age has put scientists and humanists in two widely separated camps - the phenomenon C.P. Snow has labeled 'the two cultures' "(10).

(d) Again in 1966, I.I. Rabi, the Nobel Prize Winner, spoke as follows at a meeting of the Educational Policies Commission, A.A.A.S. Meeting in Washington, D.C., USA:

"So what I propose as a suggestion for you is that science be taught at whatever level, from the lowest to the highest, in the humanistic way. By which I mean, it should be taught with a certain historical understanding, with a social understanding, and a human understanding in the sense of biography, the nature of the people who made this construction, the triumphs, the trials, the tribulations"(11).

(e) In 1967 A.J. Woodall wrote:

"The rapidity with which the facts, theories and techniques of science are changing ensures that the currently accepted version of science will be drastically modified in many ways within the next couple of decades. If we could present to our pupils a fair version of 'science today', without bothering ourselves or them with what has gone before, as preparation for a career in this increasingly science-dominated technologically-advanced world, it would be like using a single still from the middle of a film as preparation for viewing the next portion of the film, we must know something of what went before in order to form a mental picture of this vital, developing entity we call science and fit it into its setting as an essential part of modern civilization"(12).

(f) In 1969 L.E. Klopfer wrote:

"In a fast-moving, ever-changing world of events, it is easy to ignore the record of past accomplishments, struggles and defeats; history, the teacher may claim, has little relevance to the contemporary scene or to future problems. In the face of numerous scientific discoveries, science teachers feel overwhelmingly pressed to reshape their instruction so as to keep it up to date; the history of science, they may claim, can contribute little to knowledge their students need today. Both of these claims are erroneous. Familiarity with political history does enrich an understanding of contemporary world events and issues. Likewise, the history of science can help students to attain a better understanding of science. The history of science can serve as an important source of insights and materials for the teaching of science"(13). Despite such powerful pleas over the years, the reaction of many physicists remains something like the sceptic considering the Twin Paradox in Special Relativity: "You have proved your case but I don't believe a word of it!" While admitting that the history and philosophy of physics is important and that students should not go in ignorance of them, nevertheless they are not to be confused with 'real' physics. This would seem to reveal a profound misunderstanding concerning the meaning of 'real'.

It is necessary to express concern that as physics teachers we are often kept busy constructing models of what we believe is happening in our classes whereas the reality is frequently very different. Now models as used in science have negative analogies (i. e. features in the model that are different from the thing or process that the model is describing) as well as positive analogies (14). It is possible that one of the negative analogies of the models of the learning/teaching situation in physics classes that we construct at conferences and in curriculum development and research groups as compared with the actual situation in a real classroom lies in the nature of science. It is precisely in this area of clarifying the nature of science that the history and philosophy of science have a vital part to play.

As educationalists we must not listen too closely to the narrow views of professional physicists, however competent they may be within their own restricted areas of research. Such competence does not compel educationalists to accord automatically any special virtues to their views on physics education. Still less ought such views to dictate our actions and ideas within our area of expertise. In the December 1971 issue of Scientific American there is a reproduction of the ambiguous picture by S. Dali "Slave Market with Apparition of the Invisible Bust of Voltaire". When viewed at close range the figures of people predominate; when viewed at a distance the bust of Voltairs becomes dominant.

Equally a narrow, close view of physics must yield a very different picture from that obtained by someone standing back from the esoteric frontiers of contemporary research in order to attempt to see physics as some sort of organised pattern connected and unified by certain basic underlying principles. I would want to argue that it is the latter view that is overwhelmingly the more important for physics education.

It is essential to consider again the problems of how we present physics at all levels because the situation facing us in schools and colleges is radically different from the one that has existed in the immediate past. There has been a violent change in the status of science. From enjoying a relatively high reputation as a result of spectacular achievements, science finds itself now scorned and often reviled. H. MacMahan recently wrote:

> "No one can deny that careless exploitation by science and technology has contributed to the multi-crises of our times. To name a few: the possibility of total destruction by nuclear war; an irreversible polluting of our entire planet; a totally unsupportable and largely miserable society brought on by an uncontrolled population explosion; a world-wide alienation of citizens, especially young people, from a highly complex technological society in which they themselves are irrelevant pawns"(15).

While it would be an exaggeration to claim that the new view of science has yet a firm hold on the majority of today's youth, nevertheless a substantial minority do adopt extreme anti-rational views in regarding science as basically evil. Thus, P. Goodman in "Growing Up Absurd" writes:

"Dissident young people are saying that science is antilife, it is a Calvinist obsession, it has been the weapon of white Europe to subjugate colored races, and scientific technology has become manifestly diabolical."

Now this is a violently extreme view but we need to take heed of it and we certainly must not let any case that we have concerning the manifold benefits that science has brought to the world go by default. For the influence of extreme positions is not to be gauged simply by counting the heads of extremists. They often have an influence out of all proportion to their numbers. Extremist views are usually superficially seductive even for great silent majorities who may well use the views, frequently unconsciously, to establish frames of reference.

So we need to re-examine carefully the fundamental principles that are used in constructing physics syllabuses. A. Baker in "Physics and Antiphysics" argues that the educational system is changing with great rapidity. He writes:

"The universities have two responsibilities, and to some extent these are in conflict: one is to contribute active leadership during periods of political and emotional crisis; the other is to preserve islands of reason and objectivity and to keep as many people intellectually free as possible. I do not believe that these objectives are best served any longer by maintaining the traditional separation between physics and the rest of life. The humanities are in touch with the majority of young people and the academic humanists are in the vanguard of the new movement. Yet we continue for the most part to teach physics as if nothing has happened"(16).

Baker is, of course, referring to the American situation where a larger proportion of students goes on to college or university than is the case in most European countries. So the duties which he outlines for American universities must in some sense devolve upon the European schools. I want to argue that by paying due regard to the history and and philosophy of physics, we can help to shape the image of physics in such a way that we can meet Baker's requirements even in initial physics courses.

We need to modify drastically the idea that real physics consists of learning several methods of measuring the value of certain physical properties or of performing mathematical gymnastics on cunningly-devised artificial problems made manageable by ascribing idealised properties such as zero friction or point masses to the world. Students of physics at whatever level must be presented with something of the ways in which hypotheses are generated and tested, models are developed and modified, laws are formulated and circumscribed and theories are constructed and inter-connected. Though the word "real" is notoriously difficult to define, surely it is the uses of hypotheses, models, laws and theories that are the "real" physics. The professional physicist may learn the uses of such concepts within his own research. For the majority of people who learn physics there will be no such opportunity and we need specifically to deal with such areas in all our courses if students are to emerge with any understanding of the true nature of science.

In order to reshape the image of physics we need to alter the style of our teaching as much as its content. Emphasis should be placed upon the "verb" aspect of physics, in the sense of physics as a dynamic developing discipline, as well as upon the "noun" aspect of physics in the sense of a collection of facts, definitions, laws and theories which have to be learnt without real understanding for regurgitation at specific points in space-time such as examination halls.

Above all we need to reveal to our students that physics is done by people who have the normal range of human feelings (17). Physicists do not believe that they are infallible nor that their subject is without its own inherent limitations. Most recognise the dangers of the all-too-common misconception that science is the all-powerful final authority. Perhaps fewer recognise the dangers of dogmatic tendencies within physics. Landé writes:

"... if you cannot explain it, call it a principle; then defend it as fundamental and absolutely irreducible, so that speaking of the unsolved riddle from here on becomes the mark of naiveté if not of heresy"(18).

In general, however, physicists do hold that their subject properly used can provide long-term solutions to many of the very real problems facing the world.

Before presenting the more positive aspects of my argument, mention needs to be made of certain features of the presentation of the history and philosophy of physics that should be avoided.

(a) We must surely look beyond the mere presentation of a rag-bag of photographs of the busts or tombs or monuments of famous physicists so beloved by authors, presumably as a means of humanising their texts. Such things have a strictly limited appeal for students and may indeed deflect attention from the more important examination of the way in which the person concerned has taken an idea and developed it within the context provided by the society in which he lived.

(b) There is no need for students to be burdened by minute details of the events considered. There is little to be gained by insistence on the memorisation of dates (and indeed many of the dates scattered through the average physics textbook are factually incorrect). Furthermore, even if they were correct they would contribute little to the historical understanding of physics that we are after. We should instead deal with the broad sweep of ideas in which students have an idea of the relative chronological position of famous physicists as great themes of physics develop.

(c) The philosophy of physics is often said to be abstract and incomprehensible. If our development of the philosophical ideas of physics leaves students with this impression, then it has failed. It is not difficult to avoid over-complex ideas at the early stages and yet still present certain features of scientific methods to our students so that as they become more mature they quite naturally approach scientific problems in the right frame of mind.

(d) The philosophy of physics can be expressed in a highly technical and symbolic language. This would be quite inappropriate in the kind of course about which we are talking.

Some comment needs to be made at this stage on the connection between the history and the philosophy of physics. In this paper I have accepted the view that for the historical record to have any useful meaning it has to be interpreted and related to present knowledge. This interpretation inevitably involves philosophy. Again, the influence of philosophy on the development of physics is most clearly brought out in terms of concrete episodes from the history of physics. For reasons such as these it would seem that for our purposes the history and the philosophy of physics are inextricably related.

Concerning the background of my proposals, it is not my intention to argue that all that we need to do is to insert a section with the title "History and Philosophy of Physics" into every physics curriculum and simply allow it to take its place alongside "Mechanics", "Heat", "Optics", "Magnetism and Electricity", "Modern Physics" an so on. Still less is it my contention that a course on the history and philosophy of physics should replace the physics course. My plea is that we should allow the history and philosophy, used judiciously, to influence our whole style of teaching. In my view, the style of our teaching is the most vital single factor to the success of any curriculum. It is also the most difficult factor to get exactly right for it is so elusive (19).

Many of us proceed at an enormous rate through the syllabus, making definitions, introducing concepts, deriving formulae, creating problems and so on, so that it is little wonder that even with the best will in the world, our students sometimes feel that they are standing at the bottom of a veritable waterfall of knowledge. It is natural for them to grasp at definitions and formulae out of this welter of information as given them at least some sense of security. Not surprisingly they too easily assume that such things form the essence of the subject.

J. Rigden in an article "Reshaping the Image of Physics"(20) argues persuasively that there are three changes in style of teaching which could help to change the image of physics as being little more than a vast collection of isolated facts:

First, we need to share with our students something of the wonder and pleasure that we feel concerning the intellectual structure that physicists claim to have built in order to explain the physical world.

Secondly, we need to lay emphasis on physics as a dynamic process rather than simply a static product. Facts stated in a straight-forward way are rarely interesting and compelling. But the same facts placed within the context of how they came to be discovered and understood can become fascinating. It is difficult perhaps to give the context of many of the more intriguing contemporary advances in physics on an initial physics course since to understand them adequately necessarily involves a good acquaintance with some quite sophisticated mathematical techniques. This is no excuse, however, for failing to present physics as a dynamic process. Here is one point where the history of physics is able to help, for it is not difficult to find topics that can be developed in a way that will reveal something to students of the drama and intrigue that was originally present. Rigden writes:

> "The historical development of selected topics, perhaps in case studies, would show students how ideas are born, tested, modified, compressed, integrated into more general schemes, or devitalized to the extent that they slowly fade from the scene"(21).

Thirdly, it is necessary to reduce the sheer bulk of material that is presented on initial physics courses. The teacher needs to gain elbow room so that he can show by tracing the evolution of selected themes how today's process becomes tomorrow's product in the development of physics.

It is now necessary for me to be positive and specific concerning the role that it is my belief that the history and philosophy of physics can and ought to play in the physics curriculum. This role may conveniently be analysed in terms of certain attributes, aptitudes and attitudes which might plausibly be held to be desirable in a student completing an initial course whether or not he intends to go on to specialise in physics. And as Professor Eric Rogers has remarked, we must be concerned with the student not only during the course and at its end but also a dozen or so years beyond, for some at least of his feelings concerning his physics course may well influence his children when they in turn come to start their own physics courses. It might be a salutary experience for us to ask our own pupils, twelve years after they have left us, what they remember of the courses that we gave them. I suspect that in the old days it could well have been some vague recollection of density bottles, pulleys and inclined planes; I hope that with all our new courses the future will not yield a similar sort of restricted recollection but then in terms of linear air tracks, ripple tanks and power packs!

I shall not rehearse all the grand reasons for introducing the history and philosophy of physics into the physics curriculum. This has been done so often and so well in the past and more recently in a fascinating and timely paper by Professor G. Holton with the title "Improving College Science Teaching: Lessons from Contemporary Science and the History of Science" (22). Nor shall I give an extended discussion of methods of using the history of physics in physics teaching since a comprehensive discussion may be found in an excellent article "A Sense of History in Science" by I. B. Cohen in the American Journal of Physics 18, 343 (1950). Rather I simply wish to point to some trends that I believe are desirable and which can conveniently be emphasized by using historical and philosophical perspectives in our physics teaching. Some physics teachers may well feel that some of these trends will arise incidentally in their teaching. They may feel that they extracted the features that I will be describing out of the physics courses, many of which were highly traditional, that they themselves took. I believe, however, that we should not too readily assume that what has happened to those of us who eventually chose to become physics teachers will necessarily happen to all our students unless the points are made explicitly at some stage in their courses.

2. Students should be able to appreciate that physics is a pretty grand affair and yet is a profoundly human activity

Physics is so grand that it vitally needs the very human trait of imagination if it is to begin to accomplish its task. Physicists do not become desiccated calculating machines on passing through the door of a laboratory. Too often we underestimate the part played by imagination and intuition in physics. Emerson wrote:

"Science does not know its debt to imagination."

And while one might quarrel with the depersonalising effect of using 'science' rather than scientists, one can heartily agree with the opinion here expressed. Max Planck does not make Emerson's error when he writes:

"The pioneer scientist must have a vivid intuitive imagination for new ideas, ideas not generated by deduction, but by artistically creative imagination." (23)

The history of physics shows many examples of great discoveries being made by the stubborn adherence to ideas that have arisen in a great physicist's imagination. There are leaps in the dark which yield stupendous results. To take but two examples, think of Louis de Broglie's almost mystical conjecture that if waves could behave like particles, particles might behave like waves. Remember that at the time this could equally well have been the inspired guess of a genius or the wild fantasy of a fanatic.

Or think of Dirac's interpretation of the equations of relativistic electron theory in which he suggested that if all energy states of electrons defined by his equations are equally permissible, then even in a vacuum we can imagine a space teeming with electrons, but having negative energy. If from this "sea" of electrons, an electron jumps into a state of positive energy this would mean the appearance of a negatively charged electron, with a "hole" left behind which acts like an electron of positive charge.

How can one possibly believe that these examples give evidence of any sort of automatic straight-forward computer-like activity? And yet physicists manage it all often! Thus in the case of Dirac's suggestion, many physicists at the time thought that it was no more than a mathematical curiosity - a trick with the equations, having no real relevance to the world of material particles.

The two examples given above are chosen more or less at random from the many possible ones available from the history of physics. This area is pursued much further in a very interesting book by A. M. Taylor "Imagination and the Growth of Science"(24).

But, of course, imagination is not the only mark of a human being which is manifested by physicists. For example, tenacity and hard work are also required. In the Project Physics course developed at Harvard University (25) there is an experiment which illustrates these traits neatly. The student uses a set of unretouched sky-photographs to plot the orbit of Mars. By doing this he begins dimly to appreciate the magnitude of the task that Kepler faced for so long (and without the advantages of photography!).

This is not the point at which to develop the idea of physics as a human activity much further except to say that students have much to gain by knowing something of the very complex personality of a man like Newton (26), the eccentric character of a man like Cavendish and the unusual background of a man like Faraday. An interesting modern example of the part played by personal relationships in an important scientific discovery involving physicists appears in Watson's book "The Double Helix"(27). The somewhat violent reactions to this book give an indication of the kind of pressures existing to preserve the picture of scientists as cold, impersonal, rationalists rather than as people possessing the normal human virtues and faults.

3. Students need the opportunity to see the requirement of a balance between the various components of physics

The ideal paradigm of physics' development involves the maintenance of some sort of balance between theory, experiment and technical development of equipment. It is a simple matter by choosing different periods in the growth of physics to show that, allowing one component to become over-emphasized at the expense of the others, leads to a lop-sided growth which may even cause the whole process to wither and die, at least temporarily. This point may well be illustrated by looking at Babylonian astronomy where sterility eventually set in because of the lack of interest in developing any theory to interpret their very fine collection of data resulting from a patient collecting and recording of observations over many centuries. In the case of Greek science, though experimental work was by no means entirely absent, it was the over-emphasis upon theory at the expense of relevant observations that effectively brought development to an end.

The dependence of the development of physics upon the availability of equipment is easily illustrated at almost any stage of its growth. A particularly striking example, however, is the development of whole important lines of physics as a result of the confluence of methods of securing good vacua and high potentials in the nineteenth century. And yet not too much must be made of the dependence on equipment. As H. Butterfield points out, many sensational steps were taken in science in periods when the instruments that we might feel to be absolutely essential, were not in fact available. He quotes the example of the Copernican revolution coming in advance of the telescope, Harvey's discovery of the circulation of the blood before the Microscope and Galileo's work on kinematics coming before the production of accurate timing devices. He writes:

"... change is brought about, not by new observations or additional evidence in the first instance, but by transpositions that were taking place inside the minds of the scientists themselves"(28).

4. Students need to be aware of the impotence of asking the right question

In Project Physics students are treated to a few of the adventures of that marvellous J. Hart cartoon character B.C. In one cartoon in Unit 3 "The Triumph of Mechanics", B.C. is asked the question,

"Why are you dragging that chain around?"

To which he provides the sensible answer,

"Did you ever try pushing one?"(29)

So many of our initial courses are organised in terms of asking students to solve problems, both theoretical and practical to which there is already a single established answer, conveniently provided for them either in an appendix at the back of the book or in a book of constants in the laboratory preparation room, that it is necessary to make a conscious effort to show that in the development of physics, it is asking the right question and framing it in the right way, rather than finding the right answer, that has been the crucial factor. And, of course, asking such a question is often much more difficult than finding an answer.

Examples illustrating this point are abundant both from ancient and modern times in the history of physics. Certainly the problem of the motion of the planets in their orbits is one of these cases. We can contrast the explanations given by Kepler and Newton. Kepler explaines the tangential motion of a planet along its orbit in terms of the drag which magnetic lines of force emanating from the rotating sun was supposed to exert on the planet as they swept over it. (He explained the radial motion by a quite separate magnetic force between thr sun acting as a spherical magnet with one pole at the centre and the other distributed over its surface and the planet itself magnetised like a bar magnet with a fixed axis (30).) Newton, however, was able to formulate a much more satisfactory answer essentially because he asked himself the right question. Instead of asking "what pushes the planet along its orbit?"; he asked "what stops the planet moving in a straight line?"

5. Students need to realise the important part played by models in physics

It has been said the idea of a model is the most important notion that a scientist needs to grasp (31). It is, however, by no means a simple idea to bring home to students in terms of the models now being used in contemporary physics research - quarks, dions, partons, stratons and the like. Once more, the history of physics enables us to develop this important philosophical idea.

The property of a model being useful rather than "right" is illustrated by a cartoon in Unit 5 "Models of the Atom" of Project Physics. In this cartoon a somewhat complacent artisan is shown holding a physical three dimensional model of an atom of welded metal hoops. He is standing next to a rather apprehensive but clearly erudite physics lecturer who has just finished writing Schrödinger's equation for three dimensions on the blackboard. The question beneath the cartoon asks:

"Images of the atom. Which is more useful? Which one is the atom really like?"

The process of trying to visualise an incompletely understood physical phenomenon in terms of familiar objects and ideas is a common one and is almost indispensable to progress in the theoretical treatment of physical phenomena. Indeed, one might justifiably claim that the development of physics has been, in essence, a process of representing the physical world at each stage of our understanding by a temporary model which incorporates certain fundamental ideas and which lends itself to the application of simple quantitative rules of behaviour. It is by the definition in a mathematically tractable form of those features thought to be essential in a phenomenon, which allows the correspondence with experimental results to be critically tested. Significant anomalies revealed in this way mean that the model has to be suitably modified, and in this way the physicist's view of nature has gradually developed. An excellent example of this process has occurred in the evolution of ideas concerning the structure of the atom. If we consider the chain: Dalton atom model → Thomson's plum pudding atom model → Rutherford's planetary atom model → Bohr's atom model → quantum mechanical atom model, it is immediately apparent that each fresh model resulted from a crucial anomaly thrown up by experiments used to test the reigning model. On each occasion the new model had to explain all that its predecessor had explained and in addition it had to account for the anomaly.

Students need to appreciate that the relationship between a model and the thing or process it is being used to describe involves positive, negative and neutral analogies. It is a great disappointment for me when after having accompanied a student through a three or four year physics course, he sidles up to me and in a conspiratorial whisper asks: "Is light really a wave or really a corpuscle?"

6. Students need to learn that there is no such thing as the scientific method

We should try to eradicate the myth that there is a single unalterable method applicable to all situations, at all times, in all branches of science.

Scientific methods are best seen by looking at the way actual scientists made actual discoveries. Conant writes:

"The stumbling way in which even the ablest of the early scientists had to fight through the thickets of erroneous observations, misleading generalizations, inadequate formulations, and unconscious prejudice is the story which it seems to me needs telling. It is not in courses in physics or chemistry or biology or any other of the natural sciences as far as I am aware. Take up any textbook of any of these subjects and see how very simple it all seems as far as method is concerned, and how very complicated the body of facts and principles soon becomes"(32).

The misunderstanding concerning the existence of a single unique method of science arises at least in part from the way in which research papers are written. P. Medawar in 1963 gave a broadcast talk entitled "Is the Scientific Paper a Fraud?"(33) At one point he says:

"As to what I mean by asking 'is the scientific paper a fraud?' - I do not of course mean 'does the scientific paper misrepresent facts?', and I do not mean that the interpretations you find in a scientific paper are wrong or deliberately misleading. I mean the scientific paper may be a fraud because it misrepresents the processes of thought that accompanied or gave rise to the work that is described in the paper. That is the question, and I will say right away that my answer is 'yes'. The scientific paper in its orthodox form does embody a totally mistaken conception, even a travesty, of the nature of scientific thought."

R. Taton in his marvellously entertaining book "Reason and Chance in Scientific Discovery"(33) shows quite clearly the role of intuition, error, unconscious activities, chance and accidental observations in scientific discoveries. Such a book would surely make any physicist echo Professor Eric Roger's words:

"To most of us who are practicing scientists there is no unique "scientific method" such as the idealized scheme set forth by Sir F. Bacon and still advocated by some philosophers. However, there are scientific methods - the ways in which we gather knowledge and build an increasing sense of its validity"(34).

There are certain aspects of these methods which should be emphasized in our courses. M. Boldrini in his book "Scientific Truth and Statistical Method" comments on how Galileo tells the story of how the Babylonians cooked eggs by 'centrifugal' action in swinging them rapidly round in a sling. Galileo says that if in repeating an experiment we cannot get a result that someone else has got, then it must be because we are lacking something that was the cause of the original successful result. Now, he goes on, we do not lack eggs, or slings, or strong men to swing them round or air for friction and yet they do not cook. The only thing we lack is being Babylonians, so that being Babylonians is the cause of the cooking and not the friction of the air.

This is a doubly historical story and it is a story that brings home an important truth for students - a single negative result is sufficient to belie a hypothesis while thousands of positive results are not sufficient to demonstrate its truth.

Another feature of scientific methods that needs to be made explicitly to students is the danger (and it is a very seductive one) of extrapolation. The Babylonians did extrapolate most successfully in their astronomy. But it was successful only because of the simplified motions that they were dealing with and the same methods did not work at all well when it came to forecasting locust plagues and so on. But the Babylonians bequeathed the tendency to extrapolate to their successors and the desire to extrapolate as far as possible is a very human tendency. If our students

look at what Boyle or Ohm actually did, they might be less inclined to believe that Boyle's law or Ohm's law are universally applicable in all circumstances.
The whole of our courses should be gently leading to the gradual realisation by students (perhaps unconsciously) that physical theory is neither a kind of deductive system (deduction proving that something must be the case) nor a kind of inductive process (induction showing what actually is operative) but rather an abductive process which merely suggests that something may be the case.

7. <u>Students should be made aware of certain persisting themes in physics</u>

It may come as a surprise to students when they realise that there are certain a priori commitments which in some cases at least have persisted from early times in the development of physics. (35)
Examples of such themes include symmetry, simplicity, the constancy of nature and conservation principles. We only have to think of the part played by conservation principles in the hypothesis of the neutrino to show how such themes are built into the way in which physicists approach nature.
Consider briefly just one of these themes - symmetry. It has played an important part in the development of physics in every era from Greek astronomy to fundamental particle physics. Some of the ideas of symmetry are so deep rooted that we may apply them without explicit recognition. There are, however, dangers that need to be avoided in applying principles of symmetry even when the application is a deliberate one. We must ensure that we are applying the right kind of symmetry. One might perhaps illustrate this point for students by gently suggesting the use of symmetry considerations in the following two problems:
(i) A young man has two girl friends who lived in diametrically opposite directions from his house. He was fortunate in being served by a bus route which passed in front of his home and both girl friends' homes. Buses went in each direction with the same regularity - one bus in each direction every ten minutes. Now he was equally fond of the two girls and so he decided to leave home at completely random times and catch the first bus that came along. Since the situation seemed "symmetrical", he argued, his plan would ensure that he saw each of them the same number of times over a sufficiently long period. After following his plan faithfully daily over a year, however, he found that he had seen one girl about four times as often as the other. What was wrong with the "symmetry" argument behind his plan?
(ii) In a recent letter to the London newspaper, The Times, it was argued that since there was a kind of symmetry between dates and days of the week taken over a long enough period of time, then it was quite impossible that the 13th day of a month should occur more often on a given day of the week than on any other day of the week. Yet in fact the 13th occurs more often on a Friday than on any other day of the week! What is wrong with this "symmetry" argument?
In fact, in each case the kind of symmetry argument applied has a flaw in it. (The author of this paper would be pleased to supply solutions to these problems on request!)

8. Conclusion

There are, of course, many other desirable attributes, aptitudes and attitudes which need to be developed during our physics courses and which would perhaps be realised in terms of the use of the history and philosophy of physics. Space-time, however, does not allow further development in this paper. Nevertheless, it is possible to end on an optimistic note in view of some of the excellent new physics courses that are now available. In this regard special mention must be made of PROJECT PHYSICS. This course is to be thoroughly recommended in every way, but in particular, as far as the author is concerned, because it accomplishes so much of what we have been discussing in this paper. (36)

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(21) Op. cit. p. 51.
(22) G. Holton, Improving College Science Teaching: Lessons from Contemporary Science and the History of Science. Journal of College Science Teaching 1, 31 (Oct. 1971).
(23) M. Planck, Autobiography. New York: American Philosophical Library (1967) p.109.
(24) A.M. Taylor, Imagination and the Growth of Science. London: John Murray (1966).
(25) The address of Project Physics is as follows:
Harvard Project Physics, Longfellow Hall, Appian Way,
Cambridge, Massachusetts 02138, USA.
(26) On Newton see:
J.M. Keynes, Newton, the Man. Reprinted in J.R. Newman (ed), The World of Mathematics. New York: Simon & Schuster (1956) Vol. 1, 277-285.
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(28) H. Butterfield, The Origins of Modern Science. London: Bell. (1957) p. 1.
(29) It is suggested that cartoons can often be used as a "sparking-point" for introducing class discussion of certain ideas and concepts. Many suitable cartoons occur in Project Physics. The author has made a collection of cartoons from a variety of sources and which have been photographed on 35mm slides. He would be pleased to exchange copies with any other physicist who is interested in using cartoons in this way.
(30) See G. Holton, Johannes Kepler's Universe: Its Physics and Metaphysics. American Journal of Physics 24, 340-356 (1956).
(31) R. Harré, An Introduction to the Logic of Science. London: Macmillan (1963) Preface.
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(33) R. Taton, Reason and Chance in Scientific Discovery. New York: Science Editions Inc. (1962).
(34) E.M. Rogers, Nuffield Physics Teacher's Guide 1. London: Longmans-Penguins (1966) p. 71.
(35) See Ref. 22.
(36) The author of this paper would be delighted to give an account of his experiences in using the Project Physics course as an introductory college course over a period of a number of years. He may be contacted at the address given at the head of the paper.

Additional Notes

(a) In connection with Ref. 18 some interesting articles on Quantum Physics may be found in: Ted Bastin (ed), Quantum Theory and Beyond. Cambridge: Cambridge University Press (1971).

(b) With reference to Medawar's talk mentioned on page 10 of this paper, the talk is printed in "The Listener" 12th September 1963 pp 377-378. Reprints of this paper of Medawar's are avilable on request from the author of this paper. Attention may also be drawn to two very interesting books written by Medawar:

P. B. Medawar, The Art of the Soluble. London: Methuen (1967).

P. B. Medawar, Induction and Intuition in Scientific Thought. Methuen (1969).

Discussion

Mr. BAURMANN asked for clarification on the meaning of the terms "positive" and "negative analogies" which had been used in the paper.
Mr. EBISON replied that the term "analogy" is here used to describe certain properties of a model.
Positive analogies refer to those qualities that the model possesses in which it is like the thing or process for which the model is being used. Negative analogies refer to those qualities in which the model is unlike the thing or process for which the model is being used. Negative analogies must always exist, of course, because if all connections between the model and the thing or process it described were positive, the model simply be another exact example of the thing or process.
A third kind of analogy is the neutral analogy which refers to a quality of the model where it is not yet known whether the analogy is positive or negative. It is in this area that scientific research is so often accomplished.
Mr. BAURMANN replied that he would prefer to express the connections between the thing and its model by some degree of similarity though this is not easy to manage either.
Mr. MILLER pointed to the human aspects of scientific research.
The philosophy of science and the personal attitudes of scientists ought to be made clear to the minds of students.

Torstein Harbo

Curriculum theory – another look

1. Introduction

It appears to me that our acquaintance with the field curriculum theory will run through three stages if we approach it from the outside. In the first stage, where we can only get a superficial first impression, we will be struck by the great activity which can be seen at the present moment, by the last decade's vigorous theorizing, and by the many bold attempts at bringing rational clarity to a complicated matter.

In the second stage we become acquainted with the tasks and problems which in some way or other form the basis of the theoretical advances. We get to know a good many curriculum projects which have been developed since the middle of the 1950's in the United States and Europe; indeed, all over the world. Projects, where the aim has been to renew the content of instruction and the teaching methods: in mathematics, in the natural sciences, in the social studies, in languages, and in fields which cut across the traditional subject boundaries. We also get acquainted with the curricular tasks and problems which have arisen in quite a few European countries due to changes in the structures of the school systems. In countries where the tradition is tenacious and stubborn and the call for reform impatient, these problems can assume enormous dimensions. Confronted with all these very real curriculum problems our first enthusiasm for the somewhat free play with theoretical models decreases. Besides, we become aware that the originality of most of the models is not nearly as great as it appears at a first glance. The many apparently bold attempts at bringing rational clarity to the curriculum questions are unmasked as pale imitations of one and the same model in curriculum theory. Which model? The model is not normally identified with a name by its standard bearers, because it is regarded as the model. I prefer to call it the means-ends model.

This model rests on the assumption that the pedagogical activity is first of all a goal-oriented activity. In any educational context one is first concerned with deciding the aims of the objectives, and then with choosing the relevant means to achieve the objectives. A typical variant of this model has - within the English-speaking tradition – been particularly well known for the last twenty years: "the Tyler rationale".

With the knowledge we have gained in the second stage, we try in the third and last stage to get to the bottom of the curriculum questions. We concentrate once again on the last decade's theorizing. But we do listen not only to the powerful choir: "First you have to state the objectives", but also to clear single voices: "Friends, a cautionary note"(1).

Besides, we enlarge the time-span. To limit ourselves to the years of the last few contributions does not give the right perspective. We should at least be informed about what has taken place in this century. Our field of orientation is also enlarged in another way. We follow the development within curriculum theory in two different countries. We choose the United States and Germany. As regards practical and theoretical reform efforts in the educational field, both countries have had a leading position for the last few generations. During this somewhat more intimate acquaintance with curriculum theories, we come up against quite a different view of which curriculum phenomena are central and essential. We discover that in different quarters there have been considerable objections not only against single elements in the means-ends model, but also against the model as such. It must be admitted that very often the alternatives to the means-ends model have not been so clearly formulated as the criticism directed against it. But there are alternatives.

The alternative views take as their starting point the fact that any educational situation contains two basic elements: the pupil and the content of instruction. The central task in any form of curriculum planning is thought to consist in establishing the right interaction between the pupil and this content. One may be in doubt about what to call this model. An American writer has suggested "educational encounter"(2) and in Germany the term "Begegnung" is current in connection with curriculum and teaching.(3) Provided that the existentialist undertone does not become too strong, I cannot find any better name for the phenomenon of which we are speaking here than "educational encounter". I therefore choose to call this model the encounter model.

This gradual acquaintance with curriculum theories has led us toward two models. In this lecture I will give a closer description of these two models. First, I will try to give a picture of their development in the twentieth century. Secondly, I will concentrate on some characteristic features in both models. Furthermore, I will ask which are the models that consciously or unconsciously underlie the development of new curriculum projects. Time and space force me to concentrate on projects within the natural sciences.

2. The means-ends model and the encounter model. An historical survey

In the United States curriculum theory grew up as a specialized field in the 1920's.(4) A central figure in this movement was Franklin Bobbitt of the University of Chicago. According to his view it was not difficult to construct a curriculum:

"The central theory is simple. Human life, however varied, consists in its performance of specific activities. Education that prepares for life is one that prepares definitely and adequately for these specific activities. However numerous and diverse they may be for any social class, they can be discovered. This requires that one go out into the world of affairs and discover the particulars of which these affairs consist. These will show the abilities, habits, appreciations, and forms of knowledge that men need. These will be the objectives of the curriculum. They will be numerous, definite, and particularized."(5)

Bobbitt compared the curriculum maker with a "great engineer". He starts off with a survey of man's life, specifies the different activities, then identifies the corresponding skills, divides the skills into units, organizes these units into learning experiences, and finally arranges the experiences for the pupils. Bobbitt is particularly preoccupied with the question of how "educational objectives" are to be formulated. In other works from the same period we also find the same belief in the importance of formulating objectives clearly and specifically.

By the early 1930's, however, this movement had become a victim of its own techniques. In this schools the teachers got tired of all the highly specified objectives which they were unable to manage. In addition, both a new view of the child - regarding it not as a complex machine, but as a growing organism - and a new view of the school activities - regarding them not as means to remote future ends, but of value and importance in themselves - had been established. John Dewey is a typical representative of this new view. To him the means-ends dimension is not fundamental in educational activity. It plays a secondary role. The primary thing is the activity. Ends arise and function within action:

> "They are not, as current theories too often imply, things lying beyond activity at which the latter is directed. They are not strictly speaking ends or termini of action at all. They are terminals of deliberation, and so turning points in activity".(6)

To have an end or an aim is a characteristic feature of present activity. It helps the activity to become unified and adjusted, when otherwise it would be blind and disorderly. This gives the activity meaning where it otherwise would be mechanical. Ends are means in the present activity. To be too preoccupied with future aims leads the attention away from our resources in the present situation.

After the Second World War the picture changes once more. Again rational curriculum construction becomes a popular activity. R. W. Typer and V. Henrick carried on the work of Bobbitt. Tyler, as we know, built his curriculum rationale - "Basic Principles of Curriculum and Instruction", 1950 - around four major questions:

"1. What educational purpose should the school seek to attain?
2. What educational experiences can be provided that are likely to attain these purposes?
3. How can these educational experiences be effectively organized?
4. How can we determine whether these purposes are being attained?"(7).

The questions fall, as we see, wholly into the means-ends dimension. It is first a question of deciding purposes, stating objectives. Secondly of selecting and organizing the experiences necessary to attain these purposes. And finally of evaluating in relation to the starting point. R. W. Tyler's rationale for curriculum development can properly be said to be the prototype of the means-ends model. And it is this model which in the United States has dominated the curriculum field for the last twenty years. In a survey from 1969 J. I. Goodlad maintains that " ... as far as the major questions to be answered in developing a curriculum are concerned, most of the authors in /the/ 1960 and 1969 /curriculum issues of the Review of Educational Research/ assume those set forth in 1950 by R. W. Tyler." (8)

The great support for Tyler's rationale has undoubtedly several causes. The model was well suited for the decade which produced teaching machines and programmed instruction. It was suitable for a decade which so eagerly wanted to give general importance to the demand for precise teaching aims, preferably expressed in behavioural terms, and which formalized the procedure of finding and deducing aims and objectives. Tyler himself let educational objective have a dominating position in his scheme. Educational objectives are, he says, "criteria by which materials are selected, content is outlined, instructional procedures are developed and tests and examinations are prepared". (9) An intense preoccupation with educational aims and objectives on different levels and within different domains, such as we find in the work of B. S. Bloom and his associates for instance (10), is therefore quite in accordance with the intention in Tyler's rationale - and with any means-ends model for curriculum development.

It is characteristic that the criticism which at the end of the 1960's was levelled against this dominant mode of thought within curriculum development is first of all concerned with the question of rational aims and objectives. (11) Are educational objectives, in behavioural terms, a help or a hindrance? When teachers start planning curriculum guides, do they really start with over-all educational aims, then pass on to specifying school objectives, and then finally end up with identifying behavioural objectives for specific subject-matter? Is such a formalized procedure applied in the successful curriculum reform projects which were planned and started in this period? Or is this an approach which may be possible in a theoretical connection, but hardly probable in the world of reality? As late as 1969 one of the most zealous spokesmen for educational objectives in behavioural terms had to admit that Tyler's "excellent monograph" from 1950 "failed to have any dramatic effect on the educational community" and that Bloom's taxonomy of educational objectives from 1956 had sales figures "surprisingly modest" in the first years after it had been published. (12) We perceive a certain dissatisfaction even in J. I. Goodlad's survey mentioned above: "General theory and conceptualization in curriculum appear to have advanced very little during the last decade." (13) And H. M. Kliebard who belongs to the critical wing finds that "the twentieth anniversary of the publication of the Tyler rationale is an appropriate time to reexamine and reevaluate some of its central features". According to his view, the Tyler epoch of curriculum inquiry is "long overdue". (14)

But what is the alternative? It must be admitted that up to the present time no correspondingly clear alternative has been formed. The recent array of criticism regarding the limitations of behavioural objectives and the evaluation practices related to such a concept, and a certain critical attitude toward Tyler's curriculum model in general, has, however, laid the foundation for a new approach in curriculum theory. Against this background the contours of an alternative to the means-ends model gradually seem to emerge.

This is first of all seen in quite a few authors who go back to J. Dewey's contention: the primary thing is the activity. H. M. Kliebard, for instance, writes that this will mean "that the starting point for a model of curriculum and instruction is not the statement of objectives but the activity (learning experience), and whatever objectives do appear will arise within that activity as a way of adding a new dimension to it." (15) J. B. Macdonald argues in a similar way. Our objectives are only known to us in any complete sense after the completion of our act of instruction. Educational objectives function as "heuristic devices." They initiate the first teaching sequences, but are changed in the flow of instruction. "In the final analysis, it could be argued, the teacher in activity asks a fundamentally different question from "What am I trying to accomplish?". The teacher asks, "What am I going to do?" and out of the doing comes accomplishment." (16) If we say that the means-ends model stresses the "endings", then the alternative model focuses on the "beginnings". Instead of focussing on the result of performance our attention is directed toward the starting conditions: are they such that the pupil will become engaged in what is worth becoming engaged in?(17)

The contours of the alternative model appear, secondly, in that characteristic traits about these starting conditions are brought to light. Quite a few writers have dwelt upon these conditions in recent years.(18) Here we will follow the mode of thought expressed by two of them. According to D. Huebner the current conceptions of curriculum are inadequate. This inadequacy stems from an overdependence upon a conception of value as goals or objectives, and a consequent over-dependence upon learning. This inadequacy, Huebner argues, can be partially corrected by a conception of curriculum as the design of an educative environment in which valued educational activity can occur. The alternative, then, stresses "educational activity" as the central and most significant part of curriculum, and heavily emphasizes the "educative environment" in which this activity occurs. The interaction of these two main factors takes place, Huebner suggests, mainly through "language, human encounter, and the encounter with awesome world of the non-man-made". The task of the curriculum specialist is one of designing an educative environment:

"To build an environment which structures educational activity means to select content from the whole, wide, wonderful world and to make it available for the students. So conceived, content is that which is available in the classroom for educational activity. This includes man-made objects, aspects of the natural world grouped or organized in certain ways, symbol or language systems, and usages or social conventions. In fact, educational content becomes a selection of man's culture, thus creating a limited culture for the student. But to keep the image clear, it is necessary to use culture the way Tillich uses it. He reminds those who have been overconditioned by the behavioral scientist that the biologist uses it differently: "Culture, cultura is that which takes care of something, keeps it alive, and makes it grow". The curriculum designer fabricates an educational environment which takes care of students, keeps them alive, and makes them grow."(19)

E. W. Eisner approaches the new model for curriculum theory through a penetrating criticism of the normal usage of educational objectives. Eisner distinguishes between "instructional objectives" and "expressive objectives". Instructional objectives are used in what he calls "a predictive model" of curriculum development. It is a model in which objectives are formulated and activities selected which are predicted to be useful in enabling children to attain the specific behaviour embodied in the objectives. In our terminology, a means-ends-model. Expressive objectives differ considerably from instructional objectives. An expressive objective does not specify the behaviour the student is to acquire after having engaged in the learning activities. It does not state "endings", it states instead "beginnings" - to use some of our earlier formulations. Eisner puts it this way:

"An expressive objective describes an educational encounter. It identifies a situation in which children are to work, a problem with which they are to cope, a task in which they are to engage; but it does not specify what from that encounter situation, problem, or task they are to learn. An expressive objective provides both the teacher and the student with an invitation to explore, defer, or focus on issues that are of peculiar interest or import to the inquirer.

An expressive objective is evocative rather than prescriptive."

"In the expressive context the teacher hopes to provide a situation in which meanings become personalized and in which children produce products, both theoretical and qualitative, that are as diverse as themselves. Consequently the evaluative task in this situation is not one of applying a common standard to the products produced in order to reveal its uniqueness and significance."(20)

Eisner emphasizes that these two types of objectives - instructional and expressive - require different kinds of curriculum activities and evaluation procedures, and each one of them must occupy a distinctive place in curriculum theory and development. But only in the former case does he name the corresponding curriculum model (the predictive model). It is possible that this is due to a certain shift in Eisner's line of thought when he describes the latter. He starts to describe "an educational encounter" when there are two factors: "children" on the one hand, and "work", "problem", and "task" on the other. But he ends up with a somewhat one-sided emphasis on the activity of the children.

The German reform movement in education took a somewhat different course than the corresponding movement in the United States. By the end of the 1920's the German movement was already in its final phase - a phase marked by searching reflection and self-criticism. The one-sided radical points of view from the time around the turn of the century and after were toned down. Simultaneously the positive contributions of the reform movement, above all a greater understanding of the child, were defended and strengthened. As regards curriculum theory this self-criticism meant a break-away from both the technological means-ends model and the glorification of the spontaneous activity of the pupil. T.Litt's monograph "Führen oder Wachsenlassen" from 1927 is in this connection central and characteristic.

Litt argues that in our century a technological way of thinking and acting - first deciding the aims and then choosing the relevant means - has become so prevalent that this interpretation is close at hand: that all human activity must be understood according to this scheme. But this technological way of thinking forgets that this mode of thought, taken from man's dealings with dead things, cannot in a straightforward manner be transferred to those situations where we have to do with interaction between living human beings. True enough, certain subordinate and limited functions can be understood according to a means-ends scheme. But the central and essential things in the educational process constitute such a complex whole that a technological interpretation simply is not adequate. (21)

But a reasoning along lines that concentrate on the spontaneous activity of the pupil, on his natural interests, on his natural development, does not give us a full answer either. Education implies something more than maturation and development from within. The spontaneous activity does not give content and direction. Any genuine educational process springs from a polarity between the pupil - the learning subject - and the arranged aspects of the world outside the pupil - the object. Educational activity is therefore to be understood as activity that provides contact between the pupil and world around him. Activity that brings about encounter between two equal factors ("Begegnung zweier gleichberechtigter Gewalten"). (22)

This view was developed in more detail by E. Weniger and W. Flitner. After the Second World War they continued this together with H. Roth. (23) According to Roth the secret of all education lies in providing a constructive encounter between children or youth on the one hand and a sample of our culture on the other.

"... das Geheimnis alles Unterrichtens liegt in der Herbeiführung einer fruchtbaren Begegnung zwischen Kind oder Jugendlichem und einem ausgewählten Ausschnitt der geistig erkannten oder gestalteten Welt dem Kulturgut. Was auch die Lehrerpersönlichkeit dazu beitragen mag, sie hat auf alle Fälle mit zwei Faktoren zu rechnen, an die sie sachlich gebunden ist: das ist das Kind und das ist der Gegenstand."(24)

In education there is always talk about two factors: the pupil and the object. The teacher's role consists in constructing an educational situation where these factors meet on equal terms. A situation where the pupil is allowed to be a pupil with the traits typical for his age. A situation where the object can keep its own character. Only then do we get a real educational encounter ("originale Begegnung"). (25) E. Weniger characterizes encounter as the original phenomenon of the school ("das erzieherische Urphänomen der Schule").

"Wenn wir von Begegnung sprechen, so meinen wir damit erstens, daß bei diesen Vorgängen der Zögling aktiv beteiligt ist, daß er nicht ein passives Etwas ist, ein leeres Gefäß, in das die Erzieher die Lehrgegenstände, die Stoffe der Bildung hineinfüllen, nicht ein unbeschriebenes Blatt, auf das die Erzieher einschreiben, was sie für notwendig halten, keine Tafel, auf der etwas eingeritzt wird. Erziehung ist kein einseitiges Tun der Erzieher, kein blosser Aufnahmeprozess durch den Zögling, keine einfache Reproduktion der Welt im Kind. ... Ferner soll dieser Terminus etwas von dem einfangen, was man als die Ebenbürtigkeit der am Bildungsvorgang beteiligten Partner bezeichnen könnte. Der Zögling ist zwar bei dem Vorgang als mindergereifter der schwächere Teil, aber er wird doch als voll genommen, man begegnet ihm auf einer gemeinsamen Ebene. ... Endlich ist mit dem Wort Begegnung noch ein letztes Moment im Erziehungsvorgang getroffen, ... die Freiheit des Zöglings, abzulehnen oder anzunehmen, was ihm in der Begegnung entgegentritt."(26)

This implies, first, an active participation on the part of the pupil in the instructional teaching situation. When we speak of encounter the one factor, namely the student, cannot be passive. The pupil is not conceived of as an empty tin which is to be filled with subject-matter, or as a sheet of paper on which the teacher can write. The term "encounter" implies, secondly, an equality between the parties involved. True enough, the pupil is the weaker and immature part. But in the educational situation the world he is to meet - that is, the portion of history, the actual social life, the culture and the nature - is designed in such a way that the can master it. The term "encounter" points, thirdly, towards the freedom of the pupil in the instructional situation. The pupil can receive or he can refuse to receive what he is meeting, or he can pass it by without being aware of any meeting. What the pupil will be learning at school therefore cannot be decided in detail beforehand.

To regard the educational phenomena from the point of view of encounter, and not from point of view of means-ends, seems to have been the norm in Germany right up to the 1950's. It is characteristic that the well edited and highly up-to-date

"Pädagogisches Lexikon" from 1971 does not contain any articles on educational aims and objectives (Ziele), but only deals with encounter (Begegnung). (27) In recent years the situation has changed radically. Concepts other than those which spring from views on education as "Geisteswissenschaft" have pushed forward with great force. As a consequence the means-ends model has been employed in the theorizing about curriculum, and by some the model has been used as if it were something brand new. (28)

3. Means-ends versus encounter

The preceding sketch has shown that the last 50 years' discussions within the field of curriculum theory can be regarded as a match between two basic models: the means-ends model and the encounter model. The sketch has also shown that the concepts and models used in an educational context to a large extent have been dominated by modes of thought inherent in that age. The educational phenomena seem thus as a matter of course to fall into the means-ends scheme in those periods when the thinking is strongly influenced by the cause-effect model of the natural scientists and by the decision models of technicians and the plan economists. The encounter model offers itself as the most reasonable model in periods when life, experience, and activity are regarded as something more fundamental than just the mere ideas of life, ideas of experience, and ideas of activity. In periods when what is organically growing has a stronger appeal than that which is technically designed and constructed, in periods when the future seems uncertain while the constellations of the present stand out as the only state of certainty.
Perhaps the most decisive difference between the means-ends model and the encounter model is that while in the former the rational element dominates, the empirical dominates in the latter. There can be no doubt that the means-ends model is carried forward by the assumption that the complex phenomena within the curriculum field can be rationally managed. The development of programmed instruction may in no small measure be said to have had such effects. Here the aims and objectives are clearly formulated beforehand, here one can choose between alternative means, here the programme can be sold as a whole with the label "guaranteed learning". As long as it is about learning of simple skills and acquisition of limited information, the guarantee can be said to have a high degree of validity. The assumption that it is possible to achieve a rational view of, and control over the educational process should thus be confirmed.
The question is, however, whether this assumption can be confirmed when it comes to more complex curriculum projects and when learning stretches over a longer period of time. If the means-ends model is applied in these cases, a self-contradictory element in the model clearly appears: the model includes predictions about the future. Aims and objectives are not rooted in the present. They belong to the future and as such they do not say anything about realities. Strictly speaking, they only say something about hypothetical possibilities. The further away in time the goal is and the more complicated the situations are, the more clear becomes the element of uncertainty which is always tied up with the future. The paradoxical thing is, in other words, that the curriculum model which is motivated by the wish for rational educational planning, itself contains a clear irrational element.

It is surprising that so many overlook this. Does that mean that one regards the educational phenomena, without being fully conscious on this point, as natural phenomena in a limited and closed system where one can control all the variables and where time does not play any decisive role? If this is the case, then the urge for rational clarity must have lost contact with experience.

If we keep ourselves strictly to the realities of the educational situation, the encounter model lends itself almost naturally. Any educational situation has two poles, the pupil and the contrived educ .tional environment. Any educational process can be regarded as a dynamic proc .ss, as a continuous interaction between these poles. And the result of any educa ional programme is marked by both the individuality of the pupil and the eleme s of the educational environment. The pupil and the educational environment a. realities we are faced with here and now. None of these lie in a distant and unknown future. None of them are abstractions. They lie before us in very concrete forms. We can nearly feel and touch them. On the one hand the pupil with all the traits characteristic of his age, with his individuality, with his spontaneous activity, and with his engagement. On the other hand the contrived educationa' environment. That is to say, aspects of our natural world, of our history, of our social life, of our culture and technique, of our common social forms; a carefull' rranged selection of man's knowledge and style of life.

This polarity - the pupil and the e ..ational environment - can rightly be called the original phenomenon of the s. ool.

It may seem that the teacher doe not fit in here at all. But the contrary is rather the case. The essential task of e teacher - to be both the advocate of the pupil and the representative of ma. nowledge and style of life - is more strongly emphasized.

When what is empirically give forms the starting point, both the predictable and the unpredictable elements are t..ken care of. The encounter model thus describes in a clear and concrete way the beginning of the educational process, but it does not dare to state the ending beforehand. The outcome of the educational situation is not a fact until the process has finished. Until then the outcome is something unpredictable. It must be admitted that some followers of the encounter model stress the situational and the ur predictable elements to such a degree that methods and goal directedness in the instructional situation, which the model quite definitely implies, is overlooked. This has particularly been the case in Germany. Here the term "Begegnung" of n t. kes on an existentialistic meaning. The educational process is then split up into a series of single situations, most of them trivial, and only a few containing worthwhile elements. (29) If such a limited interpretation of the term "encounter" is .sed a a starting point, it is hardly very useful in an educational connection. The reason for this is that the solving of the many tasks in school demands goal riented and systematic activity. In the work of E. Weniger and H. Roth the term "B. gegnu g" has therefore a much wider meaning. (30) And this is undoubtedly also e case with the American writers mentioned earlier.

The encounter model i. cludes systematic and conscious activity because the point of departure is not accic ntal but arranged. This is seen very clearly, if we fix our glance, not at the nil, but at the other pole of the educational situation: the content and the env. nm nt. At all times the content and the environment have been, more or less, arranged in advance. This applies even in those cases when the essential thing has been to take care of the pupil's subjective feeling of developing freely and spontaneously; I am thinking of Rousseau's educational theory and some of the teaching programmes which have been launched with the label "Learning by discovery". (31)

The encounter model includes a statement of aims - if the term is taken to mean direction rather than a terminal point. The direction is decided by the starting conditions. The lessons in mathematics lead the pupils in a different direction than the lessons in foreign languages; those in history in a different direction than those in the social sciences. The body of knowledge which the pupil acquires and the way of thought to which he is introduced, is above all dependent on what kind of educational content he meets. The aim or objective is, in other words, a result of an interaction process between the pupil and the contrived educational situation. It must be admitted that under circumstances such as these, the goal will very often be verbalized in a rather loose fashion, and the terms used - if seen in isolation - may seem rather meaningless. One should not forget, however, that apparently empty statements of goals may rest on very concrete and firm empirical grounds: pupils of a certain age with approximately well defined capacity on the one hand, and educational content of some kind or other on the other hand. One should also remember that in this case the content and methods used are not deduced from aims or objectives. The contrary is rather the case: the aims or objectives are inferred inductively. Thus they are only a reflection of a complicated and concrete reality. Aims and objectives, then, have a different function in the encounter model than in the means-ends model. Much criticism has been produced because one could not make this distinction. (32)

4. New curricula in science - which model?

It has been said of the new curricula in science, in mathematics, in social sciences, and in the arts that "these projects are important not only in their own right, but also because they provide the necessary conditions for building the empirical foundations of the field of curriculum". (33) We will now turn to these projects and ask: Which curriculum model do they use? Has the development of a new curriculum followed the means-ends model, has the new curriculum been formed according to R. Tyler's rationale or according to B.S. Bloom's taxonomy? Or has the development of a new curriculum - consciously or unconsciously - followed assumptions similar to those which we find in the encounter model?

On this occasion it is proper for me to limit myself to projects in natural sciences. But allow me to mention just briefly M. Beberman's project in mathematics first. Not only because it was a pioneer project, but because it illustrates in an exceptionally clear way the problem with which we are dealing here. The project originated, as we know, because there was a common dissatisfaction with the state of affairs, in this case with the teaching of mathematics at high school level. The members of the project were at the beginning much more aware of what kind of mathematics teaching they did not want than what kind of teaching they were going to work out in the project. Gradually, however, the new efforts got direction, and finally two main principles crystallized. To begin with they functioned on a nonverbal level; but were then identified as 1) clear mathematical language and 2) learning by discovery. (34) These two main principles deal as we see with subject-matter and pupil activity.

If we look at the science projects generally, we will fairly soon see that in most of the projects something similar is the case. The projects have been developed along lines implying that the pupils in an active and engaging way should be introduced to the body of knowledge and the scientific way of thought. (35) In most of the projects it does not look as if one has started with a list of behavioural objectives and then - by way of deducing - has found suitable subject-matter and suitable forms of activity. There are, however, as far as I can see, two notable exceptions. The first is "Science - A Process Approach" and the second is "IPN Curriculum Physik". (36)

Let us have a closer look at the latter project. How has the project group behind IPN Curriculum Physik worked? To what extent has the group succeeded in adhering to the means-ends model which at a first glance seems to constitute the project's way of attack? Admittedly, questions such as these are rather difficult for an outsider to answer. As regards this project, we are fortunate enough to have fairly extensive statements from the project group. The reform work, one of the project-members says, ran through different stages, one planning stage and several trial stages. The planning stage ended with the project group agreeing on quite a few general principles which the work was to follow (3 "Grundsätze" and 16 "Leitsätze"). These principles concemed the selection of the subject-matter, teaching methods and evaluation. We notice that this initial planning stage, which lasted for well over a year, did not result in a list of specified behavioural objectives. Such specified behavioural objectives did not form the basis of the first trial of instructional units in schools either. And this was done on purpose, because during the first trial relevant educational objectives were to be discovered.

> "Zur ersten Erprobung (Vorerprobung) liegen meist nur grob formulierte Pläne vor, die ein Grobziel und einige mögliche Aktivitäten - insbesondere Experimente - enthalten. Es werden also während der Planungsarbeit bewusst noch keine operationalisierten Ziele und keine Arbeitsbögen und sonstige, den Unterricht genauer fixierende Materialien erarbeitet. Die Hauptaufgabe dieser ersten Erprobung ist die Entdeckung relevanter Ziele im Unterricht. "(37)

It is very characteristic that the specification of educational objectives in behavioural terms did not precede, but followed the first trial stage, and that this specification was not applied in a school situation before the second stage. It seems to me, then, that the excellent work done by the IPN group actually has followed a different, and in my opinion, a better procedure than their own curriculum theory would suggest. The IPN group has been content with stating very general aims to begin with. And pupil activity - particularly experiments - has also preceded a detailed listing of behavioural objectives.

The result of this reform work (IPN Curriculum Physik, Didaktische Anleitungen) appears at a first glance to be moulded in a clear means-ends form. Even the single lesson is outwardly built according to this scheme: 1) Educational objectives in behavioural terms. 2) Relevant concepts. 3) A detailed description of the lesson: experiments, demonstrations, class discussion, group work, etc. 4) As a clear invitation to evaluate the instruction in relation to the stated objectives the results on the pre-tests attained by the experimental groups are indicated at the end.(38) But, it seems to me that the means-ends scheme really is not consequently carried out in this respect either. The extensive description of the lesson indicates that the subject-matter and the different kinds of pupil activity are more important than the specified objectives which are set up as a heading for every lesson.

5. Conclusion

For the last twenty years there has been no lack of good suggestions as to how curriculum should be constructed on the basis of the means-ends model. Much effort, time and money have been invested in order to find, formulate and specify educational objectives. From many quarters it has been pointed out that this procedure does not seem to yield the expected success as regards the actual work at school. Is there, then, something wrong with the teachers and the schools? Many followers of the means-ends model are apparently inclined to maintain just that. The teachers must be re-educated, they must learn to think in taxonomic terms.

Things can, however, be seen from a different point of view. The means-ends model does not give a full picture of the curriculum phenomena. Therefore difficulties arise. My thesis is that the encounter model more often than not will be a better point of departure, if we want to understand and master curriculum problems.

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(34) Beberman, op. cit., p. 10.
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(37) Niedderer, op. cit. p. 427.
(38) Institut für die Pädagogik der Naturwissenschaften an der Christian-Albrechts-Universität, Kiel. IPN Curriculum Physik, Didaktische Anleitungen, see for instance Unterrichtseinheit 5,1 and Unterrichtseinheit 5,4.

Discussion

Mr. BAEZ reports that he was involved in the curriculum reform activities of PSSC. From his experience a lot of the innovated work was done by people, who had no idea what the behavioural objectives were; these ideas began to develop in the course of time. A pilot project of physics teaching, however, which UNESCO initiated in South America in 1963, actually used both the language and the concepts of behavioural objectives and some behavioural specialists were involved.
Mr. DUIT asks for a more detailed discussion about the IPN Physics material. The author states that the objectives given in the IPN curriculum material mainly are reflections of what is going on in the lesson. The objectives are predominantly formulated theoretically. The so-called "Stundenverlauf" (teaching procedure of a certain lesson) is designed for the concrete activity; evidently it was not deduced from the educational objectives. The author feels that this actually used method is better than the theoretical process of the IPN curriculum development.
Mr. THOMSEN discusses what kind of teacher's guide will be a help for introducing a curriculum. He reports from his first visit of the PSSC group. The teachers were very anxious about how far they had got. Nobody thought of omitting a chapter because of unimportance. Seemingly the PSSC group learnt in the meantime, when one looks through the teacher's guides to the IPS project: they contribute to the spirits of the course, and in addition, they give a help to the experiments. He feels that the IPN physics sometimes constraints by giving too detailed teacher's guides, which the teachers suppose to have to follow exactly.

Walter Jung

A catalogue of aims proposed by von Hentig and the objectives of physics teaching

1. Reasons for talking about aims and objectives

My main concern in this paper is with aims and objectives. At present there are very good reasons to speak about this matter in this age of ongoing reconstruction of our school system, that may well be in phase with a new trend of anti-science.(1)

In talking about aims and whys of teaching physics one always has to keep in mind whom one wants to convince. It is rather easy to convince an audience of physicists that physics should be taught. It is more difficult to give reasons convincing an enquiring educationalist or educational philosopher, though he may grant that it is somehow necessary to learn some physics.

This is exactly my starting point. I do not try to find reasons per se why to teach physics. I think it is rather unlikely that anybody may hit upon a reason unheard of so far. I discuss possible contributions of physics teaching within a given framework of aims.

In talking about this matter I intend (1) to introduce into discussion lines of thought and reasoning widespread in this country, and (2) to plead for a dialogue between two very different groups, the physicists on the one side, the educationalists on the other. As far as I can see, they do not like each other very much. Physicists have many complaints about educationalists, who constantly arouse public interest by suggestive and dangerous ideas about the process of education and the organization of school systems. We should grant that this is their business and should never forget that they have similar complaints about scientists.

The dialogue I have tried to begin is not wholly a literary affair. Discussions of this sort took place in a study of the Ministry of Education of Nordrhein-Westfalen, that was concerned with framing guidelines for curricular developments in comprehensive schools of this state. And there was a political decision that v. Hentig's aims should be the starting of the guidelines. Thus my discussion centers around the key word of "contribution". I think it is important to find out in what fields physics teaching is able to contribute much, and where we are weak.

Furthermore, we should stop discussing these questions solely within our own group, the physicists. Prof. Karplus has published a very interesting book, a collection of articles, entitled "Physics and Man"(2). One of the papers discusses reasons for the turning of mind of the public against science. (3) We cannot oppose these tendencies if we do not leave our ivory tower, listen to other points of view, assimilate them and get qualified for a discussion within a much more comprehensive group than physicists and even physics teachers are. This may suffice to enlighten the background of my paper, at least to some measure.

The first part is meant to link the discussion of aims and objectives to the process of implementation. My main point is the role of the teacher in innovation. I think it is quite essential that the classroom teacher is convinced about the aims and the philosophy of the new curriculum, and well-informed about the links between this philosophy and the objectives. And to my mind this should not be done by subjecting him to a massive bombardment by statements purposely constructed by the curriculum development staff. I feel a certain disparity between constructing nationwide curricula and securing a proper share of the teachers in shaping the curriculum.

My tentative conclusion would be to reject all curricula that are too tight in structure, in sequencing, and objectives. I would prefer curricula that display opportunities for the teacher to make creative use of materials offered. As an example in the elementary level I should like to mention the English Science 5/13 Project. Also the work of Dr. Thomsen as reported in this conference seems to me in line with my ideas.

Of course, one may raise the question of teacher qualifications. Offering perfectly organized and scheduled curriculum hardware and software may bring about better instruction in some respects, but scarely will it improve the qualification of the teachers. This can only be done by participating in curriculum development. What girls and boys need, and have a right to be supplied with, is qualified teachers, and not "instructional personnel".

2. Implementation and decision on aims

The last decade has seen a rising tide of curriculum development and correspondingly many processes of installation in schools.

Many papers describe the implementation process as seen by the curriculum development staff or by engaged teachers. But on the whole we are lacking scientific studies of implementation processes that may form a basis of a theoretical scheme to guide further implementation processes as a therapeutic and diagnostic device saving time and energy. One gets the impression that every team has to meet all the problems anew unguided by the experiences of other teams.

G. W. Bassett (4) has given a rather detailed comparison of the different strategies of innovation in the United States and in England, with the emphasis on central agencies in the States, and the emphasis on the local group in England. His chapter "Factors Influencing Change" lists many important variables and makes some crucial points concerning innovation. One of the most vital remarks refers to the role of the class-room teacher. He says: "Confronted with such a cloud of witnesses, there is a danger that the teacher will lose some confidence in his own professional skill, and adopt uncritically the various schemes placed before him. The mere following of educational fads is a travesty of any real expertise, and a denial of professional freedom. It is important that this danger of a servile attitude on the part of the teacher should actively combated ... One obvious way to do this is to secure the participation of teachers in their own schools ... Didactic courses which simply tell the teacher what ought to be done are usually unsuccessful in achieving any effective change... Without a well-understood body of principles to guide them they will be overwhelmed by the flood of materials, and the innovative steps presented by the production of these materials will be self-defeating!" (5)

There are other signs that the role of the teacher is recognized as a vital one in the USA, too, e. g. in a paper by R. J. Merrill and D. P. Butts (6) and I may refer also to the well-known attack of M. Atkin upon planning strategies that seems to be borrowed from the industrial construction techniques for materials with pre-designed properties. One of Merrill and Butts' tenets seems to be in disagreement with the spirit of Bassett's remarks. They write: "Science teachers will and should become less autonomous that they typically are now in making decisions about what to teach, when, and how!"(8) But this is only the consequence of a more careful consideration of the network of decision-making processes which is implicit in Bassett's approach, too. He has a useful chapter on "The Nature of Educational Objectives" in which he discusses sources of conflict and embarrassment on the part of the teacher by unduely mixing levels of objectives.

I may be allowed to extend this line of reasoning toward a theory of levels of decision - making in the innovative process.

What should be better understood is that teachers, and other people such as subject matter oriented institutions, parents, political bodies and so forth,, play different roles within the decision making process at different levels. Thus it seems to me to be a perversion of the democratic doctrine to hold that the individual child should decide upon the aims of education or the content of the curriculum, just as it would be inappropriate for the individual teacher to think himself competent to decide upon these matters. We should carefully analyse the different qualities of participation in the decision making processes in different levels and types of objectives. This implies a doctrine of the defining characteristics of the teaching profession besides other things. And it may be that Merrill and Butts hold somewhat different definitions compared with Bassett's. But both stress the fact that the teacher is responsible mainly for adapting to the needs of the individual child and decisions regarding the individual child. Bassett more than Merrill and Butts seems to be aware of the active role of the teacher in the development process, in participating in the goal seeking and decision making process, though he has developed no explicit theory of these different roles in different levels and of the different qualities of participation of diverse groups. And this seems to me a desideratum of an effective strategy of innovation and implementation. Otherwise there is danger that implementation is seen within the categories of successful business and sales politics. But implementation is primarily not a problem of selling a good for consumption, it is a problem of shaping the future of lots of people in a virtually decisive way. Just as the development strategy of production with prescribed qualities is oversimplified, so the strategy of sales talk and advertisement is mistaken.

Bassett discriminates between the societal or philosophical level, followed by the strategic or systems level, and ending with the tactical or instructional level. (9) He seems to me right in his observation that teachers are confused by extensive discussions of aims that are difficult to relate to their daily business of class-room teaching. But he underestimates in this opening chapter the importance of an effective participation of teachers in this aims-seeking process. Teachers as anybody else have a right to participate in shaping the goals that are essentially political in nature.

But so shaping the goals is not a professional competence with teachers, it is their competence as citizens. Certainly the teacher has something special to contribute to the formation of aims; he may be in a better position than other people to know the "boundary conditions" in the language of the theoretical physicist. He has an expert opinion on the possibilities of realizing aims and he may possess more power to interprete the philosophical statements and the policy declarations of political bodies in terms of realities.
Nevertheless, there is some danger in this expertness insofar as it relies exclusively upon so-called experience; and there is some truth in the saying that twenty years' experience may be simply twenty years' mistakes repeated. Thus a more complex pattern of interrelationships emerges. The competence of deciding upon aims resides with the political bodies. But their wisdom is derived from other groups with special competence in goal seeking in exploring different alternatives, in investigating the implications of different aims. And in this process teachers can and should take an important part.

3. Knowledge of objectives as a variable in implementation

We know from other sources that knowledge of objectives is a variable in the implementation process. The Eastern Regional Institution for Education (ERIE), Syracuse, has made available reports on the installation of process-oriented curricula in elementary schools. (10) Some of their observations may be specific to the grade level of the program. But my experience with the realization of new directions in High Schools I could gather some years ago is in rather good agreement with most of their points. I pick out the question of aims because it seems to me largely neglected in the implementation process.
The first thing you have to do in implementing a new program is to convince teachers that it is needed. And that means you have to convince teachers of two points, first, that their present teaching does not live up to certain goals, and second, that these goals are worthwile. Also the curriculum designer should take the opportunity to test the adequacy of his goals by carefully discussing them with the teachers. One of the ERIE papers states: "These observations could reflect lack of evaluation criteria, failure to examine and discuss disseminated goals or lack of understanding of goals on the part of the teachers". (11)
And later on: "There seems to be a tendency to accept loose, rather ambiguous instructional goals with disfavour and to also react negatively to specific measurable goals... There were, however, twice as many requests for more specific qualitative goals..."(12).
One gets the impression that these teachers neither know the broad aims sufficiently well to be able to judge class room achievement intuitively in terms of these goals, nor did they understand the relationship between quantitative measures with the goals. In both respects there is lack of competence in handling goals. But if we expect more than a short lived success we should have teachers that are well versed in the philosophy of the curriculum, of its essential agreement with the needs of the era, and with the relation between broad aims and specific aims to be realized in their class-room work.

At present we observe the creation of a new philosophy every decade or even every year. Each curriculum team tries its hand in forming a new brand of goals. May be this is a consequence of the sales talk tactics mentioned above. What we need is a substantial agreement about goals to be reached by schools and a rich supply of different approaches to realize these goals. Also the goals should be well understood by the teachers. We have some partial agreements between different schools of educational thought, but to my mind there is lack of substantial agreement. This state of affairs may be responsible for the observable weakness of teachers and schools to yield to educational fads.
Without conviction concerning basic issues there is no educational efficiency. And to my mind one of the dangers of the present situation is exactly this lack of conviction on the part of teachers. Thus one of the essential points in implementation is goal seeking and goal formation, and supplying links between broad aims and special objectives and measures pertaining to the curriculum to be implemented. The basic task of implementing a curriculum is the implementation of a philosophy and an attitude on the part of the teacher. Now, as Whitehead once remarked, "mathematics must be studied - philosophy should be discussed"(13). My purpose is to contribute to this discussion. First I shall give a catalogue of aims proposed by v. Hentig in an influential policy statement of the Deutsche Bildungsrat (14) and then enquire into its meaning in terms of physics teaching.

4. Von Hentig's aims
Conditions of living relevant for decisions on aims

Von Hentig's catalogue of aims is founded upon an analysis of the conditions of living in the present day industrial societies. What are the qualifications essential for an individual to cope with these conditions? Von Hentig notes the following conditions given here with slight changes of order and point of view.

1. We are living within a world of increasing pace of change. (15)
2. We are living within a world of specialized competence. (16)
3. We are living in a world that is more and more dominated by science and technology. (17)
4. We live in a world in which vocations need theory and practical abilities. (18)
5. We are living admidst an overwhelming wealth of means and ends. (19)
6. We are living in a democratic world requiring public virtues. (20)
7. We are living in a secularized world. (21)
8. We are living in one world that is a system of interdependent parts. (22)

Von Hentig has made some other points that seem to me to belong to another category, e. g. living with one's body or with the arts. (23) These are by no means new conditions, though living in the modern world may lead to new means in coping with them. Thus this eight conditions may suffice for my purposes. To my mind they constitute a rather adequate catalogue of factors relevant to the development of new science curricula. This catalogue is not to be entirely new or dramatic. Nevertheless, it may prove to be a reasonably safe starting ground for the process of convincing teachers that curricular changes are needed, and that these specific changes are needed. I do not mean to imply that particular changes can be deduced in a straightforward fashion from these conditions. But I do not touch upon this deduction problem in this paper.

I should like to offer some suggestions (24) as to the educational implications v. Hentig has noted. His aims are not meant to be behavioral objectives, they are a sort of leitmotif for curriculum construction. (25) Also I add some mildly critical remarks to some of the aims.

Educational implication

1. From the first condition v. Hentig concludes: The student should know the processes of change characteristic of our time and get the impression that there is a chance to influencing these processes. He stresses innovative powers of individuals and the concept of learning set.

2. From the second condition v. Hentig derives the conclusion, first, that the school should no longer aim at a liberal education held apart from specialization, and second, that there should be opportunities for the specialist to see his special competence as an element within a more comprehensive whole. The specialist should be able and willing to communicate with the less specialized members of the group.

3. Science and technology do not entail by themselves freedom from superstition. Scientific knowledge used unscientifically may become a means of irrational opinion and action. Thus, school learning should impart scientific attitudes, processes, and knowledge of the inherent limits of the scientific method. (26) In this there is really nothing new. But v. Hentig also notes the need for fostering divergent and creative thinking within the scientific field.

Now, in the history of science we observe a subtle balance between the conservative and the innovator. Conservatism derives from the fact that science settles issues. And innovation comes in because new problems arise and the settled facts take on a new meaning within a new setting. The obstinacy of the conservative scientist is necessary in the process of evolution of scientific fact and theory. It is necessary both for reasons of economy and survival of the fittest: Without the stubborn opposition of the scientific orthodoxy we could never feel the triumph of the new. Science is not art where purely private valuations constantly cry for novelty which is self-defeating. Thus this fashionable question of creativity is a delicate one, and v. Hentig realizes the need for disciplining the creative impulse of the individual within a group.

4. Here v. Hentig aims at a synthesis of theory and practical competencies. Theory should not be taken as something in an for itself but as a guide to action and reconstruction. Also the student should gain insight into different professional fields so that he is prepared to make a rational choice and can see his profession within the context of school learning and within the wider context of the functioning of society generally.

5. Within a world that offers a wealth of means and ends the student should learn to choose by his own and to be critical toward his aims. He has to learn the import of utopian conceptions and also the margin of free play within a situation. Moreover he should gain tolerance and critical attitude alike toward other people's aims.

Von Hentig thinks that art as opposed to science is the proper field for exploring possibilities. In this opposition I have some doubt. Science by exploring what he calls reality also explores what is possible. In fact, these are only two different points of view of the same thing. In the beginnings of modern science we find many statements concerning the power of science to bestow freedom and wealth upon man. (27) Science structures the space of possible actions and thus defines with utmost precision what v. Hentig calls the margin of free play within a situation. Thus we should not accept this point in our teaching of science: Science requires the free play of the imagination just as art does. The difference must be sought in the different rules of verification in the respective fields.

6. Students should come to know their own interests and find means for defending them. Von Hentig coins the term "public curiosity" for eagerness of the citizen to ask the expert questions, to press him for understandable accounts of current issues. The student should also have had experience in processes of group dynamics and social psychology. (28)

7. Von Hentig pleads for a continuous transformation of magical and mythical ways of thinking into rational forms of thought. The student should find that his own irrationality is respected as an important fact, especially in religion.

8. Living in one world entails learning at least one foreign language and he strongly pleads for English. The student should learn to see his own custom and culture as a foreign one, at a par with so many other divergent styles of living and thinking. He should have some insight into the problems of general semantics and acquire skills in applying these principles to statement in the newspaper, in broadcasts, and in television.

5. Contributions of physics teaching to v. Hentig's aims

Comparison with modern trends in science curriculum development

Von Hentig's description of conditions is one thing, the aims he deduces therefrom is another one. Generally speaking his aims are not very far from traditional humanistic ideals. This is not meant to be a criticism. He acknowledges the decisive role of science and technology in present day life and clearly sees the importance of practical activities: There is no detachment of theory from the affairs of daily life. Thus he tries to avoid the pitfalls of the traditional concept. On the whole I agree with his aims. But my main concern is with physics teaching whilst v. Hentig speaks as a general educator. Thus I am asking the question: What can physics teaching contribute to these aims? There are those questioning teaching separate subjects altogether. But this is a different issue that needs separate discussion. I start from the fact that physics is a well-established and important discipline that is studied by teachers prepared to teach physics at school. In case we should come to the conclusion that a subject like physics cannot effectively contribute to these broad aims, then we have to go a step further and enquire into other forms of organizing school learning around science. But this is not my point in this paper.

Broad aims like v. Hentig's stress the need for new principles of subject matter choice and for new ways of treatment. The "alphabetic" curricula in USA exemplify this point. There is a s ift from content to process, and another shift from details to conceptual scher e s. Of course, this is not unprecedented in this country. Shortly after World Wa I we observed in Germany a strong movement of reform in science teaching that aimed exactly at what later on became known as the 'structure of the discipline . Especially in physics teaching M. Wagenschein developed his 'principle of parad matic teaching' meant to solve the problem set by the rapidly growing subject ma er knowledge by selecting a few paradigmata of physics and working them out very thoroughly. (29) Somewhat paradoxically we could speak of a "case history method without history". By a thorough study of paradigmatic cases the student was to learn the methods of physics and science generally. Also he should learn to see these methods as a special and limited way to interact with nature.

Today these tenets are commonplace with most curriculum advertising specialists; once they arose bitter controversies in this country. To my mind it can now be seen that this controversy resulted from Wagenschein's underlying romantic philosophy more than from the overtly stated principles of 'paradigmatic teaching'.

There are two essential differences between Wagenschein's approach and that of the new curricula. First, scientific method has been analysed into a very detailed and ramified system of skills ("processes") that are trained rather formally and partly also rather detached from subject matter content, a procedure of which I do not approve. (30) And second, though the paradigmatic character of content is stressed now, the level has been shifted from cases to conceptual schemes. (31)

This latter difference is important. Traditional physics teachers always critized Wagenschein's failure to do justice to the systems character of physics. Conceptual schemes are unifying theoretical elements and thus physics teachers may be better prepared to accept this approach as a synthesis of the principle of paradigmatic teaching with the systems aspect of physics.

Finding out reasons for opposition to curricular changes is one task of implementation planning. We have to take account of two very different classes of teachers, the one subject matter oriented, the other oriented toward broad aims. It is the first class that is to be expected to opposing changes like those Wagenschein or v. Hentig propose. They feel that physics teaching serves broad aims anyway and they fear a gradual decline of the standards of subject matter teaching. Their first point seems to be mistaken, and a discussion of broad aims along the line of v. Hentig's is very important to them, because they have to be convinced of the need to change their styles and aims in physics teaching. Thus I should like to offer some hints as to the contribution of physics teaching to these broad aims preparing discussion with this group of teachers, and partly deriving from such discussions.

Discussion of specific points

Ad 1. The student should acquire the ability to adapt to scientific change. That implies teaching in an undogmatic way. I cannot see much difference between teaching facts dogmatically and teaching conceptual schemes dogmatically. On the contrary, history seems to show that it is much more difficult to abandon a scheme than a supposed fact. There seems to me only one way out of the difficulty: Incorporating the history of physics very strongly. Knowing that schemes develop, and according to Th. S. Kuhn not at all in an algorithmic fashion, the student should be prepared for changes in conceptual schemes, too. Also he should have opportunity to speculate upon the way the schemes may change in the future. (33).

One example is atomism. Since the revival of Greek atomism in the 16th century we note a remarkable transformation of the scheme still going on. It takes on new aspects in elementary particle physics. On the one side we observe research that hopes to find out still "more elementary" particles building up the presently known ones such as the proton or the neutron. On the other hand we can discern quite another scheme, that of different forms of a substrate reminding of Aristoteles or even Plato's Timaios. Also a particle such as a photon is no longer a particle in the sense of classical mechanics.

This is, of course, common knowledge with the curriculum inventors; Only, I can see no meaning in teaching the latest development without teaching the ability to follow up further changes. At least, the student should be aware of the fact that he did not learn a final truth. Nobody wants to teach conceptual schemes as final truth, I suspect. But this is not my point: What is the "meta-lesson"(34) students take away? That may be quite another story. As far as I can see there is only the Harvard Project Physics that meets these requirements. Of course, there are difficulties in thus relativizing the subject matter taught, especially with the very young child. But whatever the difficulties, in coping with the increasing pace of change we have to adapt the student to the pace, but we also have to give him knowledge of continuity amid change. This, too, can be done by an historical approach.

Ad 2. Modern science is a paradigma of specialization, of its virtues and vices. Thus there should be no difficulty for physics teaching to contribute to the aims in this category. Modern physics teaching should foster individual interests, participation in projects, and discussions of participants with each other and within more comprehensive groups such as a class, giving opportunity for the specialist in a field to express himself, and giving opportunity for the nonspecialist to questioning the specialist.

Ad 3. As far as physics teaching is concerned this point merges with the first one. Science and technology are among other forces responsible for the growing pace of change not only of knowledge but of the conditions of living. By studying physics under this aspect the student may become acquainted with science as a model for rational coping with change. (35) This model has three aspects. First, scientific knowledge gives foresight and power to planning. Second, scientific method is a way to deal rationally with data. Third, scientific research is a method of controlling changes within science. Out teaching should point to the model character and ask for possible transfer.

But we should also discuss the limits of this model. E. g. there may be human affairs that must not be treated scientifically.

At least this is the point of view of the more sensible part of mankind. Verifying scientifically that one's husband is faithful may mean the destruction of just that faithfulness and confidence. This sort of happening is now wholly alien to the thinking of modern physics. The measuring process interacts with what is under observation. Thus, imparting uncritical faith in some omnipotency of science may well help in transforming this world to more inhumane conditions. Of course, this is a value judgement. But, after all, the exercise of judgement was exactly the thing to be expected from an educated human being.

Ad 4. In physics the interaction of theory and particle is manifest. But this is not always true of physics teaching. Moreover, seeing the interaction of theory with action in physics is quite another matter than seeing physics as a guide to solving problems for an individual student: Most of his real problems are no physical science problems. It is unknown what proportion of the population puts physics to use. I have no solution to this difficulty.

Physics teaching should aim at imparting a realistic picture of a physicist. The time is rapidly vanishing that saw in the physicist a sort of modern hero or priest. We always should try to resist the swing ~~of~~ the pendulum thus increasing damping factors. We should show students that physics cannot be equated with the great discovery. Science is a piecemeal affair, and the daily routine of a physicist may be rather unattractive to young people. They should know the difference between big science and little science parallel to the difference between handicraft and mass production. A modern institute of physics is a sort of factory for knowledge with exacting plans for production. On the other hand we should oppose tendencies to despise science as the one agent responsible for all evils of the day.

A competent reviewer noted the following concerning vocational education: "In view of possible revisions of curricula, it is felt by the author that educators at vocational-technical institutions should think primarily of providing generalized basic courses rather than specialized subjects with currently fashionable names and content. Teaching more courses in mathematics and physical science for instance will have to serve the need of technological changes... More than 90% of the respondents expressed their strong feeling that technical education - including the training of highly specialized technicians - should focus on establishing a broad intellectual foundation..."(36) Thus he advocates teaching basic structures in physics, not for specialized needs, but for the best way to be prepared for changing needs. The point is that the pupil should know that physics may prepare him to face change intelligently. Because the nature of the changes is inforseeable this cannot be done directly. To my mind it can best be done by casesshowing the interaction between scientific and historical changes.

Ad 5. As I see it physics teaching cannot do much to further these aims. Of course, students should have opportunities to develop and follow up their own interest. (37) They should learn to see that the most refined equipment does not give always the best insight. So we can do something to sharpen their wits in a sort of consumer criticism. But it is unknown how effectively such strategies, never tried out, will transfer to daily life. Also we may discuss with students standards of precision and standards of quality generally. But the same objection can be raised as before.

Ad 6. In teaching physics students should learn to ask questions. Traditionally physics teaching has had largely the effect of silencing the questioning impulse of the majority of students. (38) I can only speculate upon the reason for this phenomenon. First, we have to take account of the impression of physics as an overpowering construct that no one can hope to manage. Second, questions that arise by studying physics are often rather difficult to answer, even if and especially if they refer to ordinary events. Thus, why the sky is blue, or why the glass is transparent, and iron a ferromagnetic substance? A very high level of subject matter sophistication is necessary to understand the answers physics can give to these questions. Thus the student gets the impression that the really interesting questions are beyond him anyway. Third, by forming hypotheses in answering a problem the student experiences failure in most cases. One answer, one idea, one plan is right, the others are wrong; and in any case the teacher knew the answer beforehand. All these points constitute a rather effective counterconditioning of asking questions and taking one's stand against others or authority.

Thus teachers should take the burden to convince students that a mistaken hypothesis, a false idea, are not failures; they mean a contribution to exploring the limits of possible solutions. Students should be prepared to insist upon their conceptions till the issue is settled, and they should definitely know that those opposing the 'true' conception and forcing the other party to justify and expose their own ideas in an understandable and convincing fashion play an essential part in the process of scientific progress. We glory those who have succeeded, and forget or even despise those who have lost their case. This preposterous paradigma or writing the history of science should be abandoned.

On the other side, in mathematics and science teaching students experience issues that cannot be decided by majority votes. There is a wide margin for conventions, in mathematics as in physics. But sooner or later in these fields we meet with our own conventions as limitations; and moreover, in physics we meet nature as a limit to conventions. As a result of physics teaching the student should have formed a clear distinction between questions of value, questions of conventional definitions, and questions of fact, and he should be prepared to react to each category in the proper fashion.

Ad 7. Concerning this point I should like to draw attention to the fact that even science has its creed. The moment we enter the theory of science we are faced with a host of uncertainties. What is a law of nature? Is it just a regularity, a protocol? How do we justify inductive generalizations? No question of this type is sufficiently well answered. Moreover, there is considerable evidence from Th. S. Kuhn's writing that paradigma shifts cannot be described as a wholly rational affair. Thus, physics teachers should avoid overstating their case. Physics is a great instrument within narrow bounds of applicability. But it is no substitute for that energy that makes life and even physics itself run.

Ad 8. The contribution of science to uniting people of all countries, of all religious and political faiths, is manifest. Consciousness of the one world is consciousness of science and technology as essentially the same all over the world. Also these are the main unifying powers supplying means of communication and shared experiences. This fact should be stressed in physics teaching. Moreover, I cannot see why it seems impossible to develop forms of cooperation between physics and language teaching. In this country students enter university to study physics that took courses of English for eight or nine years, and yet they are appalled by the suggestion to look into an article in English. The language teacher tries to impart a sense for the foreign culture, for its peculiarities. But he forgets to show that the scientific culture is independent of language. Reading and discussing short paragraphs from English written scientific articles in the science lesson might prove a way out of the difficulty.

I should like to add a concluding remark. Implementation of modern physics curricula is a difficult and complex task.

I am perfectly aware of the fact that my problem of convincing teachers of the aims is only a small facet of the problem. There are many others I cannot deal with here. One of the most important seems to me the need to supply links between broad aims and objectives. Most curricula discuss goals but fail to point out why this special material or procedure is apt to serve these goals. But that is another question.

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(1) cf. H. Ruchlis, The Challenge of Anti-Science, Science Education, Vol. 55, No. 2.
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(3) R. S. Morison Science and Social Attitudes.
(4) G. W. Bassett, Innovation in Primary Education. London, New York et al. 1970.
(5) o. c. p. 125f.
(6) In: A Design For Progress In Science Education. Editor D. P. Butts. Washington 1969, Chpt. 5.
(7) M. Atkin. Curriculum Design: The central development group and the local teacher. IPN Symposium 1970. Kiel 1971.
(8) cf. 6, p. 39.
(9) cf. 4, p. 8.
(10) Eastern Regional Institute for Education. Program Report R. 1+2. Installing a New Curriculum: Observations and Recommandations. Syracuse, New York, Oct. 1969. Also: M. Mahan, Ch. W. Wallace, A. C. Buddle, Program Report 104. The Role of the Teacher-Leader in Curriculum Installation. Jan. 1970.
(11) Ch. M. Mohan, J. M. Maham, Program Report 106. University Professors View the Installation of Science - A Process Approach. Syracuse, New York, Jan. 1970 p. 13.
(12) o. c., p. 16f.
(13) Dialogues of Alfred North Whitehead. As Recorded by Lucien Price. New York 1956. p. 264.
(14) Deutscher Bildungsrat. Gutachten und Studien der Bildungskomission. 12. Lernziele der Gesamtschule. Stuttgart 1969. Therein: Hartmut von Hentig, Allgemeine Lernziele der Gesamtschule. pp 13-43.
(15) o. c. 1. 1. p. 17f.
(16) o. c. 1. 2. pp. 19f.
(17) o. c. 1. 3. pp. 22 f.
(18) o. c. 1. 4. pp. 24f.
(19) o. c. 1. 5. p. 26, together with 1. 8: Living in an affluent society.
(20) o. v. 1. 7. pp. 31f.
(21) o. c. 1. 9. pp. 35f.
(22) o. c. 1. 13, p. 42.
(23) I refer to paragraphs 1. 6, 1. 10, 1. 11, 1. 12.

(24) It is impossible to translate the whole of his paper here. I admit that by paraphrasing I am selecting and valuating subjectively. Thus, for a full discussion of von Hentig's point of view the reader should consult the original German text.
(25) cf. 1.0, Introductory Remarks.
(26) This is a divergence from prevalent US curricula. But curriculum designers ought to discuss this matter because of a rising tide of anti-science.
(27) E.g. Sir George Clark, Science and Social Welfare in the Age of Newton. Oxford 1970.
(28) It is interesting to note that similar aims are proposed for teacher preparation: cf. Commission on Science Education: Preparing High School Physics Teachers. Science Education, Vol. 55, No. 2.
(29) The most important contribution of Wagenschein to the theory of physics teaching is: M. Wagenschein, Die pädagogische Dimension der Physik, Braunschweig 1962. See also: M. Wagenschein, Verstehen lehren. Weinheim 1968.
(30) I refer here to Science - A Process Approach. An attempt to adapting this curriculum in a German class has been reported by Arbeitsgruppe für Unterrichtsforschung in Göttingen. Weg in die Naturwissenschaft. Stuttgart 1971.
(31) This approach is being introduced in Germany especially by K. Spreckelsen; cf. his Struktur der Disziplin und Curriculum Entwicklung. IPN Symposium 1970. Kiel 1971.
(32) Th. S. Kuhn, The Structure of Scientific Revolutions. Chicago 1962.
(33) This point is very effectively put by J. J. Schwab, Structure of the Discipline: Meanings and Significances. In: G. W. Ford, L. Pugno, Editors, The Structure of Knowledge and the Curriculum. Chicago 1964. Especially pp. 29f.
(34) J. J. Schwab, The Teaching of Science as Enquiry. In: The Reaching of Science. Cambridge (Mss) 1962. p. 45.
(35) I have dealt with this point in greater detail in a paper to be published shortly: Gesichtspunkte für die Entwicklung naturwissenschaftlicher Curricula in der Gesamtschule.
(36) R. H. P. Kraft, Manpower Planning and its Role in the Age of Automation. Review of Educational Research. Vol. 40, No. 4, pp. 504f.
(37) This is in line with the principles of most new science curricula, see e.g. Nuffield Physics' introduction of 'open-ended experiments'.
(38) For this reason Suchman et al. initiated special 'verbal inquiry training' by instigating children to ask questions very early in science teaching courses.
(39) Concerning the timeworn controversy between science and religion there is very interesting new material in chpt. 2 of R. Karplus, Physics and Man. New York 1970.

Discussion

Mrs. WOOD asks for some additional comments to v. Hentig's conclusion no. 2 (specialized competence). Mr. JUNG answers that the term specialization is used here in two different meanings. He did not think of the question of teaching integrated science or nonintegrated science. Rather he thinks of a class, in which a student develops a special competency in some patch of work and will then communicate with his less specialized fellows.

Mr. BAEZ proposes to teach physics in a foreign language, e. g. English, or - as a task of less difficulty - to reinforce concepts in physics in English language.

Mr. JUNG takes it to be a good idea, which is, however, preferably manageable at the university level. - Mrs. WOOD points to the difference between reading a novel and reading a science textbook. Often in the schools the students are brought to rapid reading for just getting the general idea. On the contrary, science requires denser reading and writing. She suggests to give 2 paragraphs to the students, from which one is a story and the other one science. Then the students would be asked to to express the contents of each paragraph in as few words as possible; they will then start to realize the difference. Mr. JUNG feels that this would be very profitable. But at first students ought to learn the science language of their mother tongue.

It is discussed, if the history of physics were to be included in the course. Some people argue that the danger of dogmatically teaching facts and schemes could be decreased by historical considerations and reflections. The inclusion of historical material would integrate the reflections about methods. The history of physics, however, must not be an aim for its own sake, at school.

The advantages and disadvantages of a prefabricated curriculum are considered. Mr. JUNG states that the demand of some teachers for a prefabricated curriculum means a demand for a cookery book. This is a symptom of sickness, and one ought not to be glad about it. He feels that a prefabricated, well constructed curriculum, which is open for teachers to choose, will be valuable. He warns of too great a rigidity of a curriculum. If a curriculum is made for one, two, or more years, it will be difficult for the teacher to take in extraneous material that is not contained in the curriculum. Another procedure would be profitable: to offer topics to the teacher, from which he can choose, and where he can arrange and even rearrange the sequence and can take in additional material. - Mr. ROGERS also emphasizes that the teacher must be able to choose. A new curriculum must not include too much new apparatus.

Mr. WESTPHAL reports that the teachers often modify the IPN curriculum. He will gladly agree, if the teachers only use it as a possible framework for constructing their own curriculum. But he feels that for the first trial of working with the curriculum, it might be favourable to teach it in its original mode in order to find out, how it works.

III. Strategies and dispositions for the construction of science curricula

Poul Thomsen

The development of a new physics curriculum for the secondary schools in Denmark

1. Preconference notes

1.1 Plans for a new physics curriculum

In 1972 the Danish Parliament will probably pass a law defining the main features of a new structure for the Danish "folk school" (the public school for students of age 7-17). According to the plans the implementation of the school reform will be effected from the autumn of 1973. The preparation started 2 1/2 years ago when a curriculum committee started its work. As usual, the members were important people having lost all connection with practical teaching several years ago: administrators from the Ministry of Education, school directors from different parts of the country, and high-ranking members of the teachers' union, who work full time for the union. In due time subcommittees for the different subjects or groups of subjects taught in school were formed. Physics and chemistry were grouped with arithmetic and mathematics, the members of the subcommittee mainly being interested in arithmetic and mathematics.

Considering the fact that radical changes in the physics curriculum usually take place only in connection with school reforms of the above-mentioned kind, you might feel discouraged and get the impression that, whatever you do, very little progress will be achieved this way. And if you analyse the changes in the physics curricula of most countries in the past, anyway up to around 1960, you easily get support for this depressing impression. On the other hand, important steps towards better physics teaching may be caused by a minor reform, as the reform itself may act as innovator for progressive pedagogical activities, for inst. development of new textbooks, laboratory guides and laboratory equipment, but unfortunately it will usually be too easy just to proceed with the old system when some minor changes have been made.

The activities in the interval between two successive curriculum reforms are of outstanding importance. In this period new fruitful pedagogical ideas may be born, at home or abroad, and if sufficient efforts are made to make these ideas publicly known, the result may be that the curriculum committee become aware of the new ideas and find it natural to include these in the new curriculum. To illustrate this I only need to point out the enormous influence of the PSSC-project on the physics curricula of many countries all over the world in the sixties.

At the physics institute at the Royal Danish School of Educational Studies we of course feel it as our obligation to keep Danish physics teachers well-informed about the great physics projects developed in different countries during the last years. Therefore, we were especially interested in the school-political game in connection

with the school reform to see if our informative activities might cause significant influence on the new curriculum.
Now, it turned out that we got the chance to influence the new curriculum much more than we had anticipated, as the subcommittee for arithmetic, mathematics, physics, and chemistry chose to invite different groups interested in the teaching of physics and chemistry to send in suggestions for the new curriculum. In this way two of my colleagues and I got directly involved in the work concerning the new physics curriculum together with representatives from other groups who had contributed to the work of the committee, for example representatives from the physics teachers' union.
Being engaged in this activity at the the time when I was asked to deliver a lecture at the UNESCO-Seminar on "The Implementation of Curricula in Science Education with Special Regard to the Physics Teaching" I found that one of the best ways to contribute to the conference was by giving an account of our efforts to secure reasonably good conditions for the teaching of physics and chemistry within the new school structure, and by giving a survey of the ideas and plans we have worked out so far to set up a new curriculum, which we hope will serve as innovator for new improvements within the teaching of physics in Denmark.

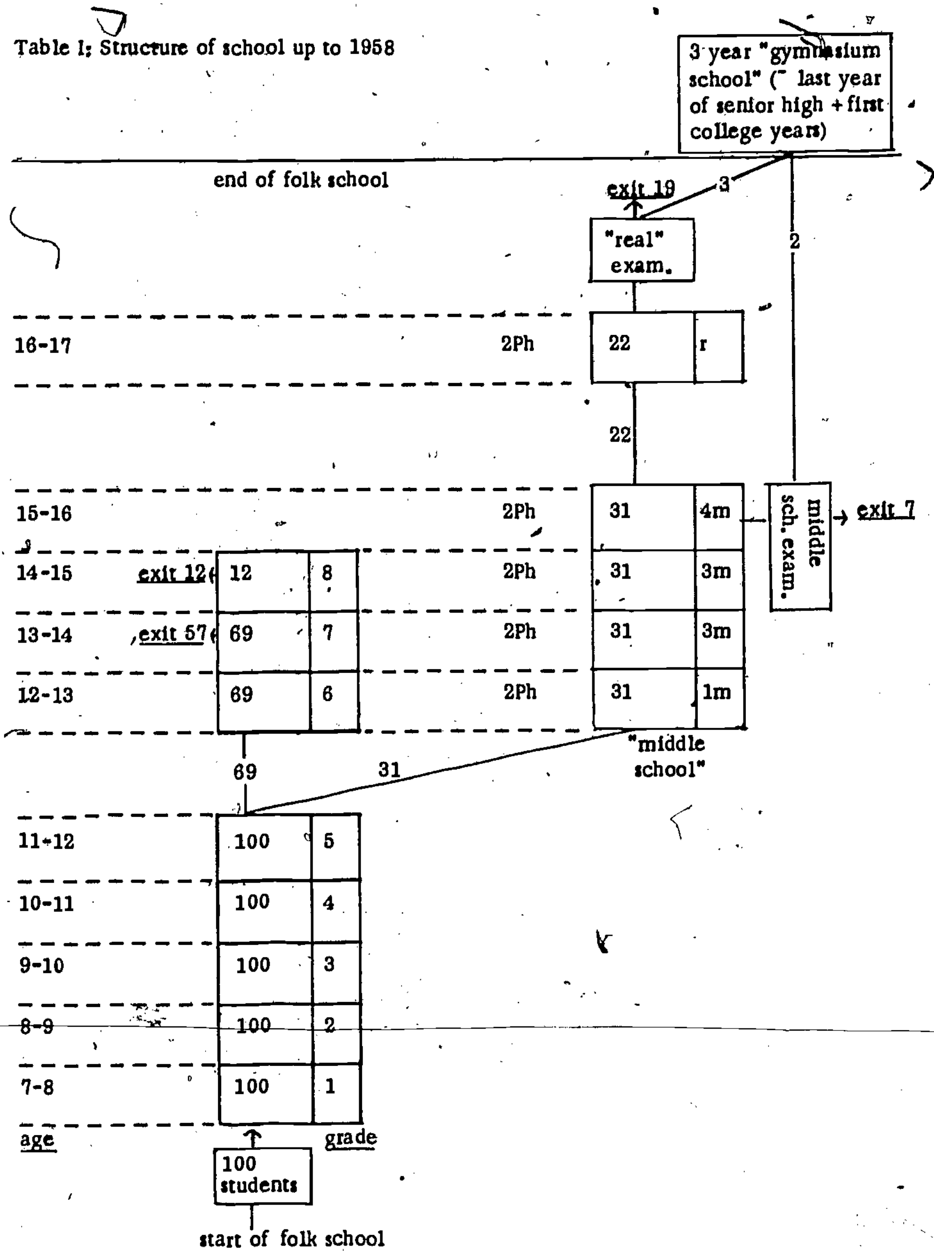
1.2 Historical background

You will be in a bad position to evaluate, if the new curriculum is a progressive one or not, if you do not have some knowledge of the present state of physics teaching in Denmark, and how this state has been obtained. The remaining part of this paper therefore will give a short survey of the different school reforms in Denmark in this century, specifying the amount of time spent on the teaching of physics and chemistry in each case. All this time the two subjects have been taught together as one subject, which in practice has meant a physics syllabus including a little chemistry.

The school reforms of 1903 and 1937

We got a school reform in 1903 which was followed by a minor reform in 1937, essentially extending the organization of the education in towns according to the reform of 1903 to the whole country. Table I gives a survey of the structure, the numbers followed by Ph indicating the number of periods per week spent on the teaching of physics and chemistry. The number of children passing through the more theoretical part of the school, the "middle school", during this period increased from 20% in 1937 to about 30% in 1958. Table I gives a rough idea of the situation in 1958. From the table can be seen how 100 students entering school at the age of 7 (grade 1) passed through the different grades of the school system.
The table shows that more than 50% of the population at that time left school with the minimum of education required by law: 7 years of education. Roughly speaking only 31% of the population, who entered and completed the middle school, got essentially more education than these 7 years, and it can be seen that only this minor part of the population received education in physics and chemistry. To tempt some of the students that did not enter the middle school to stay in school

Table 1: Structure of school up to 1958



The number of students leaving school at the different levels has been calculated from statistical information on schools for the year 1958.

some years more, an alternative to the middle school was set up: the so-called "free middle school" teaching roughly the same subjects as the middle school but in a more free way not requiring an examination at the end. This effort turned out to be an enormous fiasco, so I have not even considered it worthwhile to include this possibility in the table.

The topics taught in physics and chemistry in the folk school during the period from 1903 to 1958 were only slightly changed during the whole period. The general opinion seems to have been that the brains of the students at this age were of a capacity enabling them to understand the topics of the curriculum from 1903 and not much more. And yet a very important improvement of the teaching of physics took place in these years. An active group of physics teachers in Copenhagen formed an association in 1919, and in the following years this association became an exponent for the idea that physics should be taught in a more practical way, based on teacher's demonstrations and students' experiments instead of being lectured by means of chalk on the blackboard. To a certain degree they succeeded in making physics an experimental subject of the Danish folk school.

Unfortunately, the students' experiments up to 1958 were not too exciting. Usually, the students spent most of their time in the lab investigating whether their experimental results were in accordance with a well-known theoretical law, or they spent a lot of time trying to find for example the density or the heat capacity of a lot of different materials. The demonstration experiments were generally better, cultivated as they were by many enthusiastic physics teachers, but as a whole the education was very old-fashioned in many respects, and sometimes the experiments were experiments for the experiments' own sake and not a logical part of a well-planned course.

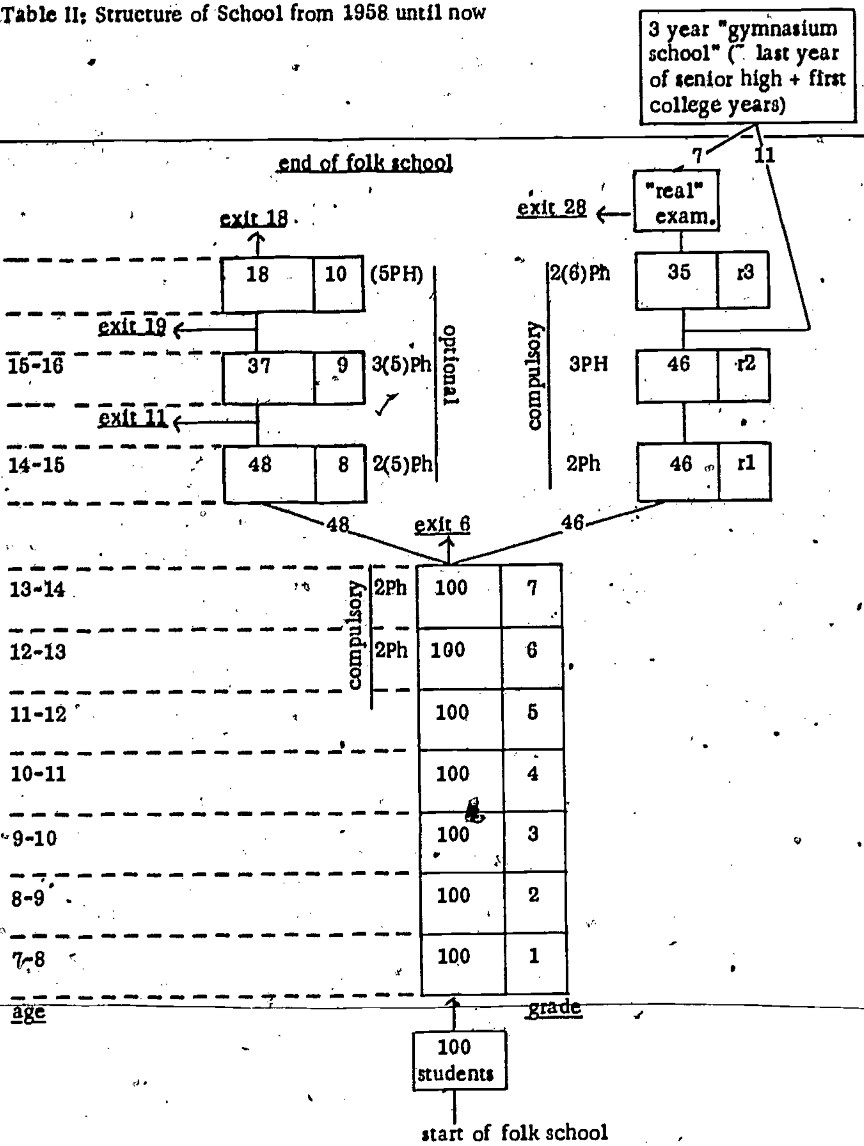
The School reform of 1958

One of the aims of the school reform of 1958 was to build up a school structure of appeal to the big amount of students who until then had left school at the age of 14. However, there was considerable opposition in Parliament against a general raising of the school-leaving age as a solution of this problem. To get more than 7 years' of education in school should be an offer to the students, not an obligation. Table II shows the main structure of the school according to the 1958 reform.

The school reform was well received, and the number of students dropping out of school after grade 7 gradually dropped down to near zero during the last 10 years. Now nearly all students stay in school for at least 9 years, and an increasing number of students also take a tenth school year.

A comparison between table II and table I clearly shows that the importance of physics and chemistry as school subjects was generally accepted. All students should now study these subjects for at least 2 years, and all the students of the "real-line" should go on studying physics and chemistry as a compulsory subject. The number 6Ph in parenthesis indicates the students' possibility to get 6 periods of physics and chemistry a week by preferring a technical "real 3" to a normal "real 3".

Table II: Structure of School from 1958 until now



The number of students leaving school at the different levels has been calculated from statistical information on schools for the year 1970.

In the other line physics and chemistry should be optional, and it turned out that physics and chemistry were chosen by a fair amount of students. The number 5Ph in parenthesis refers to the possibility that the students can choose a special technical education in grades 8, 9 and 10, where the teaching is mainly concentrated on the topics: mathematics, physics and chemistry. The idea of the big number of periods per week was to make it possible for the students to reach the same level as the students of the "real-line", but in a more pratical and therefore more time-consuming way. In practice this idea proved very valuable. According to the teachers, the technical students often got a better understanding of physics than the students in the "real-line".

The teaching of physics in the technical real 3 with 6 periods a week was not a success. Only few schools made use of this possibility to offer technical real 3 as an alternative to the normal real 3, and 3 years ago the technical real 3 was removed by law.

The subcommittee responsible for the physics curriculum in 1958 did understand that the syllabus needed a radical change. A lot of new topics were introduced and it was stated that, whenever possible, the teaching should be based on the concept of atoms and molecules. One of the most important renewals was that Newtonian dynamics was included in the syllabus and that energy was made the fundamental topic to be studied in "real 3".

To support an experimental treatment of a large part of the topics it was required that the examination in physics and chemistry at the end of "real 3" should include a discussion of an experiment done by the examinee.

It was much harder for the committee to get rid of old-fashioned topics than to introduce new ones. To the great dismay of many older physics teachers the steam engine should not be taught any more, but other topics, just as old-fashioned, as for instance different kinds of pumps, not much in use any more, are still included in the syllabus.

The teachers were not prepared for all the changes, and during the first years there was a heavy opposition against the new physics curriculum, but when new teaching materials had been developed it was realized that these topics could be treated very well in an experimental way, and the opposition gradually faded. Today, the teachers mainly critizise the curriculum because, in their opinion, some of the grades seem to allow too little time for the teaching of the many different topics.

1.3 The reputation of physics in 1958 and now

The main reason for the improved position of physics and chemistry in the curriculum from 1958 was partly that physics and chemistry at this time were very esteemed subjects. Nearly all people in Denmark knew the name of Niels Bohr and were a little proud of Denmark's ability to create world famous physicists. Furthermore, Denmark at this time was short of technicians, and the politicians were much concerned about it. The prime minister appointed a committee to suggest what to do to increase young peoples' interest in technics, and in 1958 this committee declared that one of the best things to do was to increase and improve the teaching of physics, chemistry and mathematics in the folk school. Furthermore, the committee recommended that it should be required of all schools in Denmark that a

good physics laboratory and a modern collection of physics teaching apparatus should be available. In some periods of the sixties Denmark's financial standing was good, for once, and the demands were satisfied to rather a high degree, so now the situation is that the facilities for physics teaching in the Danish Schools are very good.
It is difficult to say, to which degree the improvements of the tea ning of physics, chemistry, and mathematics has been responsible for the increase in technicians during the following years, but in fact we avoided the threatenin shortage of technicians, and today we have, on the contrary, a surplus of the. n.
Unfortunately, the attitude towards physics has changed also, not o much the attitude of the children in the folk school, who are often looking f - vare to the start of physics teaching, but the general attitude from society and of ials. It can be seen from the fact that the teaching of physics in grade 6 was cance d in 1969, when school's amount of periods per week was reduced to make it pc ble to go from a 6-day-week to a 5-day-school-week without the school day b oming too long. Also, the above-mentioned cancellation for technical real 3 w an indication of a new official course towards physics and chemistry.
In view of this situation I am not quite sure that the title of my lecture t this conference should be the announced one. Perhaps the title: "The Fight for ysics and Chemistry in a New Danish School Structure" would be more covering.

2. Conference notes

In my lecture I describe our efforts to secure a reasonable position for physics and chemistry in the new curriculum for the Danish folk school, and I present some of our basic ideas concerning the new physics curriculum.
I express it as my experience that - whenever a school reform is being prepared - it is worthwhile to analyze how the teaching of physics can contribute to the general aims of the school. Physics has indeed much to offer, no matter the contents of the aims. But we must work hard to convince the officials responsible for the reform of this fact.
As documentation I refer to the fact that it seems that we in this way have prevented a severe reduction of physics and chemistry in the new Danish curriculum. Table III indicates the general school structure according to the planned reform, table IV shows the probable number of weekly periods of physics and chemistry in the different grades. The general aims of the folk school according to a preliminary paper by the curriculum committee, are shown in table V.
In accordance with general aim no. 1 one of the aims of the compulsory teaching of physics in grades 7 and 8 will be to make the students familiar with fundamental physical and chemical concepts. In accordance with general aim no. 2 a natural purpose seems to be to make the students familiar with the scientific method used in physics and chemistry.
To fulfill the last aim the students must have ample time for experiments in the lab, but lab-centered teaching is very time-consuming which means that there will only be room for a limited number of topics in the syllabus. Therefore, it is

of vital importance to find out which concepts will be of special value, for example from the point of view that familiarity with these concepts is a necessary condition for a reasonably good understanding of the information presented in newspapers, TV-broadcasts, and other sources of information.

As a first, incomplete investigation of this question a group of physics teachers attending my courses "Methods and Ways in the Elementary Teaching of Physics" went through a volume of a Danish newspaper (from October, 1970 to October, 1971) and noted how often physical and chemical concepts were mentioned. Each concept was counted only once in each article, and special columns as for example "Motor and Traffic" and "Photo" were omitted. Two of my students, mr. Axel Johannisson and mr. Bent Balle Petersen, analyzed the material and prepared the statistical surveys shown in tables VI, VII, VIII, and IX.

These tables were taken into account together with other important aspects (for example concepts considered especially valuable by physicists) at a meeting with the subcommittee responsible for the physics curriculum. There, it was decided that the syllabus for the compulsory teaching of physics in grades 7 and 8 should include the following themes:

- An elementary treatment of Newtonian dynamics.
- Temperature and pressure.
- Chemistry.
- Electricity and magnetism.
- Atomic structure, radioactivity.
- A qualitative treatment of energy.

Some ideas for the syllabus for grades 9 and 10 were also suggested. In grade 9: an extended course in electricity including electric oscillations and an extended course in atomic and nuclear physics. In grade 10: optics, waves, the nature of light, statistical phenomena, an extended course in Newtonian dynamics, and a more quantitative treatment of energy.

At the Physics Institute of the Royal Danish School of Educational Studies we have discussed these possibilities, and we have found it very difficult to give an extended course in atomic and nuclear physics when the students have not yet studied the topics suggested for grade 10.

At the next meeting we will therefore suggest that an extended course in Newtonian dynamics, energy and energy-conservation is to be given in grade 9 together with a reduced course in electricity and magnetism. In return, electrical oscillations should be treated in grade 10 together with waves.

In addition to the subjects mentioned in the general school curriculum it is also possible that other subjects can be taught, if a competent teacher is available and enough students want to study the subject. Of subjects related to physics we think that electronics and astronomy might be taught in this way in some schools.

Our intentions concerning the new physics curriculum are just as much to inspire the physics teachers to concentrate more on active teaching methods where students' laboratory work plays an important role, as it is to introduce new topics. In fact, the situation is the one that we are considering how much we can reduce traditional topics to allow room for the time-consuming lab activities.

Inspiration to change teaching methods does not come all by itself from a list of topics in the syllabus. Therefore, the physics syllabus is to be published in a booklet, carefully discussing the aims of physics teaching in the light of the general aims of the school. Furthermore, this booklet will include a discussion of a variety of teaching methods, and their advantages and disadvantages illustrated by a number of examples. In this way we intend to exercise a mild pressure towards more lab-centered methods.

We hope that the physics teachers and the different teams of authors writing text-books in physics will be inspired by this booklet and find new and fruitful ideas for the teaching of physics in Denmark.

Therefore, we do not want the list of topics in the syllabus to be too detailed. On the other hand, we would like to make it impossible to go on using the old text-books and laboratory guides, unless these undergo radical changes. At the Physics Institute we are working on these problems just now.

My own ideas of new materials for the physics teaching according to the new curriculum go in the direction of a textbook integrating the laboratory activities in a way similar to the IPS and PS II courses, and suggesting more open activities where this method is considered useful (inspiration from the Nuffield Project).

Table III: Model for a general structure

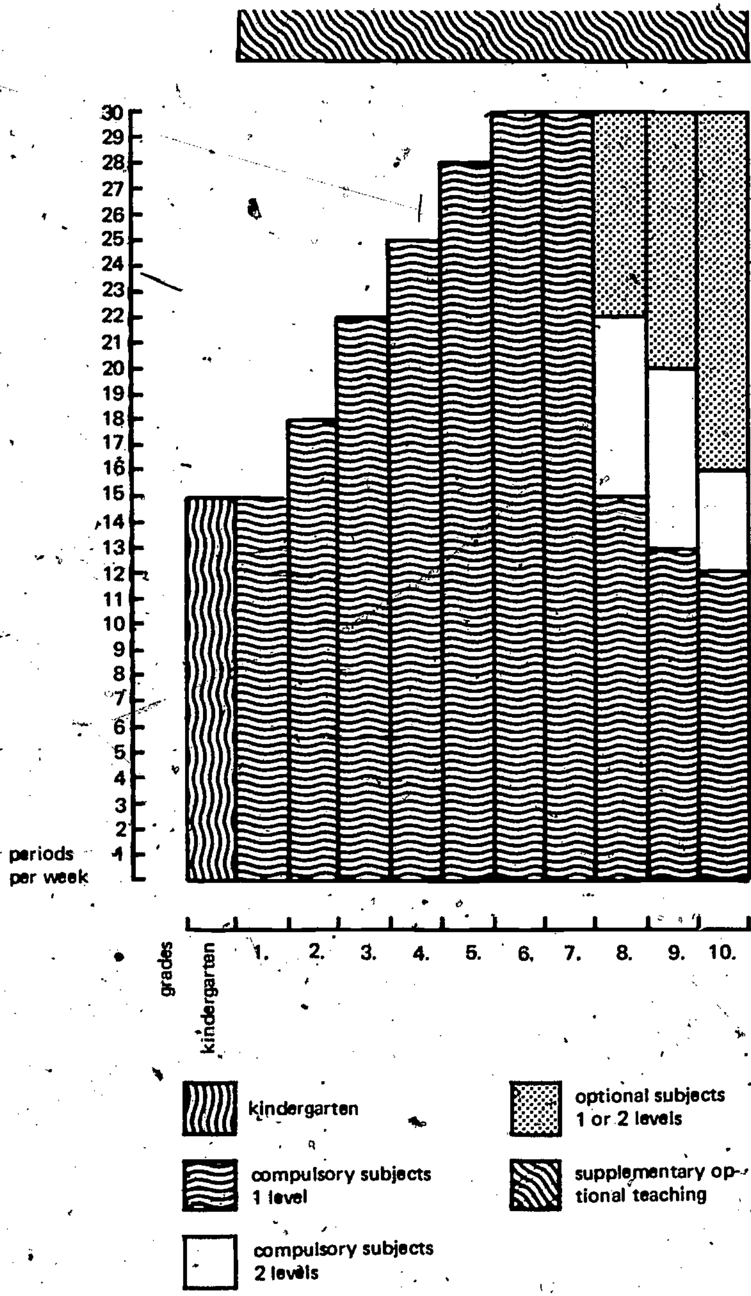


Table IV:

age	grade		
16-17	10	4PH	optional (2 levels)
15-16	9	2PH + 2 Chemistry	
14-15	8	3PH (Chemistry included)	compulsory
13-14	7	2PH	
12-13	6		
11-12	5		
10-11	4		
9-10	3		
8-9	2		
7-8	1		
	0	kindergarten	

Table V: General aims of the folk school

1. That each student gets the opportunity of acquiring skill, knowledge and insight,
2. that each student gets the opportunity of independent and social development of personality.

In trying to fulfill these aims it is important

- that the student gets the opportunity of experiencing and evaluating own possibilities and limits,
- that each student can train own abilities of evaluation and independent choice,
- that the student's self-activity is encouraged,
- that the student's imagination and creative abilities are stimulated,
- that each student gets personal responsibility and influence on joint decisions,
- that understanding of other person's capabilities is furthered in each student.

Table VI: Statistics on the frequency of physical concepts - in the newspaper "politiken" for the period october 1, 1970 - october 1, 1971

mech. energy 7	thermal e. 12	electric energy 26	atomic energy 22	atomic bomb 8	(total: 75)

radioactivity 22	radioactive elements 13

Frequency	Concept
19	velocity/speed
19	pressure
18	electric voltage
17	temperature
16	electromagnetic waves
14	sound intensity (db)
9	atom
8	acceleration
8	condensation, evaporation, vapour pressure
8	melting, freezing, supercooling
8	magnetism
8	accumulator/dry cell
8	nucleus
8	nuclear-physical instruments
7	force
7	electrolysis
7	x-rays
7	spectrum
6	atmosphere
5	electric supply (generator)
5	frequency
4	wavelength
3	electric current
3	electric resistance

Table VII

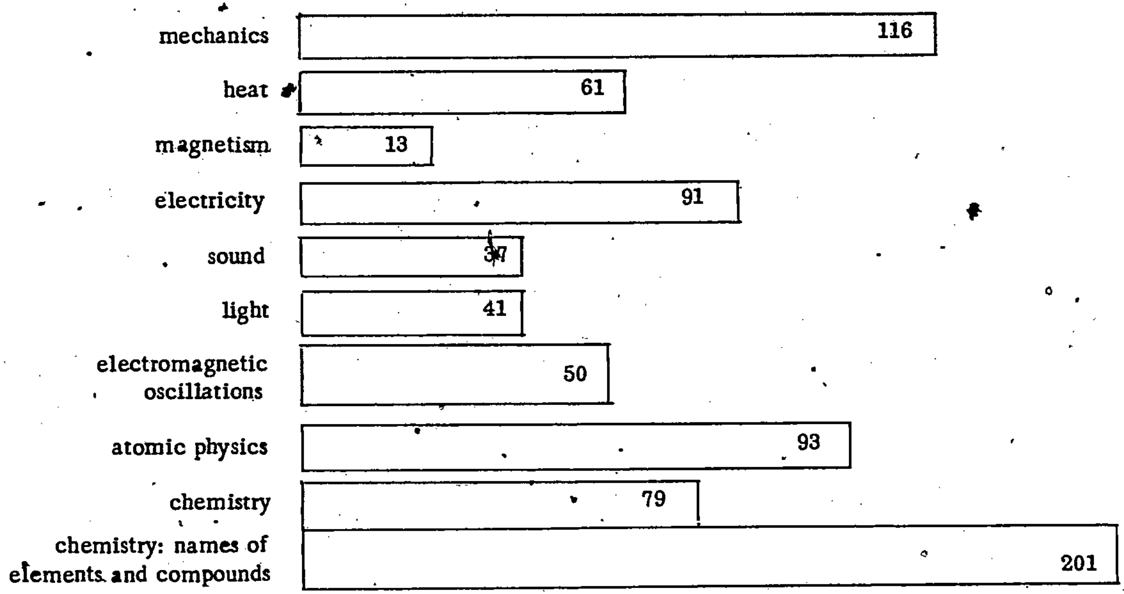
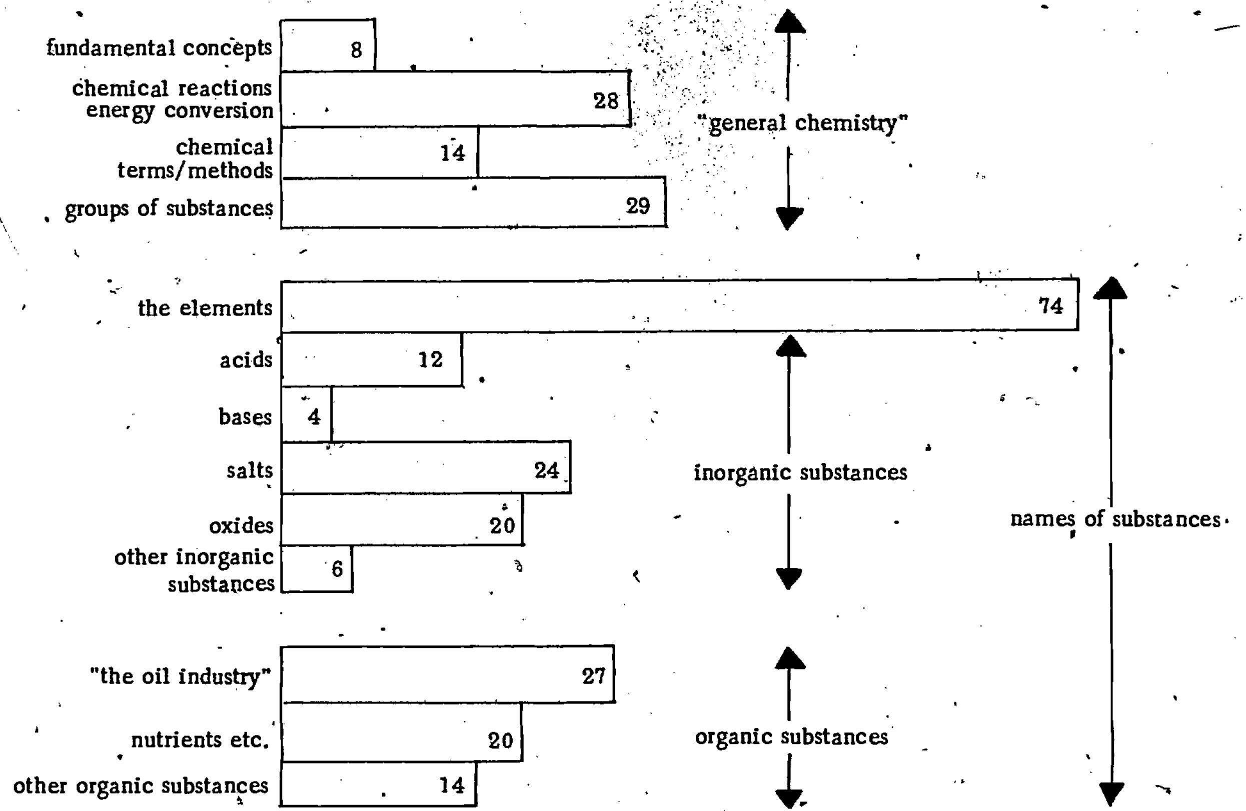

mechanics
116
heat
61
magnetism
13
electricity
91
sound
37
light
41
electromagnetic oscillations
50
atomic physics
93
chemistry
79
chemistry: names of elements and compounds
201

Table VIII: Physics

MECHANICS	fundamental concepts	32
	mechanical energy	10
	pressure	28
	geophysics	9
	gravity	6
	friction	5
	rotating movements	5
	space travelling	14
	astronomy	7
HEAT	fundamental concepts	23
	states of matter	22
	changes of volume	4
	heat transfer	2
	energy conversion	10
M.	magnetism	13
ELECTRICITY	fundamental concepts	25
	effect/energy	26
	power supply	15
	electrolysis	7
	static electricity	3
	electrotechnics	7
	danger	8
SOUND	fundamental concepts	12
	propagation	10
	sound intensity	15
ELECTROMAGN. OSCILLATION	fundamental concepts	12
	propagation	10
	units	4
	instruments	6
	technical concepts	15
ATOMIC PHYSICS	fundamental concepts	17
	nuclear energy	30
	radioactivity	21
	nuclear reactions	4
	nuclear-physical instruments	8
	radioactive elements	13
LIGHT	fund. conc.	8
	propagation	4
	frequency dependency	19
	geometrical optics	10

Table IX: Chemistry



H.P. Hooymayers

The set-up of a Dutch curriculum innovation project for physics

1. Introduction

During the past decade considerable attention has been paid to curriculum study and reorganisation in many nations.
Until about 10-15 years ago curriculum innovation was only minor - when it did take place - and in most cases meant no more than adding a new section to a syllabus or replacing some physics topics by more up-to-date physics. Generally ad-hoc committees of subject specialists made some modifications. Since these modifications were mostly small, teachers found no difficulty in applying them, at least they did not require any further training.
In the past decade, however, it was generally felt that minor modifications were no longer sufficient to keep science education at the secondary school level on a satisfactory basis. Curriculum reorganisation had to include a lot more.
Consequently the more recent curriculum changes in UK and USA were often so fundamental that most teachers felt uncomfortable without further training, implying that the dissemination of such courses must go hand in hand with training of the teachers.
Such a training should not only concern itself with the subject matter of the course (for instance physics) but, and I believe with increasing emphasis, with the behaviour and the function of the science teacher in the various elements of the teaching process. Curriculum innovation in this manner needs study, research, and last but not least a lot of money and creative people.
When we wonder why curriculum innovation can no longer follow the simpler way of the past, it is appropriate to think of a paper of B.S. Bloom published in Educational Sciences (Febr. 1966) entitled:
"The role of the educational sciences in curriculum development".
Here Bloom states that curriculum change is required not only because of the rapid growth of new knowledge, the changing conception of the subject itself and its relation to other subjects or the political and economic changes in the social system, but also because the students in the present schools are different in many ways from the students before World War II.
For instance there is less and less motivation available to do a task without knowing why. Blind obedience to authority is much less common among pupils than it was 20-30 years ago.
Furthermore curriculum changes are resulting from new knowledge about the learning process. The theories of learning and the methods of educational research give us the means of investigating the effects of particular methods of teaching and particular curricula.

On the basis of such considerations and also with a view to the considerable changes that have taken place in the Dutch school system in recent years, we are convinced that in the Netherlands the only way which will lead to a justified curriculum change is the expensive way. This way requires a team consisting of experts from different educational sciences and subject specialists. We believe that only such a team working in close cooperation with a large number of trial schools can answer adequately questions as

1. For which ages and for which levels of education can physics contribute in a relevant way to the education of the individual and to the more general objectives of education?
2. Which essential principles, ideas, structures and organizing concepts of physics as a science should be included in the curriculum in any case?
3. How far has one to go with the mutual tuning of physics and the related disciplines with a view to the selection and sequence of the developed materials (combined science course, separate physics courses or something in between)?
4. To what extent should the course material embrace theoretical and mathematical treatment of physics, labwork, technological applications, historical considerations, biographical background data and philosophical issues?
5. What are the special weaknesses in the present curriculum in the light of the major changes in the conceptions of leading physicists concerning essential principles and ideas of the subject field, its methods of investigation and its relevance for contemporary problems?

To find answers to such questions in order to improve the present physics courses on secondary schools, we shall start a curriculum innovation project for physics in the Netherlands in August of 1972.

2. Shape of the project

The schedule for the development of the new course embraces four phases.

1. The orientation and planning phase.
2. The construction phase.
3. The experimental dissemination and revision phase.
4. The conducted dissemination phase.

3. The goals of the successive phases

The main goal of the first phase is to gather, analyse and interpret the data required to arrive at a justified set-up of the following phases. The activities of this phase can be distinguished in some main components.

A. The formulation of instructional objectives for the new curriculum after a critical study of the goals, that are pursued by existing national and foreign courses and a stock taking in this field of thoughts and ideas of leading physicists, physics teachers and educational specialists. These objectives should lie in the domain of knowledge, understanding, attitudes and skills, and should embrace furthermore the essential elements of the structure of physics as a science, such as facts, principles, underlying concepts, methods of investigation etc.

B. A critical study of the instructional procedures of existing courses and a rough selection of the subject matter. In the stock taking of the instructional procedures we can distinguish

1. Learning activities/ teaching techniques
2. organisation of the components of the teaching process
3. subject matter
4. teaching aids, such as
   a) skills of the teacher that are necessary for the use of different teaching techniques
   b) audio-visual aids (hard ware and soft ware) lab equipment for student work and demonstration purposes.

C. A critical study of the aids and techniques that can be used for evaluation and feedback.

In this field we can distinguish:

1. tests and observations used to determine how well the student has achieved the instructional objectives
2. questionnaires for students and teachers to determine the effectiveness, and the motivating value of the learning activities
3. the subsequent organisation of the total feedback system.

D. The organisational and financial planning of the following phases. -

The information produced by these activities should give us at the end of the first phase the answers on the following questions:

a) what student attitudes and student skills should be pursued by means of the physics course for the various kinds of secondary school education;
b) to what depth and breadth should students know and understand the essential elements of the structure of Physics as a science;
c) which subject matter is required as a consequence of the choice of some alternative endpoints of the course;
d) which learning activities and teaching techniques are useful in physics education and to what extent are physics teachers already familiar with aspects of educational psychology and sociology such as motivation of students, teacher-student relationship, the effects of tests, group dynamics, processes of perception and reasoning involved in scientific procedures;
e) which teaching aids can be used in physics education and which materials are already available at home and abroad;
f) which evaluation techniques are most effective to test whether the formulated objectives are achieved and to what extent the teachers are familiar with the evaluation of the comparative effectiveness of tests, lab-work, teaching techniques etc.

The detailed plans for the second and following phases will be made in the first phase. For that reason it is only possible to give a rough outline of these phases. In the construction phase the total set of learning materials should be designed. These materials can include (see for instance Project Physics) student texts, laboratory guides and equipment, teachers guides, tests, programmed instruction, single concept films, overhead transparancies, readers (i. e. books of selected readings) etc. A great variety of course materials creates the possibility for the teacher to shape the course to fit the diverse needs and interests of the pupils. With course materials that allow varied approaches, it is possible to teach groups of pupils with mixed abilities and interests. Of course for a correct use of such materials you should have a clear notion of their practical possibilities. For that reason the materials must be designed by a team of curriculum developers working in close cooperation with a number of trial schools. In this phase special attention should be given to the construction of the teachers guides to prevent that these contain only information about alternative content and problems for teaching and nothing on how science is learned, in other words nothing about teaching strategies. Furthermore in the second phase special training programs for teachers should be worked out for a conducted introduction of the course materials in a second-group of schools which did not take part in the construction of the materials.

Then in the third phase, called the experimental dissemination phase, these training programs must be verified for their usefulness and validity. During this period the feed back should be intensive, because this is the first time that the materials are used in the second group of trial schools. This experimental dissemination phase is planned to prevent that the introduction of the new course into schools is largely mis-directed. In this phase the teachers are not upgraded in course content only, but are also informed about the underlying educational framework and modes of instruction to successfully teach the new course. Once experience is obtained with the planned and if necessary improved methods of dissemination, the dissemination on a large scale can start.

At that moment we are at the beginning of the fourth phase of the project, the dissemination phase. This is the most expensive and most important phase. At this moment, however, too few data are available, so that it is not very appropriate now to try to say something relevant about this last phase.

A more detailed working-out of the activities and ideas of the first phase. Formulation of instructional objectives

It is well-known that the formulation of useful statements of instructional objectives is a very difficult task.

However, at this moment there is much literature about the methods and techniques to formulate explicit objectives in terms of terminal performance.

Of course, when doing this one should take into consideration the total number of hours available for physics in the secondary school program. Moreover it is necessary to know the entering behaviour of the pupils, i.e. you should know what they have learned previously, their intellectual ability and their motivational state before instruction begins. In our school system we have a reasonable idea of the entering behaviour of the pupils because of the results of the entrance examinations, psychological tests and advices from the teachers of the primary schools.

To illustrate the complexity of setting objectives, it is perhaps useful to give a more detailed account of the variety of goals as given in some wellknown innovation projects for separate physics and applied science courses, such as P.S.S.C., E.C.C.P. (Engineering concepts curriculum project), Project Physics, the Nuffield Project and others. Concerning the P.S.S.C. course, much has been done by Trowbridge (1965) who compiled a list of objectives which were unique for this course (see L.W. Trowbridge, Science Education 49, 112-22).

He also listed 39 objectives which were common to both the P.S.S.C. and the traditional Physics courses. The list of the unique P.S.S.C. objectives is given here as an example.

A. Broad objective
   1. To emphasize the continuity and unity of Physics.
B. Development of student attitudes
   2. To emphasize that physicists are typical people of academic life with typical human aspirations.
   3. To develop a view of contemporary physics that is consistent with that of the professional physicist.
C. Relatedness to experience (association, application)
   4. To emphasize the major concepts and principles of physics from the standpoint of their contributions to physics as pure science.
D. Scope and sequence
   5. To emphasize the study of a few major topics at considerable depth.
E. Teaching aids and techniques (textbooks, tests)
   6. To employ tests as a means of determining the ability of students to reason to logical conclusions when working with unfamiliar data.
F. Teaching aids and techniques (laboratory)
   7. To emphasize the use of simple apparatus and inexpensive materials where educationally feasible in the laboratory.
   8. To emphasize the method of laboratory investigation for learning.
   9. To emphasize the use of equipment and instruments whose working parts are clearly visible.
   10. To make the laboratory central in the learning process by designing it as a process of inquiry on natural physical problems.
G. Teaching aids and techniques (visual aids)
   11. To emphasize an integrated film program for helping to teach the principles of physics.
H. Skill and concept development
   12. To show the importance of scaling and its role in physics.
   13. To emphasize development of the ability to organize and display data in useful forms for effective analysis of it.
   14. To emphasize the understanding and use of physical approximations and models in helping to explain theoretical concepts.
   15. To emphasize the meter-kilogram-second system of units.
I. Content objectives
   16. To study electricity predominantly from the standpoint of fundamental charge units, their nature, measurement, and behaviour.

Next to the P.S.S.C. course are the more recent Physics and science courses for secondary schools such as Nuffield, Project Physics, the E.C.C.P. project called "The Man-Made World"[4]. Some of these projects have formulated objectives differing in many aspects from the P.S.S.C. ones. For instance the applied science project E.C.C.P. claims to bring a systematic approach to problems as pollution, traffic control, waste disposal, health care, urban housing etc.
In this way they try to make their course attractive to non-specialists, because they are convinced that students feel involved in solving todays problems.

Some other statements of the E.C.C.P. group are:

A. Students develop the skills to relate technology to community problems
B. Man-machine interaction is made clear
C. Environmental problems are emphasized to give students realistic insight into potential solutions.
D. Students learn about the use and operation of computers.

Perhaps it is interesting to know some decisions made by the E.C.C.P. group about the character of the course such as:

A. it should be a cultural course with technical and scientific content
B. it should not be a vocational course emphasizing detailed technology and engineering skills
C. it should not replace biology, chemistry or physics in high school, but provide an alternative course, and
D. it should be written to interest the seventy per cent of high school graduates who do not take physics.

Project Physics, on the other hand, appears to put less emphasis on this type of aims but states that the course materials were designed to achieve the following goals:

A. To help students to increase their knowledge to the physical world by concentrating on the ideas that characterize physics as a science at its best (for example, the conservation laws), rather than concentrating on isolated bits of information (such as the lens formula).
B. To help students see physics as the manysided human activity that it really is. This means presenting the subject in historical cultural perspective and showing that the ideas of physics have not only a tradition, but methods of adaptation and change.
C. To increase the opportunity for each student to have immediate rewarding experience in science while gaining knowledge and skill that will be useful throughout life.
D. To recognize the importance of the teacher in the educational process, and the large spectrum of teaching situations that prevail.
E. To make it possible for teachers to adapt the physics course on the wide range of interests and abilities among their students.

All these objectives and the corresponding course materials should be carefully analysed in the first phase. However, next to the analyses of the foreign courses it is extremely important to find out the needs and wishes of the national physics teachers, research physicists and specialists of education.

Interviewing the physics teachers is not only important because they know their schoolsystem and the needs and wishes of their students better than anyone else, but they can also value the usefulness and validity of developed ideas and materials from their own experience. All the work done to the formulation of explicit statements is necessary to achieve that the goals are not obscure in their meaning so that they can be reflected in the textbooks and related instructional materials.

The content and shape of the teaching process and the choice of the subject matter

Once having formulated the objectives the teaching process must be described, i. e. the set of learning situations in which pupils, teachers and materials interact to produce the desired changes in pupils' behaviour.
In the first place we have to analyse the instructional procedures and learning materials developed in the curriculum innovation projects from abroad just as the selected subject matter.
The main problem that arises in the selection of subject matter is to find the balance between the depth and breadth of its treatment. In this respect, it is always good to consider the endpoints of the course first. So, the treatment of high energy physics as endpoint of the course will require, at least in some important aspects, another basic knowledge than the treatment of solid state physics. When the chosen endpoints do not need the treatment of a special topic, for instance hydrostatics it is possible to leave it out of the program. For such a topic, that is not strictly needed to reach the endpoint of the course you should require that one reason is almost never enough to put it in the course. There should be at least 4 or 5 reasons.
For the determination of the depth and breadth of treatment of the subject matter Bloom's taxonomy of educational objectives can be perhaps of great help. Bloom and cooperators have arranged different classes of behaviour in hierarchical order from the simple, i. e. from the recall of specific facts, conventions, trends and sequences to the complex, i. e. the judgement of the value of materials in terms of internal evidence and external criteria.
For example, you can require that pupils only recall the law of conservation of momentum but you can also ask them to apply this law in concrete situations, which is a more difficult task. Much more difficult, however, is to require, as terminal performance, the ability of judging a written text about conservation laws in terms of logical accuracy and consistency. Using this classification scheme it seems possible to give the depth and breadth considerations a more quantitative background.
When the developed curriculum is thought of as a set of learning experiences to produce changes in the pupils I am convinced that these changes should not lie in the field of passive imitation but in the field of creative thinking and acting. We should not force the pupils to think along lines we have in mind, but we should appreciate and stimulate them to give their own solutions to the problems we offer, even when these solutions are not the best we know. It means that the teacher should not act like the teacher in the following anecdote, who asked a pupil to explain how the height of a building can be measured with a barometer.
The first answer of the pupil was: take the barometer to the roof of the building, tie it with a rope and sink the barometer till it touches the ground and measure the length of the rope afterwards.
The teacher says: you are right but can't you give a solution that shows more understanding of physics.
Pupil: Make a pendulum from the barometer and a piece of rope. Let the barometer swing on the groundfloor and on the roof of the building.
Measure in each case the frequency of the swinging pendulum and calculate the height of the building from the ratio of these frequencies and the earth-radius.

Teacher: Again you are right but the answer is not very accurate and I want a more accurate result.
Pupil: Go upstairs and measure the height of the building using the length of the barometer as unit of length.
Teacher: Is it also possible to measure the height of the building with two measurements only.
Pupil: Of course, place the barometer on the ground and measure the length of the shadow of the building and the barometer. From the ratio of the shadow lengths and the length of the barometer follows the height of the building.
Teacher: Try to give a solution without the use of the arbitrary unit of the barometer length.
Pupil: Bring the barometer and a stopwatch to the roof of the building. Drop the barometer from the roof and measure the time that the falling barometer needs to reach the ground.
From this time and the acceleration due to the gravitational field the height of the building can be found.
Teacher: Do you really not understand what I mean?
Pupil: Oh yes, but we know both already the answer that you want to hear but why am I obliged to think along the lines you have in mind?
Of course this is a rather exaggerated example, but it shows a teaching activity that I do not endorse.
The key to understand physics is thinking about physics. The emphasis on thinking demands flexibility of the teacher, because only then it is possible for the pupils to follow their own routes when solving a problem. I believe that it is now widely agreed that creative thinking and acting can be best achieved by activities where pupils are gradually allowed to work rather independently.

Aids and techniques for evaluation and feed back

As already has been said a new curriculum may be seen as the planning of learning experiences and instructional materials to achieve a set of goals.
Whether the teaching process has attained these goals or not is a matter for evaluation.
The evaluation should be used to determine where in the teacher and student activities and the learning materials can be improved and whether the new curriculum works well for some students but not for others.
In the more recent projects a growing emphasis is being placed on evaluation, because this information should be on hand when decisions are made about the adoption of new courses in schools.
For instance the "Engineering Concepts Curriculum Project" and especially Project Physics have built into their development work a scientific evaluation of their materials, and of the attitudes and interests of both students and teachers. This is important, I believe, because the curriculum developers should know, whether or not the pupils find the course enjoyable, and whether or not they have gained some understanding of physics out of the course.
The research methods, instruments and statistics of the evaluation of a physics project can be found in the report, "A case study in curriculum evaluation: Harvard Project Physics".

As an example I would like to draw your attention to an educational experiment described in one of the Teacher Resource books of Project Physics. A random selection of fifty-three teachers was made from a list of 16.000 high school teachers in the U.S. during the school-year 1968/69. Thirty-four teachers were assigned to attend a summer institute and then to teach Project Physics. The remaining nineteen teachers were requested to continue teaching what they had been teaching. At the end of the course a satisfaction score was deduced from questionnaire responses.
In these questionnaires the student was asked to indicate as to how far he was likely to agree with statements as.

a) I think this physics course is designed in such a way that even those who have little background in mathematics can gain much from the course
b) The book was really enjoyable to read
c) I think learning about men and women who made physics grow helped to make the course more interesting
d) Physics is one of the most difficult courses I have taken in high school
e) No matter how you look at it, physics has to be a difficult course.

The teachers groups in this evaluation were randomly assigned from a randomly selected pool, sothat the results of the satisfaction score can be legitimately generalized to the national population of high school teachers, this in contradiction to the results obtained with volunteer groups as used in most cases.
I believe that in every new project more and more self-evaluation should be built, because we have to realise that most of the ideas and statements about curriculum innovation are no more than hypotheses which should be empirically tested in trial schools on a scale as large as possible.
Again we may say, that quite a lot of experience about research methods etc. is stored in the documents of the most recent U.S. and U.K. projects.
This implies that the making of an inventory will be one of the main tasks in the first phase of our project.

4. The organization of the first phase

Responsibility for the project

The responsibility for the total project rests with a commission (23 members) which is established to modernize the Dutch physics curricula for secondary schools. This commission of national stature exists about six years and is appointed by the Ministry of Education. The membership of this commission includes university physicists, physics teachers, teacher trainers and inspectors of education.
In fact this commission has delegated its responsibility for the project to a subcommission (9 members). This subcommission, enlarged with some specialists in social pedagogical research, is the advisory board for the projectgroup.

The advisory board

This board consists of physics teachers (to represent the prime users), physicists (to guarantee the up-to-dateness and accuracy of the course materials), teacher trainers (to discuss with the project group the ways in which the teachers can be helped to use the materials developed), a psychologist (to assist in the evaluation of the effectiveness of the course materials) and educational specialists with experience in curriculum innovation (to assist in the set-up of the second and third phases of the project).

The project group

For the first phase a project group will be formed consisting of
1) three full-time curriculum developers (selected from the most able physics teachers available),
2) one part-time psychologist or sociologist with methodology as specialism.
3) one secretary.
The project group will be housed in the Physics Laboratory of the State University of Utrecht and will work in close cooperation with its department for training of physics teachers and educational research.

Costs and duration of the first phase

The first phase will start in August 1972 and will last about one year. The costs of this phase are about f 400000,- (or app 125000 dollars), including the salaries of the curriculum developers. Financial support will be given by a national foundation for educational research. (S.V.O.)
The costs of the second and third phase will be at least twice as much per annum, because then the project group will be enlarged with teachers of trial schools with reduced teaching commitment.

Tasks of the members of the project group

The tasks of the members of the project group follow from the activities in the first phase as described already. For each of the full-time physicists a working scheme has been designed, in which the activities that are expected from him, are given from week to week. Of course, this scheme is only a rough outline, but the designing of such a scheme forces the advisory board to consider in detail the realizability of every sub phase in the first year. Moreover this scheme is very useful during the formation of the project group, because every applicant can read beforehand what is expected from him during the first phase. The part-time psychologist is mainly concerned with the evaluation of the effectiveness of the course materials. Furthermore he has to prepare the documentation on educational psychology and sociology in order to supply the other members of the group with relevant data concerning the effects of tests and evaluations, group dynamics, learning processes, the formulation of explicit objectives and so on.

Task of the university group

The university group of the Physics Laboratory of Utrecht will provide the project group with advice, help and guidance during the execution of the successive phases.

The leader of the university group is a member of the advisory board and he is charged with the special task to closely supervise the project group.
In order to give some insight in the know-how of the members of the university group it is perhaps useful to mention some of their daily activities.
They are physicists and responsible for the educational part of the training of the physics teachers graduating from the Utrecht university. Furthermore they develop demonstration experiments and experiments for student lab-work on secondary school and university level. They also try to stimulate didactic renovations of the physics education at these levels.
This group has built up good relations with secondary school physics teachers by organizing regularly different types of in-service training such as: conferences about didactics of physics, local meetings of physics teachers, subject matter courses and so on.
Moreover they provide the teachers with all sorts of advice on new apparatus for demonstration experiments, student lab-work, equipment of student laboratories etc.
This know-how, rather unique in the Netherlands, is at the service of the project group. It should be noted that the time spent on project activities by the university group will be compensated by an expansion of staff paid by the project funds.

Responsibilities and tasks for the advisory board

The advisory board is charged with
1) the quality control of the project results
2) the financial control
3) the responsibility for the execution of the plans according to scheme and the reporting of the results in good time
4) the personnel management of the project group.

From these responsibilities it follows that the advisory board has to select the curriculum developers and it is clear that the choice of the developers is one of the key tasks in the whole project,
This, because experience teaches that the success of a project is determined in the first place by the quality of the curriculum developers and only in the second place by the approach of the project and the efficiency of the organisation scheme.
The advisory board must also make a decision, considering the funds available how to involve teachers in the project.
For instance you can spend much money, time and effort to involve a large number of physics teachers in the project right from the beginning. In that case, however, you can only afford to give these teachers small reductions of their teaching commitments as compensation for their time spent on project activities.
On the other hand you can spend the major part of your money and effort on a small number of carefully selected teachers. In that case you can give them far-going facilities concerning their teaching commitments so that they become, in fact, part-time members of the project group.
In our project this is still under discussion. Anyhow, the major part of the advisory board is convinced of the importance of the involvement of physics teachers on a scale as large as possible in all phases, to ensure the quality of the feedback and

to stimulate the interest of the teachers in the project results. This standpoint is for instance supported by the Nuffield group. They experienced that new ideas were quite as much due to the teachers as to the members of the project group.

One of the possibilities to ensure the influence and interest of a large number of teachers is the forming of local groups of physics teachers which will meet regularly to discuss the progress of the project. The leader of such a local group should be a successful teacher who should be given reduced teaching commitments. Teachers journals or perhaps a bulletin issued by the project group should report the discussion results of the local groups, so that every teacher can follow the project closely.

The local groups should be spread over the whole country so that they can act as point sources (according to Huygens' principle) from which the waves of curriculum reform emerge.

Of course the final examinations of our secondary schools will be modified to match the new curriculum, first in the trial schools only and later on in all other schools adopting this curriculum.

This implies, as has been said before, that the project activities should include research to find the tests to verify whether the project materials have accomplished the expected results.

Discussion

(Because of the thematic connections between the papers of Mr. HOOYMAYERS and of Mr. THOMSEN, the two discussions were combined.)

Mr. THOMSEN has shown statistics about the frequency of physical concepts in a newspaper (table VI of his paper). It is commented by Mr. ROGERS that the physical concepts listed there are not independent of each other.
Mr. THOMSEN answers that these statistics are to be regarded as a first trial. Nevertheless, the dominance of the concepts "energy" and "radioactivity" is evident. He feels that a more systematic investigation would be important. - As his basic idea the author expressed that the teaching of physics in school should enable the students to adjust themselves to modern society and make it possible for them later in their lives to keep themselves informed of new progress in science and technique through modern sources of information, such as newspapers, radio and TV. It is objected, however, that students of this age do not read newspapers very often and that therefore the possibility of causing a strong motivation of the students should not be overestimated. It is proposed to include that literature into the investigation, which the children actually read in this age. Then it is discussed to which amount those concepts, which are relevant for the everyday-life of adults, are to be taught to children. Mr. LORIA feels that the investigation should be extended over a longer period of time; otherwise the momentary fashion (which also exists for scientific topics the public is interested in) would cause a wrong selection of subjects.
It is asked, whether astronomy could be included in the syllabus. Mr. THOMSEN answers that astronomy is not included in the compulsory course, but in the future it might be offered as a voluntary subject. Mr. ROGERS warns that one must not include the superabundance of nice and wonderful subjects which too many kind people want to press into a project. but to restrict a project to subjects of general importance.
Mr. SVANTESSON remarks to both the papers of Mr. HOOYMAYERS and Mr. THOMSEN that at first attention should be given to the problem of implementation. There were many curriculum reforms, and nothing happened in the classroom. The knowledge of what has to be put into a reform is already very high. At Göteborg they could not afford to make a great curriculum, and therefore they adapted and implemented the SCIS program. He emphasizes that the process of implementation must not end with the distribution of the material; the reaction of the teachers and of the parents must be considered, a continuous touch to the teachers and a continuous revision of the material are necessary.
Mr. HOOYMAYERS is asked, how it could be enabled that many teachers will contribute to the new curriculum and will therefore have a reduced commitment in teaching: the shortage of teachers is said to be great. He responds that in the Netherlands they will put with this disadvantage in order to get a good curriculum. Besides it is hoped that after two years no shortage of teachers will exist any longer. - He also feels that the problems of the implementation must be strongly considered.

Much information from the beginning of the project is intended. They are reasoning to train a group of teachers and then to spread them all over the country. He hopes that the teachers will have the idea that the pace of the project is effected by themselves and that they so will have a strong stimulation; he does hope that a planned change of the ideas about physics teaching will occur. However, it willnot be possible to establish direct contact to all the physics teachers of the country.

Mr. HOOYMAYERS is asked about the new aims and contents of the Dutch curriculum. He answers that the first phase of the project starting in August 1972 is provided for the formulation of explicit objectives, the selection of the subject matter, the teaching techniques, and the teaching procedure. Provisional courses already exist. - The question for the general aims of the Dutch project is repeated. Here Mr. ROGERS and Mr. BAEZ remark that it is difficult to produce a curriculum in such a manner that the aims of the start are actually realized. They remind of the example of PSSC. Its staff announced that they wanted something and then they achieved something different.

Mrs. WOOD, who was involved in the PSNS project, reports that it was decided there to have precisely described aims. The whole story of the production of this course from the beginning to its completion is written in the final report of the PSNS project: what was aimed, what actually happened and what the steps were.

Emilia Constantinescu

The basic ideas of physics in the elementary schools

1. The theoretical condition of research

Research hypothesis

At the Institute of Pedagogical Sciences, Bucharest, Romania, researches with a view to improving the teaching of physics in school were based on the following hypothesis:
- one of the principal modalities to solve the contradiction between the huge amount of information constantly accumulated by science and the capacity - relatively steady - of pupils to assimilate this information is by emphasizing the formative function of learning.

This would imply:
- development of the pupils' ability to acquire knowledge and development of their creative capacity;
- assimilation of the basic concepts and procedures of scientific investigation;
- acquiring of the habit of independently storing up new information and elaborating new modalities of action.

On these lines, a modern course in physics should provide the pupils with:
- the system of concepts required for understanding and interpreting the physical reality;
- the methodology of this science, i.e. the system of its methods of knowledge based on the very system of the most general laws and fundamentals of physics.

Application of this work hypothesis to curricula and textbooks would require:
- securing of a logical structure of information which should reflect the unity of this science by avoiding excessive sectioning, repetitions and contradictions. The organic and normal blending of classical and modern physics into one single organized system - physics - by reconsidering all notions from the viewpoint of new scientific developments.
- Assimilation in the contents of school physics of the methodology specific to the present level of scientific progress. The process of learning should be stamped with operativeness, that is one should first get acquainted with some working methods liable to being steadily improved and restructured in terms of the requirements of science;
- explicit presentation of both the structure of the system of knowledge and its methodology so that the pupils could use the notions of physics in a conscious manner;
- teaching of notions throughout school by successive approximations so that these notions be perpetually completed and enlarged without being essentially replaced

Curricula should be structured in such a way as to assure continuity of learning at all levels of teaching physics so that each grade should benefit to the utmost by the knowledge and abilities formerly acquired pointing to analogies and facilitating transfers between the various fields approached.

The basic concepts of physics

Applications of these views to the experimental curricula and textbooks raised the problem of the selection criteria of information. As a matter of fact the main criterion was the extent to which the respective information can contribute to achieving the goals aimed at.

In this way, we included in our curricula the basic notions i. e. the notions indispensable for a course in physics to have a unitary structure. We eliminated the "closed" notions i. e. the notions which are not necessary prerequisites for the understanding of further information (and are usually taught merely to increase the volume of knowledge).

We assumed that the understanding of present-day physics is based on the following notions which should be taught from the very first lessons of physics: matter with its two structural aspects, the substance and the field; motion; energy; physical system - the idea of structure and interaction included; physical phenomenon; physical magnitude (scalar, vectorial; of state, of process); physical law; observation; experiment, measurement; modelling (similar, analogous), etc.

The great methodological value of these categories lies in their applicability to almost all the realms of science thus facilitating the transfer of information from physics - whose study begins much earlier - to other subjects so that one may develop some systems of knowledge integration both along intradisciplinary and interdisciplinary lines.

Evidently, in the selection of physical information, stress was laid on the basic notions specific to physics so that these notions should be, as much as possible, integrated into the fundamentals mentioned earlier.

Viewed from this point it was sometimes necessary to make concessions - in point of unity of structure to assure the accessibility of information.

Elements of physics

Methodology

The pupils' approach to the study of physics by simultaneously performing a succession of experiments from the main chapters of this discipline was viewed as a means of putting them in touch right from the very beginning with the work specific to a physics laboratory, to familiarize them with the basic aspects of investigation in this field and to enable them to get those representations required by an accurate understanding of the meaning of such notions as: observation, experiment, measurement, phenomenon, physical magnitude, physical law, etc. Experiments could consist in the measurement of lengths with the ruler, of volumes with a graduated measuring glass, release and observation of some phenomena like boiling and mel-

ting. image formation in plane mirrors, electrization of bodies, behaviour of bodies sunk in liquids (water, oil), etc.
The method of work during these first lessons when the pupils' practical activity replaces the teacher's demonstrations, becomes subsequently an ordinary way of learning (obviously only if the subject studied would permit it). The pupils performing some experiments, as a starting point in acquiring information and not simply as the application of knowledge already acquired, stimulate the active character of the process of learning; in this way each lesson becomes an experimental lesson, affording actual learning through discovery. The construction of lessons, as shown above, is a first step toward the formation of prerequisites that would allow pupils in some future stage to develop an experimental activity much more diversified.

2. Structuring of experimental curriculum according to our hypothesis

On the view of the ideas previously discussed, experimental curricula in physics in the grades 6-8 (11-14 year old pupils) have the following structure:
- grade 6: 1) Pupils' approach to the study of physics by simple experiments; the object and methods of physics; 2) Notions of the structure of substance; 3) Elements of mechanics.
- grade 7: 1) Mechanics of solid bodies; 2) Fluid mechanics; 3) Thermal properties of the substance.
- grade 8: 1) Oscillations and mechanical waves; 2) Electricity; 3) Notions of geometrical optics (Experimental curricula for grades 6-8 are shown in the appendix).

Furthermore, by a detailed exposition of the contents of these curricula we shall try to point to the way in which our views have been applied.
Sixth-graders' approach to physics is made, as already reported, by a series of experiments from the main chapters of this discipline so as to familiarize them with the elements of physics methodology.
On the ground of the experiments made during the first lesson, some basic notions such as observation, experiment, phenomenon, magnitude, law, etc. (already discussed above) are explained in respect to the assimilation capacity of the sixth graders. Further, the object of physics is defined and the structure of the course in physics as a whole is being outlined.

The notion of structure

Substance. The next chapter entitled "Structural Notion of the Substance" is highly important as it is the first step to the understanding of the notion of matter. The pupils become familiar with the structure of substance and the notion of particle, the lessons being taught at the level of their understanding capacity i. e. that of 11-12 year-old children. Thus the atom is discussed on the analogy of the solar system pattern (known by the pupils from the study of geography in the sixth form). The presence of the various types of atoms (over one hundred) is explained by their peculiar structure, the very great number of substances resulting from the different grouping of atoms into molecules, molecular interactions (cohesion and repelling) explain also the grouping of molecules, and the occurence of inter-molecular spaces; with the phenomenon of diffusion the pupils come to know the natural notion of molecules. In this way, from this early stage in the study of physics, the pupils start getting familiar with the notions of structure, interaction, and the substantial aspect of matter. In this way they can realize that motion is a natural attribute of substance manifesting itself in the very essence of the latter.

Field. It is obvious, however, that a definite outline of the notion of matter is highly necessary for the knowledge of its other structural aspect, namely field. We assumed (and this is a deviation from the "perfect" structure of the curriculum) that because of the difficulty of understanding this notion it would be better to introduce it when studying some phenomena in which the field - as a basis for interactions - could be better demonstrated, the pupils imagining its existence as a necessary hypothesis for the explanation of phenomena. In our curriculum this element appears when dealing with gravitation (the chapter on "Force") when instead of outdated theories (e.g. action at a distance) it is admitted that there should exist a form of matter as the basis of this interaction. The "gravitational field" pattern thus built will be further used in approaching potential - conservative - fields (e.g. in a study on the analogy of the electric potential). The notion of field as employed in the teaching of physics in all grades will, by successive approximations, acquire all the attributes that determine it (scalar, vectorial, uniform, stationary field; the field-particle unity; transformation of field into substance and the reverse process so that it will finally be full outlined and understood.

Motion. Let us go back again to the progress of the experimental curriculum. The notion of motion is expounded upon in the section on "Mechanics". In the introductory chapter, the viewpoints from which mechanic motion in kinematics, dynamics, and statics should be approached, are set forth.

In dealing with kinematics after specifying the elements characteristic of mechanical motion (path, relationship between space and time), motions are classified in terms of these elements. Further, each type of motion is detailed out.

Scalar magnitudes.

Vector magnitudes.

The study of velocity in the uniform rectilinear movement is the right moment for discussing vector magnitude, stress being laid on the fact that knowledge of the velocity of a mobile is conditioned not only by its numerical value but also its orientation in space (direction and sense). Finally, the graphic model of the vector is presented.

On these premisses, after the necessary mathematical rules will be gradually learned in higher grades, the analytical representation and the mathematical model of the vector will be taught as well.

For sixth-graders the understanding of the notion of vector is an efficient tool in acquiring further knowledge. A study of the changes occurring in the state of motion of the mobile (a varied rectilinear motion) leads to the notion of velocity variation and acceleration of the directional magnitude. In this way the basis is laid for the understanding of the curvilinear movement and later on of the dependencies between force - as a directional magnitude - and velocity variation, also as a directional magnitude (the chapter on "Dynamics"). Generally speaking, a real understanding of vector magnitudes implies treating as such from the very first they are being dealt with (and not as scalar magnitudes as it is still customarily done in the eightgrade school).

Energy. The next chapter deals with the notion that underlines all knowledge in this chapter. Although the basic, primitive notion is mechanical energy, a magnitude that bridges the way to the other realms of physics (heat, electricity, optics), it is not possible yet to circumscribe information to this magnitude because sixth-graders lack the notions that can precisely delimit it i.e. mechanical work and force. For these pupils (sixth-graders) it is necessary to structure the elements of dynamics on the notion of force, since the chapter on kinematics prepares them to understand it by resorting to the notion of velocity vector and velocity variation. The notion of force has also the advantage of being intuitive and its effects - dynamic and static - can be easily demonstrated by simple experiments. By the study of force pupils can get acquainted with other notions: inertia, mass, volume mass (density), and as mentioned earlier, the gravitational field.

In the seventh form, magnitudes are discussed based on the notion of force, mechanical work and strength. A careful analysis of the notion of mechanical work enables one to pass on to the most important magnitude in mechanics, namely mechanical energy and furthermore, through transfer, to the notion of energy in any section of physics. An outline of the notion of mechanical energy involves elucidation of what mechanical system means. Only in this way (giving as many conclusive examples as possible), a correct definition of potential energy can be formulated for processes in which field interaction prevails - as being the energy of a system due to the possible motion of its constituent parts.

Knowledge of mechanical energy is best applied in the chapter covering the "Thermal properties of the substance". "Heat" is shown as a mode of energy transmission. An approach to this chapter is made by discussing the notion of internal energy. According to it, bodies contain nothing mysterious called "heat", but only internal energy: they may receive or transmit energy through thermal motion.

On these lines, temperature is not discussed as "the state of heating" of a body, but as a magnitude of the average kinetic energy of the molecules which are subject to random motion.

In the eight form, the meaning of many notions previously approached is being elucidated, completed and more thoroughly dealt with. In the chapter on "Oscillations and mechanic waves; acoustics" stress is laid on the continuous - ondulating aspect of matter. Under "Electricity" the electric field and the magnetic field are discussed as well as the relationship between electric and magnetic phenomena. Pupils may go deeper into the notion of field so that the unity between the two aspects of matter, substance-field, can be emphasized. In the chapter regarding the "Electrokinetics", the study of electromagnetic phenomena - as interactions of the magnetic field with electric conductors - points to the fact that in case of these phenomena the magnetic field has no influence on the electric current (which is a process) but only on the conductors in an electrokinetic state. The notion of energy is better understood by studying the electric potential on the analogy of mechanical potential energy.

The notions of optics, which conclude the eight-grade curriculum, resort to the information stored in the chapters on "Oscillations and Waves" and "Electricity" affording a better understanding, in a first approximation, of the electromagnetic notion of light waves.

The few examples given so far were aimed at illustrating the way in which our views on the teaching of the basic notions of physics in the eight-grade schools have been applied to our curricula. The results obtained by testing these curricula with the help of some textbooks also worked out by the Institute of Pedagogical Sciences allow us to state that our work hypothesis was checked by practical activity.

Draft curriculum in physics for the elementary schools

1. Pupils' approach to the study of physics by simple experiments
   Experiments performed simultaneously by the whole class. Physical phenomena, measuring, physical law. Physics as a science of nature. Research methods in Physics. The importance of physics in the knowledge of natural phenomena and technology.
2. Structural elements of the substance
2.1 Notions of the structure of substance
2.1.1 Introduction
2.1.2 The atom; the structure of the atom. The molecule. Simple and complex substances.
2.1.3 Molecular interactions
   Molecular attraction (cohesion). Molecular repellence. Intermolecular spaces. Molecular movement.
2.1.4 Body, object.
   Special properties of the bodies. General properties of the bodies (Divisibility, expansion, impenetrability, state of aggregation and inertia).
2.1.5 The states of aggregation explained with the help of knowledge of the structure of substance
3. Elements of mechanics
3.1 Introduction
   The object of mechanics. Mechanical motion.
   Relativity of motion and rest.
   The chapters of mechanics.
3.2 Some notions of kinematics.
3.2.1 Elements of motion. Measuring of space and time as physical magnitudes. Classification of motions by path and the space/time ratio.
3.2.2 Uniform rectilinear motion. Velocity of uniform rectilinear motion. Velocity measuring units. The velocity/space and the time ratio.
3.2.3 Velocity as vector magnitude.
   Characteristic elements of a vector. Graphic representation of a vector. Comparing vectors.
3.2.4 Varied rectilinear motion. Velocity variation.
   Accelerated and decelerated motion.
   Mean velocity.
3.2.5 Circular motion.
   Uniform circular motion.

3.2.6 Oscillating motion; periodic motion.
3.3 Some notions of dynamics.
3.3.1 Force as body interaction.
3.3.2 Law of inertia. Mass. Measuring of mass.
Mass measuring unit. Density.
Body density experimentally determined.
3.3.3 Force as vector magnitude.
3.3.4 Effects of force: a) static - body deformation; b) dynamic - velocity vector variation. Force/velocity vector variation ratio.
Measuring force.
Force measuring units.
3.3.5 Gravitational force (gravity). Gravitational field.
Pressure. Pressure measuring units.
3.3.6. Friction force.
3.3.7 Centripetal force and centrifugal force.
Applications.
3.3.8 Elementary notions of rigid body motion.
Translation and rotation.
4. Mechanics of solid bodies
4.1 Energy and mechanical work
4.1.1 Mechanical work. Measuring units of mechanical work.
4.1.2 Mechanical force. Force measuring units. Mean force.
Efficiency of machines.
4.1.3 Mechanical energy. Mechanical system. Kinetic and potential energy.
Law of energy transformation and conservation in mechanical processes.
4.2 Statics.
4.2.1 Centre of gravity. Theoretical and experimental determination of the centre of gravity. Significance of knowledge of the centre of gravity of the body.
4.2.2 Equilibrium of suspended and supported bodies. Stability of supported bodies.
4.2.3 Simple machines. Levers. Sheaves. Inclined plane. Wedge and screw.
Efficiency of simple machines.
5. Fluid mechanics
5.1 Statics of fluids (Hydrostatics)
5.1.1 General properties of fluids
5.1.2 Hydrostatic pressure
5.1.3 Transmission of pressure through fluids. Pascal's law.
Communication vessels. Practical applications of the principle of communication vessels (level gauge, artesian wells, sluices, hydraulic press, etc.).
5.1.4 Pressure forces acting on a solid body sunk in a liquid.
Archimedes' law. Testing of Archimedes' law. Floating of bodies.
Applications of Archimedes' law.
5.2 Statics of gases (Aerostatics)
5.2.1 Air pressure. Determination of air pressure value. Barometer.

5.2.2 Compressed and air-free gases. Compression pumps and suction pumps. Measuring instruments for gas pressure (manometers).
Pumps for liquids. Suction pump and suction repelling pump.

5.2.3 Archimedes' law applied to gases. Archimedes' law experimentally checked. Baroscope. Practical importance of Archimedes' law: aerostats, registering ballons, dirigibles.

6. Internal energy

6.1 Introduction. Internal energy. Heat as a form of energy transmission from one body to the other.
On temperature and the quantity of heat. Measuring the quantity of heat; calorimeter; Law of energy transformation and conservation in mechanical and thermal processes.

6.2 Transmission of thermal energy. Sources of thermal energy. Thermal conductivity, convection and radiation.

6.3 Expansion of solids, fluids and gases.
Measuring of temperature. Thermometers.

6.4 Alteration of the state of aggregation.
Melting and solidification.
Vaporization and evaporation.
Condensation and distillation.

7. Oscillations and mechanical waves, Accoustics.

7.1 Oscillating motion.

7.1.1 Specific magnitudes of oscillating motion.
Diagram of oscillating motion.

7.1.2 Free oscillations; damped oscillations.

7.1.3 Forced oscillations; mechanical resonance.

7.1.4 The pendulum. Applications.

7.2 Propagation of oscillations in an elastic medium.
Transversal and longitudinal waves.

7.3 Accoustics.

7.3.1 Sound production and propagation.

7.3.2 Properties of sound.

7.3.3 Sound reflection.

7.3.4 Accoustic resonance; applications.

8. Electricity

8.1 Electroaccoustics.

8.1.1 Introduction

8.1.2 Electrization of bodies. Interaction of electrized bodies. Electrostatic field. Conductive and non-conductive bodies. Electronic interpretation of body electrization.

8.1.3 Electric potential, potential differences.

8.1.4 Electrostatic devices (Van de Graff).

8.2 Electrokinetics.

8.2.1 Electric current production. Electric generators.
Electric circuit; sense of current. Electronic interpretation of the electric current. Effect of electric current.

8.2.2 Current intensity. Current intensity measuring unit; Amper (SI). Constant of non-branched current intensity resulting from the conservation of the quantity of electricity.

8.2.3 Electric tension between two points of the circuit. Resistance of conductors. Resistance unit Ohm. Ohm's law for a portion of the circuit. Series and parallel arrangements.

8.2.4 Electric energy. The energy developed in a circuit through which an electric current is passed. Electric energy unit; Joule (watt sec). Electric power. Power unit: the watt. Multiples used in practice. Kilowatt (for power), kilowatt-hour (for energy). Electrocaloric effect. Joule's law; applications.

8.2.5 Chemical effect of electric current. Electrolysis and its technical applications (in short).

8.3 Electromagnetism.

8.3.1 Magnets, interaction of magnets. Magnetic field. The magnetic field of the Earth. The compass.

8.3.2 Magnetic field induced by an electric current. Electromagnets; technical applications.

8.3.3 Effect of a magnetic field on a conductor through which an electric current is passed. Electromagnetic force. Fundamentals of the electromotor.

9. Notions of optics.

9.1 The nature of light.

9.2 Propagation of light.
Sources of light. Rectilinear propagation of light. Velocity of light. Shade and half-shade.

9.3 Reflection of light.
Reflection laws. Plane mirrors. Images in plane mirrors. Spherical mirrors. Images in spherical mirrors. Application of plane mirrors and spherical mirrors.

9.4 Refraction of light.
Refraction laws. Prism. Converging and diverging lenses. Images in lenses.

9.5 Optical instruments and apparatus.
The Camera. The eye as an optic device. Projector. Cinema. Magnifying glass. Microscope.

E. Balasubramaniam and I.M. Brazier

Problems of teaching physics concepts to New Guinea students

(Paper read by E. Balasubramaniam)

In the continuing study of science two important areas of knowledge and understanding have been uncovered; the one to do with materials; the other to do with man. Ever since civilized communities began there have been intimate relationships between men and the material fabric of their existence. For instance, the effectiveness of the boomerang is determined not only by its physical characteristics - shape, weight, angle of twist, type of wood and so forth, but also by the physical and mental attributes of the thrower - motor skills, attitudes controlling the use of the boomerang and knowledge of the situation in which the weapon is to be used.

Similarly, the development of these man-machine systems may be traced to present day. Thus the boomerang has been replaced by intercontinental missiles with hydrogen war heads and a sophisticated agression detection and control analysis system for aiding man in his decision making process, whether or not to strike, to kill or be killed. But what ever the degree of complexity, man still makes a simple final yes/no decision. In the one case the Aborigine has obtained his supper; in the other many will be denied their last supper.

It is the understanding of the basic laws of the Universe and the understanding of behaviour and the social sciences that permit us not to be slaves to a machine.

Our present attainments have been reached largely on the basis of an understanding of the natural laws and the application of these laws to devising improved and more efficient machines that can produce increasingly more goods or services for lower and lower costs, for we have not until relatively recently begun to seriously consider making machines as man's slave.

It is hoped therefore that students not only acquire the motor skill to build roads, power stations, factories and cities, but also achieve an understanding of the basic sciences governing the laws of these materials as well as the social sciences; thus they will indeed be working slowly but steadily toward satisfying the deeper needs of life.

Our immediate problem is to devise a teaching-learning environment which will meet the needs of those who are influenced by it until well into the twenty-first century. The problem is similar to that of trying to predict from a picture of life a generation ago the nature of life today.

Although education has traditionally changed and evolved with time, there are a number of indications that the next twenty years will witness changes which are different and more revolutionary than those in the past. The causes are on the one hand, the technological revolution which is forcing society and commercial and educational enterprises into dynamic forms of behaviour and, on the other, the emergence of higher education as a major competitive and economic force.

These trends will change both the form and the context of education and training. The central problem of education is to anticipate the new situations and to train technologists capable of coping with them. As a consequence, educators are confronted with several key problems. They are summarised below:

A. They must be able to foresee and prepare for the changing relationship between the trained technologist and his environment.

B. They must understand and interpret the changing nature of education and training.

C. They must be active in developing the educational technology needed by a changing society.

D. They must train and educate for a largely unknown future.

E. They must provide graduates with skills and opportunities for career long learning.

A formal higher learning environment may be characterized by two interfaces - School and Higher Learning Institution and Society.

At both interfaces there are complex problems caused by different expectations and systems of values. But one thing is certain, the more successful of the graduates of a higher learning environment are those whose motivational characteristics are such as to drive them to continue their own education. They have learned how to learn without the continuing aid of their teachers or tutors.

In a rapidly changing society such as Papua/New Guinea, the knowledge, skills and insights which are accentable by graduates at the time of graduation tend to decay unless they are continuously utilized and replaced.

The Papua and New Guinea Institute of Technology realizing its responsibilities as the only institution that trains professional engineers, surveyors and architects in the territory, hopes to give students an understanding of the fundamental concepts of Science as well as training them towards self learning in order to be highly relevant to the particular society in which they will practise their professions.

Papua New Guinea has an even shorter history of science education than most developing countries in the world. It was only in the 1930's that the inhabitants of the Highlands of New Guinea were discovered and only recently has law and order been established in some areas.

Considering the country's short history, education has been quickly established and secondary schools were started in 1957. It was not however until 1960 that Science was introduced to the high school syllabus. Because of Papua New Guinea's close ties with Australia, the science syllabuses since then have been strongly influenced by Australian secondary school science courses, especially those of New South Wales. An independent science syllabus is however gradually being developed as experience and manpower become available.

A number of studies have been made of the development of the scientific concepts among Papua New Guinea students. Generally these have tended to be based on Piaget's work and have shown that concepts of conservation tend to be grasped by a student some years later than expected in a western society. Such results raise problems for advanced tertiary science teaching.

Students enter engineering courses at the Papua and New Guinea Institute of Technology after a minimum of six years primary education followed by four years secondary education. This is gradually being extended to six years secondary education. There was one such Senior High School in the Territory in 1971 and another opened at the commencement of this year.

This Physics Department has been using tests developed by the Australian Council for Educational Research (A.C.E.R.) to determine students' readiness for further studies of physics. These tests are designed to test fundamental generalizations upon which further concepts can be developed.

Results indicate that students at entry to the Institute have a background of science concepts similar to that of an equivalent Australian student about one year earlier in his education. Teaching at the Institute tends to reduce this gap noticeably in the first two years.

No obvious cultural differences have been observed in background knowledge of scientific generalizations. As practically all science education is by expatriate European staff using only English as the medium of instruction, this lack of cultural variations may be the result of the education process, showing that only those students who had adapted to the western style scientific education have been selected for engineering courses at the Institute. Some cultural differences may be discernible if testing were performed on the much wider population of all high school students in Papua New Guinea.

Although students selected for the Institute are from the upper ability group their knowledge of scientific generalizations is well below that expected of a tertiary student in a developed country. As a result much of the instruction during the first two years at the Institute is closer to that expected during secondary education in a western culture.

As mechanics forms a major part of the early physics course there is a strong tendency to follow the P.S.S.C. approach, particularly integrating experiments with formal lectures and less formal tutorial work.

Because of the generally mountainous terrain in New Guinea the basic concepts involved in uniform motion on plane surfaces need careful development. Firstly plane surfaces are uncommon in the villages and motion of objects normally observed (e.g. rocks rolling over the ground) is far from being uniform. It is a big step from natural phenomena to the idealized world of rectilinear propagation. Similar large conceptual steps will be found to be necessary for many areas of physics. For example electricity is unknown in most villages and the only experiences students have had of its existence are through their formal high school teaching. It is hoped, however, after three years at the Institute, that students can appreciate mobility of holes and electrons in a semiconductor material. At this stage it is well worth while mentioning an experience one of our lecturers had which may be of value to you. He was teaching about tension. To make it realistic he said, "Imagine you have a lift full of people and it goes down on a wire cable. Find out what the tension is in the wire." He went through the example very carefully and slowly and gave them some problems to do. When the problems came back, it was quite obvious that the students had no idea of what he had been talking about; it was completely hopeless, so obviously something had gone wrong. So he went over the topic again as clearly as possible pleading, "If there is any point here that you do not understand, please let me know what it is". One student rather hurriedly asked, "What is a lift?" This was the whole problem then; the students had no concept of what a lift was.

It was thought by staff that students in Papua New Guinea would have particular difficulty with the concepts of electricity. Although it has been found that this is a problem area for students, it would appear that they are having no more difficulty with it than their Australian counterparts.

Despite the fact that there are inherent difficulties with the use of water analogies for the teaching of current electricity, the terrain of New Guinea with its numerous rivers flowing from Highlands to coast leads naturally to the use of such analogies. All students are familiar with the flow from one area to another and then on to a further area and hence can visualize series currents. Similarly they have observed branching of the stream to go around obstacles and then rejoining as one stream as in parallel currents.

Gravitational potential changes are readily observable with many streams and hence the additive nature of potential changes in a series system can be deduced. Parallel stream flow with equivalent potential changes can also be observed despite dissimilar flow around various branches. Transfers to equivalent situations in the laboratory are generally satisfactory provided a multiplicity of meters are used so that students can monitor everything without the "black magic" of pulling a circuit to pieces to re-locate a meter in some other branch. For example it is only after a number of practical cases of series resistors with current measurements before and after each resistor, that a student is convinced of conservation of current and will be content with only one ammeter in a branch of a circuit.

It is from this basis of conservation of current that a concept of current flow is developed and hence a "life cycle" of a charge moving in a circuit can be developed. The maxim of "from the known to the unknown" is therefore used in this and many other areas of concept development.

Development of concepts is aimed at by variety of measures and a wide range of integrated teaching procedures is used. In optics for example, movie films, overhead projectuals, single concept film loops, programmed texts, ripple tank experiments, optical disk demonstrations, experimental ray tracing etc. are used in conjunction with formal class instruction. The student, through his direct involvement in these activities and via assignments and tutorial exercises is able to obtain feedback and determine, how he has grasped some particular step.

Consider for example cassette recorders and Instruction Booklets which have been used for three main purposes.

Firstly, to teach the students to use laboratory equipment e. g. micrometer, slide rule, desk calculators and cathode ray oscilloscopes (this supplements instructions for the class as a whole).

Secondly to teach the students the art of solving problems. Many students have difficulties in actually working out what the problem is about and hence they must be taught how to go about solving a problem and how to set out a solution.

Thirdly, to revise the basic physical theories in a section of the course.

In problem solving the following procedure is used.

Each student individually works through the following questions:

(I) What is the question asking.

(II) What is given in the question.

(III) Which part (or parts) of the course is the question associated with.
(IV) Revise those parts of the course.
(V) What are the relevant equations.
(VI) What is the first step.
(VII) Solve through to the answer, one step at a time.

In a world where there is so much to learn and know, concepts provide an intellectual economy in helping to organize large amounts of information; this is the way concepts serve scientists, and it is also the way concepts can improve learning. There is too much to be known, to expect it can be learned by rote and as isolated facts. But a large amount of information can be organized into a few concepts. Systems of related concepts can then be built to form principles or rules whereby students are able to interpret and explain new observations and experiences.

Ian Willis

A product of their country

(Paper read by E. Balasubramaniam)

The tangled history and geographical complexity of Papua New Guinea are nowhere more apparent than among the students now crowding into that country's Institute of Technology in the town of Lae.

The students are drawn from all but one of the major administrative districts. Some are from remote highland valleys where the most common tool is still the digging stick and others are from urbanized families that have been speaking English for generations. Some are from the great inland rivers and swamps, others from the coral atolls and still others from the rolling savannah lands. In class their faces betray the great diversity of their country's racial composition; out of class, when official pressure to speak English is absent, the vernaculars they break into among their closest friends are a fair sample of their country's seven hundred or more linguistic and "tribal" divisions.

The only common denominator amidst this variety is the fact that all are undertaking courses in western technology, which they will one day be expected to gear to the peculiar demands of Papua New Guinea. To generalise on Papua New Guinea is therefore hazardous; and in doing so one will invariably do its people an injustice by perpetuating the well worn clichés of the tourist guide books.

Outsiders with little knowledge of Papua New Guinea usually have one mistaken impression of the world's second largest (after Greenland) island, perhaps because the international news media still perpetuate the myth that Papua New Guinea is a wild and inaccessible; jungle clad land, peopled by ferocious cannibals or head-hunters and plagued with malaria; a country where Australians, Japanese and Americans briefly fought during World War II but were only too anxious to leave. The myth, of course, has elements of truth, but takes no account of the fact that today as Papua New Guinea is being propelled towards independence with dizzying speed and as modern social, political, commercial and industrial institutions are being built up, the country is changing. Papua New Guinea is in a transitional stage and thus shares many of the features of other developing nations. As I discuss the special problems of our students, this fact should become obvious.

The students at the Institute are taking a wide range of courses at both the diploma and degree levels, that is, they follow four and five year programs after having completed at least four years of secondary education. The courses currently offered are Civil, Mechanical and Electrical Engineering, Surveying, Architecture, Building Science, Accountancy and Business Studies. It is hoped that eventually courses in Industrial Geology, Mining Engineering, Chemical Technology and Pharmacy, Agricultural Economics and Agricultural Engineering and Science and Technical Education will be added.

The student body reflects Papua New Guinea's varied cultural background, though it does so unevenly. In 1971 the Institute drew nearly all of its intake of 163 new students from all but one of the eighteen administrative district of Papua New Guinea, though a small number (7) were returning from education in Australia. Two students came from the British Solomon Islands and one from Nauru. Only two were Europeans and there were several "mixed race"; the rest were Papua New Guineans. Of the 153 Papua New Guinean students, 114 came from thirty government high schools and junior technical colleges while 39 came from fifteen high schools run by the Christian missions. Most (129) entered first year Institute courses after having completed the four years of the Papua New Guinea secondary school program, while the other 34 entered second year courses directly after additional studies, either overseas or at Papua New Guinea's one senior high school.

The total enrolment at the Institute in 1971 was 308; and, once more, although all districts but the remote Southern Highlands (where secondary education is still in its infancy) were represented in this figure, some districts were disproportionately represented. For example, the Central District (the area around Port Moresby, the country's capital) sent us 22% of total enrolments, the East New Britain District (the area for which Rabaul, the pre-war capital of New Guinea, is headquarters*), provided 14%, while Manus Island (the smallest district by population but for long an area of almost universal primary education) accounted for 10%. Yet these districts combined amount to only 10% of the country's population (Central, 5.1%; East New Britain, 3.9%; and Manus, 1%).

On the other hand, the populous but, until recently, neglected highlands districts sent very few students to the Institute. The figures for the four highlands districts were: Eastern Highlands, 3% of Institute enrolments; Western Highlands, 3%; the Chimbu, 2%; and Southern Highlands, 0%. The Institute enrolled its first two students from the Southern Highlands in February 1972. The four highlands districts however, account for four fifths (39.8%) of the country's total population (Eastern Highlands, 9.8%; Western Highlands, 13.8%; Southern Highlands, 8.4%; the Chimbu, 7.8%). We thus have a situation where 40% of the country's population provides us with 8% of our students whereas 10% of the population provides us with 46% of enrolments.

Such a great imbalance reflects both the country's history and its present politics. The highlands were the last explored of P. N. G.'s "last unknown". It was not until the mid-1930s that European explorers broke into the populous valleys of the central cordillera and serious developmental works only began there in the early 1960s. The coastal district and in particular the areas around the big coastal towns, Port Moresby, Lae, Rabaul and Madang, have had European settlement and western education since well before World War I. The peoples of these towns are the most sophisticated in the ways of the west, supply the leadership of the progressive and radical political parties and fill the more senior positions in the public service.

* Before World War II the Australian government administered Papua and New Guinea as separate colonies. Legal union as Papua New Guinea came only several years after the war.

It is this group that is the vanguard of a growing movement for independence from the metropolitan nation, Australia. The highlanders, on the other hand, are conscious of both their lack of development and of their numerical strength, which they have thrown behind the main conservative party, a grouping dominated by white planters and traders who have obvious reason for resisting independence.
The highlanders are vehemently for delayed independence because they want a continued Australian presence. They see that as the best guarantee that they will obtain sufficient education to share equitably in the leadership of government, the public service, commerce and industry. They are highly suspicious of the educated coastal elite, which in turn scorns them for their "primitiveness" but fears them for their natural agressiveness and numerical strength.
The divisions within Papua New Guinea and the tensions these generate can easily be seen among the Institute's students. The students, coming as they do from all ends of the country, have been herded together with students from other districts of Papua New Guinea, perhaps for the first time in their lives. Living in a western style of institution with each other, speaking English and meeting westerners, they are under considerable pressure to lead a life that is, in the terms of their own background, unnatural. They are inevitably torn away from the life style of their own people. The personal cost of this in maladjustement and alienation is high and is, perhaps, reflected in the high wastage rates at the Institute, and indeed at all other tertiary educational institutions in Papua New Guinea.
The way in which the divisions and tensions of their country affect the students perhaps may best be illustrated by the case of N, an Institute student whom most staff members would describe as "average" or "typical". N is a final (5th) year diploma student in Civil Engineering. He was drafted into the diploma stream fifteen months ago when his exam results showed that he was not coping adequately with the more advanced work of the degree course. Before reaching the Institute he had spent four years as a boarder at the government high school near Wewak on the far north coast and prior to that had had several years at the school on a government station inland from Wewak. He had begun his school career as a five year old "Prep." in the local village school run by the Christian mission. He showed that he was bright from the very start, soon outstripping the other "Preps." many of whom were as much as nine years older than him. N is now nearly twenty, so that he is rather young to have reached the level he has.
N's father is an illiterate subsistence farmer with five living children. The oldest child is a deaf mute who sits in the village all day doing little because he is regarded as longlong (mad) by the other villagers. The second son was highly intelligent and was studying at P. N. G.'s only senior agricultural college when he died six years ago. He was a victim of a spell cast against him by a sorcerer from his own tribe who had been working as a plantation labourer near the agricultural college. When he discovered he had been made the object of a magic spell, the youth fell into a state of deep depression and simply wasted away; he died in a government hospital about a month later. Neither the efforts of his father and missionary, who had flown to Rabaul to be with him, nor the European doctors could save him. The sorcerer's motive was apparently jealousy of the boy's success.
N's family live in a village of about five hundred people in the Yangoru area seventy miles across the coastal range from Wewak. It is a region that was first

opened up in the late 1920s by labour recruiters, gold prospectors and missionaries and the government officers who followed them. Yangoru is an overpopulated area where the natural rainforest was long ago destroyed by continual slash and burn agriculture. Most of the people are subsistence farmers practising shifting agriculture, which they supplement by hunting wild pigs, small marsupials and rodents, fruit bats and small birds. Each year the coarse kunai (alang alang) grass that has replaced the rainforest is fired for new gardens and for smoking out the game hiding there. The staple foods are sweet potato and sago, though yam, taro and manioc are also grown.

It was hardly suprising that in 1971 the Yangoru area became the scene of one of P.N.G.'s biggest post-war "cargo cults". The "cargo cult", a phenomenon of the Melanesian islands, is a millenarian movement brought about by the people's frustration in their poverty and inability to achieve the high material standard of living of westerners. Cultists believe that the manufactured goods of westerners are not man made but have divine origin. Such movements often indicate proto-nationalism and have a strong undercurrent of anti-foreign sentiment. The usual feature is that one or several visionaries believe they have discovered the "key" to the "cargo" (western manufactured goods), the secret of which white men have selfishly been withholding from the indigenous people. The visionaries instruct the people in the procedures they should follow for "unlocking" the "cargo", which is then expected to come flowing in via cargo boats or transport planes. The inevitable failure of the cult is usually rationalised away.

The Yangoru cult centred on the tallest mountain in the area, Mt. Turu, on the top of which an American survey team erected a concrete trigonometrical marker about ten years ago. The cult broke out after a former Catholic mission teacher had a vision which told him he was to be a second Christ. If he were to be sacrificed on top of Mt. Turu and his blood allowed to flow onto the concrete marker, his people could remove the marker and discover the "cargo". The marker, he maintained, had been placed there by the government to conceal the "cargo" from the people. Eventually the visionary was not sacrificed, though the marker was dug out amidst great ceremony in the presence of several thousand villagers, carried downhill and deposited outside the government office at Yangoru. The "cargo" did not appear, but the removal of the marker served as a gesture of the people's discontent. The cult embarrassed N and the handful of other Yangoru students at both the Institute and the University of P.N.G. They became the butt of many jokes from other students who were convinced that their own people would never do anything so foolish.

N was in his third year of high school when his older brother died from sorcery. He was badly shaken by his brother's death, but as third son he now became the focus of the family's aspiration. He did well enough in his final high school year to gain a government scholarship to enter the Institute. He thus became one of the select monirity of secondary school graduates who receive higher (Institute or University) education. Only about 40% of the children of P.N.G. receive primary education and of these about 15% drop out before reaching the final year of primary, Standard Six. Of those who complete Standard Six only about 33% go on to secondary education. Only about 5% of those entering the secondary schools go on to higher tertiary education, so that the ones eventually reaching the tertiary institutions represent about.56% of those who were originally eligible for enrolment in the primary schools. The pressure on students to conform, to discipline themselves and to succeed at regular examinations is therefore intense. It is not a system designed to cater for the needs of the slow learner, the non-conformist or the lethargic. N and his colleagues at the Institute are therefore a highly select elite, the end result of a rigerous selection program aimed at weeding out all but the most diligent and most capable.

Once they are in the tertiary institutions the pressure to succeed continues as there are few places and the wastage is high. The Institute. for example, has an annual wastage rate of between 20% and 25% and this is probably typical of the other institutions. The personal cost of all this to students is high because anxiety over studies becomes a constant fact of their existence. The student who drops out feels keenly that he has failed and that his failure has sent crashing the aspirations of both his family and his village. The greatest disappointment of N's career so far has been the fact that at the end of his third year at the Institute he was channelled into the diploma rather than the degree stream. Perhaps that is why he screws up his eyes and guffaws when he is nervous; it may also be the reason for his extreme politeness and deference in the presence of strangers, particularly Europeans; and it may also explain why he cracks his knuckles absent mindedly when he is thinking deeply.

Despite its tensions and anxieties, however, life at the Institute has been a liberating experience for N. At high school he was always the smallest boy in the class and was thus the object of considerable bullying. He has now matured physically and has become a respected member of both the hockey and soccer teams. He has an ebullient outgoing personality and is very popular with both his colleagues and his (mainly European) lecturers. His main social diversions apart from sport are drinking in one of Lae's taverns on a Friday or Saturday night after pay-day (after completing second year at the Institute he took up a scholarship, offered by an oil company. which gives him an allowance of $ 30 a month on top of his fees, books and living expenses) and attending films and dances at the Institute or in Lae, six miles away. He is a relatively affluent student by local standards - students on government scholarships receive an allowance of $8 a month only and the urban cash award in Law is $7 for a 40-hour week. He can thus afford luxuries such as a radio and a record player and smart clothes that are the envy of his village folk.

N is very religious. The Yangoru area is famed for its haus tambarans (spirit houses), lofty spire shaped constructions containing the regalia, wood carvings and bark paintings associated with the male cult of the traditional religion. Nowadays the Yangoru are at least nominally Christian though much of the outer form of the traditional religion is maintained. There is a bitter rivalry between the Catholic (Society of the Divine Word) and protestant (Assemblies of God) missionaries for the allegiance of the Yangoru and western religion remains one of the decisive issues in each village. Though a number of his educated young wantoks (tribesmen) in becoming westernised have also been secularised, N has retained his Christianity, which still has a meaningful message for him. He attends the Student Christian Movement meetings at the Institute and worships regularly on Sundays, rising early to make the bus trip into Lae.

N, who on his arrival at high school in Wewak eight years ago was a manabus (primitive fellow from the bush), is now westernised and sophisticated. He recently spent six months in Melbourne, Australia, gaining practical experience with the oil firm that sponsors him, as part of his course of study. It was his first trip to Australia; an excursion regarded by many of his countrymen as the ultimate sophistication. While he was there, he enjoyed his life as a young executive. He bought expensive, fashionable clothes, dined at chic restaurants, attended the theatre and parties and dated Australian girls. He was nevertheless glad to get back to his village to meet his parents, brothers and sisters and other relations and to eat sweet potato and sago once more. His ties with the home village are weakening however, and like many young Papua New Guineans he becomes restless after several days at home, preferring to spend his vacations doing holiday jobs in town.

N is not a materialist or hedonist. He has always been aware of the needs of his people and country. He has progressive political views and resents the vestiges of colonialism that are still evident in Papua New Guinea. Last year, for instance, he was deeply hurt and angered when he went to meet his former high school headmaster, who was staying overnight in Lae. He found the headmaster at one of the "whites only" clubs, but was not allowed in to talk with him; he had to meet him outside in the car park instead. He is convinced that his country needs earlier rather than later independence from Australia, although he supports no particular political party. His visit to Australia has made him more conservative, however, for he now realises that economic development and nationhood by western standards is going to be a lengthy, tortuous process which his country will not achieve overnight. He is being groomed by his sponsor for a managerial position in which he will one day have to direct large teams of semi- and unskilled Papua New Guineans, so that it is quite likely his political and social views may become more conservative. He possibly does not realise the ambivalence of his position: that he is a product of the Australian government's deliberate policy of creating a Papua New Guinean educated elite, and that as such he will help to perpetuate the master-servant relationship with his own countrymen that is now operated by Europeans and Chinese.

At the Institute N's closest friends are all from the same administrative district as himself: the Sepik. The Sepiks (who are themselves divided into a multiplicity of "tribes") account for only about 4% of the Institute's enrolment, although theirs is the second largest district (after the Western Highlands) by population: the Sepiks are thus very much a minority group at the Institute. The only non-Sepiks he has much to do with are the students in the hockey and soccer teams and the four or five other students in the same year and stream of Civil Engineering as himself. While he does not dislike any particular tribal group within the Institute, he prefers New Guineans (the northern half of his island) to Papuans (the southern half). The reason for this is that the former speak Melanesian Pidgin as a lingua franca whereas the latter speak Motu; he thus has more in common with those from his own side of the island.

N will most probably become a very effective engineer (he has had an offer from one of Melbourne's larger consulting engineering firms of a job on graduation) and a competent business executive. To have achieved this will have meant a great struggle for him. He spoke only his plestok (local vernacular) and Melanesian

Pidgin before entering school and still has problems with English. Part of his difficulty here is that he lacks the experiential and conceptual background to the language which native speakers enjoy. For example, in Melbourne he found it necessary to keep a notebook in which he jotted new words and expressions. Some of his entries were "knickers" (he was offended by that at first, because he thought he had heard "niggers"), "express" (there are no trains in Papua New Guinea), "subway", "viaduct" and "freeway" (Papua New Guinea has mainly dirt tracks) and "ferry" (there are no wide rivers near Yangoru and little regular local sea transport in Wewak and Lae). His pronunciation and non-English speech rhythms also cause him trouble. In Australia, for example, he had great difficulty in getting to see a "wit filled" and "tileff fish-on" until someone ascertained he had never seen a wheat field or television.

He has similar difficulties with the abstract concepts and reasoning on which engineering, mathematics and physics rely. His village still consists of subsistence farmers who employ few mechanical aids, and whose rather elementary calculations are always related to visible, physical phenomena, such as bunches of bananas, baskets of taro and the number of paces or hand lengths across some space, such as a garden plot or a village house. He has thus grown up without the mechanical utensils and tools and the vocabulary of number and quantity that westerners, from their earliest years, take for granted. The western child has always been driven in his father's car and has often played with screwdrivers, spanners, kitchen measures and calibrated marking gauges; the child in Papua New Guinea walks everywhere and his father owns a bushknife and axe. Far more than the western student, then, N's training has had to be practical and related to concrete examples.

Although I have suggested that generalising about Papua New Guinea and its many peoples is unwise, I would nevertheless claim that N is as typical of the Institute students as it is possible to be. He is very much a product of his society, a society which is being forced to change and "modernise" as quickly as possible. The ambivalences and tensions that are apparent in him are the features of his emergent nation. That his own exuberant personality still bubbles up from the fissures in his western sophistication is, hopefully, a good omen for the future of Papua New Guinea.

Robert Karplus

Structure in the Science Curriculum Improvement Study program

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The research and development work carried out as part of the Science Curriculum Improvement Study (SCIS) included many hours of classroom teaching and observation that led naturally to a few generalizations about teaching and learning. These were then used to construct curriculum materials with less trial-and-error than might otherwise have been needed. The principles to be described were valuable but also quite limited, so that actual classroom trials - and the surprises they revealed - were an essential part of development work throughout the Study's effort. The findings of J. Piaget were extremely suggestive at all steps in helping to project staff members interpret their observations.

It is important to note that the SCIS did not begin its task with well-formulated objectives. Rather, the participants shared the goal of communicating scientific literacy, which was vaguely defined as a combination of basic knowledge concerning the natural environment, investigative ability (including the making and testing of hypotheses concerning natural phenomena), and curiosity. Clearly, a great deal of latitude remained as far as the activities in the program were concerned. Definitive behavioral objectives were formulated only after the program had been developed.

Further, these were stated on a general level (e. g. "Identify systems of objects that interact-at-a-distance") to avoid having a curriculum detail, such as the names of substances that interact magnetically, become an end of instruction.

If the "details" of activities were not important for their own sake, what was important? I shall try to answer this question in several complementary ways. Content, process, and attitudes were considered, not separately, but in combination.

In the SCIS program, therefore, children are introduced to scientific content through direct experiences with diverse physical and biological materials. In the course of their investigations, they engage in observation, measurement, interpretation, prediction, evaluation, and other processes. By exploring the phenomena in accordance with their own preconceptions, they also learn to cope confidently with new and unexpected findings by sifting evidence and forming conclusions.

Conceptual structure. The grand outline of the SCIS curriculum is determined by the concepts that are central to modern science. Most important of these is that changes take place when objects interact in reproducible ways under similar conditions. Changes do not occur because they are preordained or because a "spirit" or other power within objects influences them capriciously. By interaction I refer to the relation among objects or organisms that do something to one another, thereby bringing about a change. For instance, when a magnet picks up a steel pin, we say that the magnet and the pin interact. The observed change itself, the pin jumping toward the magnet, is evidence of interaction. Children can easily observe and use such evidence. As they advance from a dependence on concrete experiences to the ability to think abstractly, children identify the conditions under which interaction occurs and predict its outcome.

Within the interaction framework, the four major scientific concepts of matter, energy, organism and ecosystem are used to extend the children's experiences and investigations in the physical and life sciences. Material objects and their properties, organisms and their life cycles, are introduced early in the program (age five to seven), to help the young students describe and analyze their environment. Energy and ecosystem are introduced near the end of the program (age ten to twelve), to help the older students interpret their data concerning interaction in physical and biological systems.

The children's intellectual development - their ability to apply logical operations to evaluate and interpret their perceptions - is furthered by the introduction of four process-oriented concepts: Property, system, reference frame, and model. Properties of objects and organisms (or of abstract entities such as sets or relationships) are at the heart of classification. Further, the measurement and correlation of "variable properties", or variables, leads to the quantification of observations and the formulation of mathematical models (this latter not in the elementary school years). The systems concept furnishes the basis of conservation logic, in that a system retains its identity as long as nothing is added or removed, though the parts may be rearranged on the macro or atomic scale. Reference frames provide the student with multiple viewpoints, so that he can recognize his own perceptions as being only one of a set of possible observations. Finally, the scientific model, a mental image of a real system, helps to crystallize hypotheses about the mechanisms or explanations for observed functioning of a system.

Scientific and process-oriented concepts are woven together in an overall scheme that allows their mutual extension and application. Thus, properties are introduced for the classification of objects, but are later reconsidered as variables describing systems of interacting objects, or variables describing energy transfer. Interacting objects are grouped into systems, organisms into populations and communities, and observed changes in the properties of the system are interpreted as evidence of interaction. The ecosystem is the most complex application of this idea. The artificial observer Mr. O serves as concrete representation of a reference frame relative to which children describe position and motion of other objects or systems.

Concepts and experience. The concern with conceptual structure should not make you lose sight of the activities in which the children are involved throughout the science program. The following two aspects of the teaching program had to be distinguished from one another: the experiential (student experience with a wide variety of phenomena, including their acting on the materials involved) and the conceptual (introduction of the student to the approach which modern scientists find useful in thinking about the phenomena they study). A key problem in planning instruction was how to relate these two aspects to one another, a matter to which I shall return later.

Let me list a few examples of what was done to give the students concrete experience: The observation of magnetized or electrically charged objects interacting without physical contact, of chameleons eating crickets in a terrarium, of trajectories that can be controlled through the launching conditions, and of seeds germinating under certain conditions were useful in helping to form a picture of the broad range of physical and biological phenomena. Also necessary were more elementary experiences with the change in appearance of a liquid sample as it is transferred among differently shaped containers, with the "feel" of specimens of high and low density, with the "disappearance" of solids when they dissolve in liquids, and with the details of surface structure that become visible when a wood or mineral specimen is examined with a magnifying glass. In all these areas it was essential that students have direct experience, and that they have an opportunity to act on the materials and thereby control or influence what happens.

Supplementing experience are concepts that relate phenomena to one another. Being a physicist, I began my educational activities twelve years ago with the notion that force was the fundamental explanatory concept, since force is the cause of motion, and motion is a part of all change. Now I believe that this approach, which is also taken by most physics texts, is not valid. The reason is that observable motion accompanies only a small fraction of phenomena. Many thermal, chemical, electrical, optical, and acoustic phenomena do not involve observable motion, hence the force concept is not of direct value in dealing with them. Instead, the broader concept of interaction does apply to all these areas and this concept therefore was selected to play the central role in the SCIS program, as described earlier.

Learning theories. Major theories of intellectual development and learning were drawn upon in curriculum construction, even though they appear to be in conflict with one another. I now find it useful to distinguish three major types of theories. The "learning-by-conditioning" theory views the learner's behavior as a response to a well-planned stimulus. With repetition, practice, and suitable reinforcement, the learner will exhibit the desired behavior. Note that in this theory there is no room for spontaneous or creative expressions by the student. Everything of educational value reflects the inputs accumulated during the teaching program.

The "learning-by-discovery" theory claims that everything of which an individual is capable is latent within him. The educational program must give him opportunities to express these latent tendencies, but should not provide any input that might inhibit or redirect his natural inclinations. Given a sufficiently rich environment, the learner will, according to this theory, discover the properties of objects, conditions under which phenomena take place, and general principles relating the isolated incidents and observations in his experiments and investigations.

The "learning-by-equilibration" theory, associated with J. Piaget, views the individual as capable of mental operations which function in a self-sustaining feedback loop (equilibrium) as he acts on his environment and receives stimuli in return. When the feedback loop is disturbed by events that don't fit the scheme (disequilibrium), changes in the mental operations ultimately lead to more powerful mental operations that can cope successfully with a larger class of events (equilibration).

Input and autonomy: pedagogical structure. If children's operational schemes are to be modified and generalized by their experiences, the students must be able to test their own ideas, intuitions, and expectations in self-directed activities; I shall call this autonomy. At the same time, children need suggestions, new ideas, new materials, and new experiences to reconsider their preconceptions and/or reach operational equilibrium at a more sophisticated level; I shall call this input. A sound educational program must provide for autonomy and for input.

Most ingeniously, experiential input can be provided as feedback in the children's autonomous activities, if the experimental materials are carefully chosen. This feedback reinforces a child's investigative activity and also challenges his expectations or preconceptions. A light bulb that lights when placed in a closed circuit with a battery furnishes an excellent example of such feedback. Another example of such feedback is provided by a paper airplane whose wings can be bent so as to extend or reduce its flight time.

Conceptual input, such as introduction of the system or reference frame concepts, is not easily provided in the form of feedback. The SCIS instructional program is therefore built out of a sequence of learning cycles that allow for conceptual input in the context of appropriately related autonomous activities. Each learning cycle has three phases: exploration, referring to autonomous investigation; invention, referring to the introduction of a new integrating concept by teacher or by learner; and discovery, referring to applications of the same new concept in a variety of situations, partly autonomous, partly guided. (Each SCIS teacher's guide describes in detail how the learning cycle relates to the activities of a unit.)

Note that the learner is active during the exploration and discovery phases, which occupy most of the teaching time. Experiential input is provided during these phases. He is least active during the invention phase, which should occupy only a brief interval between the other two. Conceptual input may be provided by the teacher during this phase.

Note also how this strategy for teaching utilizes the three learning theories. Exploration is in accord with "learning-by-discovery" and "learning-by-equilibration." It allows the learner to impose his ideas and preconceptions on the subject matter to be investigated. If he comes up with a successful new idea, more power to him. If, as is often the case, his preconceptions lead to confusion, the teacher learns about these difficulties. At the same time, the exploration may create some disequilibrium, since not all students can cope with the materials with equal success.

Invention is in accord with the "learning-by-equilibration" theory, as the new idea introduced at that time suggests a way for the learner to resolve his disequilibrium.

Discovery, finally, is in accord with "learning-by-equilibration," and also with "learning-by-conditioning" view that repetition and practice are necessary for learning. It is essential, however, that the repetition and practice occur largely through self-directed activities by the learner, so that he will actually resolve his disequilibrium by interacting with the experimental materials and by establishing a new feedback pattern for his actions and observations. At this time, the same concepts are applied repeatedly in a wide variety of activities.

Developmental structure. The conceptual and pedagogical structure described above still allows wide latitude in the choice of learning activities. What other guides are there? The specific activities have great practical importance, because they carry the science program from day to day by stimulating the children's interest, challenging their reasoning, arousing their curiosity, answering some of their questions, and satisfying their need to control their environment. In choosing specific materials, the children's reasoning, manipulative ability, preconceptions, and natural interests were taken into account, as well as questions of safety, cost, and equipment reliability. Even though the latter three were frequently decisive, I shall not discuss them as they are outside the scope of this symposium, and I shall concentrate on intellectual aspects.

One of the very important considerations has been the fact that children of any chronological age represent a broad mixture of developmental stages. In the first grade, for example, most children may be in the transition from preoperational to concrete operational reasoning; still, substantial groups will not yet have begun the change, while others have substantially completed it with respect to many simple tasks. So it is also in the sixth grade, where many children may have begun the transition to formal thought, while others are preoperational or at the concrete level, and a few are capable of exercising formal thought under many circumstances. To be acceptable, any activity in the science program should have interest and yield satisfaction for all pupils, regardless of their developmental stage. One example is "Grandma's Button Box" in the Material Objects unit (Level One). Preoperational children enjoy the varieties of color, texture, and shape, the sounds made by tumbling buttons over one another, and the designs in which the buttons can be arranged. Children who have mastered classification reasoning, however, can be challenged to group the buttons into two or more kinds, to develop mutually exclusive categories by selecting criterion properties, or to transform one classification system into another.

A second example are the electric circuits in the Models: Electric and Magnetic Interactions unit (Level Six). Here the preoperational pupils can derive satisfaction from lighting a bulb through a trial and error procedure. A child at the level of concrete operations can identify the battery and bulb connections that yield a particularly bright or dim bulb. A student who is transitional to formal thought can wonder about the energy transfer from battery to bulb through the wires and formulate a model involving electricity or electric current flowing through the wire and obeying certain rules.

I shall cite two reasons why it was so important to provide activities that appeal to such a wide range of children. First, it was clearly desirable to secure the interest and participation of all pupils in an activity, even though not all can pursue it at the same level of sophistication. Second, the children at an earlier developmental level see examples of more advanced reasoning in their classmates, whose logic they may not understand completely, but whose ideas upset their operational equilibrium and thereby hasten equilibration at a higher level.

Conclusion. In this article, I have described some principles of conceptual structure, pedagogical structure, and developmental structure that have been used in preparing the SCIS program. It would not be honest for me to leave you with the impression that the program is "perfect". Many of the activities and the overall plan certainly reflect the considerations that I described. There are also parts of the program that are not ideal for various reasons - difficulties in creating economical equipment, problems with the survival of living organisms in the classroom, excessive preparation or care required to obtain reliable data, and so on. On balance, however, I believe that these problems are minor and that the SCIS curriculum materials can be of great educational service to many children and their teachers.

IV. Methods of the implementation and of the instruction on specific subject matters

Erwin Baurmann

On some principles often neglected in the teaching of physics.

When we teach physics we should bear in mind that we mostly teach to later non-physicists. This is particularly true for physics instruction on lower level. For us the motivation of our doing so is the fact that we like teaching and that we like physics. For them this is not necessarily the case. We have good reasons for teaching physics, because physicists exist and what they do plays an important part in the life we are preparing our pupils for.

So one motivation for the pupils might be that they need to learn physics and what physicists do. This form of a motivation appeals perhaps to the curiosity of our pupils, but in a very superficial way. It does not justify that physicists rightly exist, and what finally they are doing when doing physics. It does neither link their doing with the activities of man, nor does it distinguish their doing among other activities.

If we bear this in mind, we find a much stronger and much more reliable motivation for our pupils to learn physics: we can base ourselves on the fact that we all have an inquiring and a creative mind. This is the elementary characteristic of man. This mind produces its being in innumerable activities among which science in general and physics in particular.

Certainly, we cannot erect a building in the theory of knowledge and thus justify the existence of physics, and motivate our pupils to learn physics. But we can teach physics in a way that creates a reflective attitude among the pupils, an attitude that asks questions like: why do physicists exists?, what is physics? - other than physics is what physicists do.

If you look at school books or watch what finally is taught, then you will find that in most cases just the above basic questions are not answered. The points to be made are those which make physics an enterprise of the inquiring mind (E. Rogers): knowledge in physics is gained by method, this method is restricted to rational thought, the method of rational thought is limited, physics is man made and not god given, the language of models, the rationalizing attempt of description by analogy, the interaction of the inductive and the deductive method, the principle of mathematization in physics, and alike.

The following is an attempt to prove by examples chosen from introductory electricity that the goal that I have indicated earlier may be achieved even in teaching elementary physics.

As I said, that we do physics, needs to be justified. It must come out that physics is one among many modes of comprehending the world around us. Furthermore it must come out that this particularity of physics to make the world understood is man made and not god given, that in physics the wanted arbitrariness of a wanted onesidedness prevails and that its method is limited, in short: because of a permanent misunderstanding we must bring about exactly that point of view the layman will not expect to be told about science. We are obliged to do so; otherwise we ourselves would draw a one-sided picture and thus miss our commission in education.

We may not excuse ourselves by stating that such a pretention cannot be achieved in the elementary teaching of physics. The contrary is true: that the purely rational way of thinking is an intentionally wanted restriction in method, that the physicist thinks in models, that he uses the formalism of mathematics, that he uses formal conclusions to interpret his observation, that by heuristic reasons he strives for analogies, that he attempts a synoptical description of as many phenomena as possible and in doing so that he plays the alternating game of induction and deduction, all this must be, in a way, the red thread which leads through the whole enterprise, a red thread that can be made visible also in the elementary teaching of physics.

Knowledge in physics is knowledge gained by method. Knowledge gained by method means planned knowledge. In its introduction to his "Critique of Pure Reason" the philosopher Immanuel Kant explains what is meant as follows: "With its principle according to which corresponding phenomena may be considered as laws, in one hand, and with the experiment conceived according to those principles, in the other hand, reason must meet nature with the intention to be taught, this, however, not in the quality of a pupil who accepts what the teacher says, but in the quality of an installed judge who compels the witnesses to answer those questions which he puts before them" (end of quotation). Kant hence binds scientific knowledge to a plan, to a design of reason.

No pupil will miss the fact that physics is planned, that it proceeds in a mathematical way. We may reinforce this observation when we make clearly visible the systematic procedure of physics, especially when doing experiments or interpreting experimental evidence. Furthermore the pupil will notice that evidence in physics is not so conclusive as it is in mathematics. He will notice that there is some sort of uncertainty as soon as we base ourselves on observation and experiment, i.e. on experience, and that we are completely certain as soon as a mathematical deduction of our results is possible.

Example: We measure the force on a charge in the electric field. Result:

a) the force exerted on the charge is proportional to the magnitude of this charge for any given potential difference V between the charges producing the field: $F \sim Q$;
b) the force exerted on the charge in the field is proportional to the potential difference between the charges producing the elctric field: $F \sim V$;

Conclusion: the force exerted on the charge in the electric field is proportional to the product "charge times potential difference" (as defined above): $F \sim Q \cdot V$.
Depending on the quality of the experiment this result is more or less uncertain. It is undoubtedly certain, however, as soon as we are able to conclude: from $V = \frac{W}{Q}$ and $W = F \cdot s$ follows $F \cdot s = Q \cdot V$.

The pupils will also notice that physics is not dealing with humanities, with man, his art, his language, his history etc. He will notice that physics is limited to that domain that may be described exclusively by the methods of rational thought and conclusion, and that there remains a wide field which cannot be described by the methods of physics.

Up to this point, on introductory level it may be satisfying, if we do not hide and bury things, for instance in presenting physics as an exact science because it is so precise!* Beyond this point we have to explain clearly what Kant means when talking of man in his role of a judge. We must show the subjectivity of any of our decisions which are guided by reason and suggested by nature, but to which we are not compelled to.

1st example: Our experiments in electricity suggest two models:

1. There are positive and negative electrical charges. Equal quantities of positive and negative charge neutralize one another;
2. There are only negative charges, the smallest quantity of which is the elementary charge of the electron. What appears to be a positive charge is nothing but a lacking amount of the corresponding quantity of negative charge.

The second model corresponds better to our picture of a current which we do not depict as two flows of different particles in opposite directions. The first model is always suggested when the polarity of the charges plays a role. Both models are equally correct because neither one is contradictory in itself. Hence the decision on the model by which we want to describe the phenomena of electricity depends only on the experiment we conduct.

2nd example: The experiments on magnetism suggest the following interpretation: in any material that can be magnetized there exist elementary magnets, magnetic domains. These domains are not ordered and hence compensate one another in their action (effects). If we order and align the elementary magnets - for instance by sweeping with another magnet - neighbored north and south poles will still compensate, but on the end faces there will be poles now, which are not compensated. If we cut such a magnet normally to its direction of magnetization, uncompensated poles are free at once on the new end faces, and the two separated parts of the original magnet are as completely magnetic as the original one was.

At this point we must lead our pupils to the conclusion that our model explains the mechanism of magnetization, but it does not explain yet what magnetism really is. Magnetism cannot be explained. It is a concept as much as force is a concept.

On such an occasion we should also define what a model is in physics, i.e. an intuitive picture by means of which we can describe and interpret natural phenomena.

3rd example: In magnetism we see that magnets act with forces upon each other at distances through space. We describe the space in which such forces can be detected as the field of the magnet. Again, this is a model. Field means the set of all possible ordered effects of the same kind in space. In particular, a magnetic field is the set of all possible ordered magnetic forces in that space.

* Physics is an exact science because all its statements can, in principle, be deduced; but its statements are certain only to that extent to which the premises are certain which, in physics, are based on experience.

Proceeding in this and alike ways one thing gets clear: physics is man made and not god given. It is man who observes, and it is man, too, who invents the concepts.

Since we restrict ourselves in physics to the domain of purely rational thought the statements of physics can be expressed in terms of mathematics.

1st example: We define the electric current as charge per unit time and write this statement in the form of a mathematical equation: $I = \frac{Q}{t}$.

This equation may be transformed, for instance into $Q = I \cdot t$. This transformation has nothing to do with physics, it is pure logic in action, and still: this new statement has a relevance also in physics: $Q = I \cdot t$ measures the quantity of electric charge.

2nd example: In order to illustrate electricity we are looking for analogies of a water current and an alectric circuit. The correspondance may be pushed up to the definitions of current intensity and potential difference. The place of action in a circuit is the point at which work is exerted. This suggests to express both the pressure of a water pump and the potential difference by the work done. To this end we need only extend formally, i.e. mathematically, the fraction defining the pressure $= \frac{\text{force}}{\text{area}}$ by the height to which the force is lifting the water. Thus we get a suggestion for an analogous definition of the electric potential difference. This formal act of logic is one of the many examples which demonstrate how we arrive, by applying mathematics, i.e. pure logic, at useful hints for the description of nature:

$$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{\text{force} \cdot \text{height}}{\text{area} \cdot \text{height}} = \frac{\text{work}}{\text{volume}}$$

Water		Electricity	
$\frac{\text{volume}}{\text{time}}$	= current intensity	$\frac{\text{charge}}{\text{time}}$	= current intensity
$\frac{\text{work}}{\text{volume}}$	= pressure	$\frac{\text{work}}{\text{charge}}$	= potential difference.

3rd example: Later in the course we take the opportunity of demonstrating the internal closeness of the physical picture of the world with help of the possibility to thorough mathematization:

a) The motion of electric charges appears to be an electric current. The work done by the current is proportional to the amount of charge displaced:
$W = V \cdot I \cdot t = V \cdot Q \rightarrow W \sim Q$.

b) The cause of this current is a potential difference V which originates from the work W necessary to separate charges of opposite sign. This potential difference is defined as $V = \frac{W}{Q} \rightarrow W = V \cdot Q$, as above. Step by step we draw a picture of electric phenomena the closeness of which is expressed by a network of contradiction-free mathematical formulations. We shall try to describe as many phenomena of electricity as possible in one single picture or model. The better we are able to achieve this, the greater is the value of our model, the fewer laws, rules and formulae do we need.

Furthermore we have to show the tendency to analogous descriptions wherever this is possible, even in rather separate fields of physics. This tendency is the expression of a general principle, which has nothing to do with our object physics, but with the economy of thinking. The analogy, mentioned earlier, of a water circuit and the electric circuit is one 1st simple example of it.

A more refined 2nd example is the concept of a field.* We will define it as general as possible, and then insert particular fields into this general concept in using analogue formulations or wordings when defining the particular fields: in the first instance fields are named following their geometric properties. A field which shows the same effects at any point of its space, both in magnitude and in direction, is called a homogenous field; if this is not the case the field is spoken of as inhomogenous. If in particular the field is symmetrical with respect to one point it is called a radially symmetrical field. - In our course work a practical example may suggest the invention of the concept "field"; let it be the behaviour of iron filings in a magnetic field. Then we generalize the picture and will find it easy now to stress analogous formulations at any given occasion; magnetic field, electric field, gravitational field; or corresponding examples of homogenous fields: homogenous electrical field, homogenous magnetic field, homogenous section of the gravitational field; radially symmetrical fields: one pole of a magnet, point charge, gravitational field of the earth; electric potential, gravitational potential etc.

3rd example: A problem set for the gifted pupil at this stage of the course - we are talking of introductory electricity! -: a plate capacitor with a plate separation of 1 cm is charged to a potential difference of 500 volts. Then the supply is cut off and the plates are separated to a distance of 6 cm. What is now the potential difference of the field producing charges on the plates? (result 3000 volts).

- Then we may go on as follows: the work done is $W_e = \frac{1}{2} Q \cdot V$ (not $1 Q \cdot V$ as is the case for a free probe charge in the electric field!). Q is the charge on the plates of the capacitor and V the voltage difference of 2500 volts. The potential difference increases in a linear progression from 500 to 3000 volts when pulling the plates apart, whilst the charge on the plates remains unchanged. Explain the relationship $W_e = \frac{1}{2} Q \cdot V$ and compare with the work $W = \frac{1}{2} F \cdot s$ done when pulling a perfectly elastic coiled spring. Sketch a diagram of f vs s and the analogous diagram of V vs Q.

Already on introductory level the pupils must know and meet the continued interaction of induction and deduction as the characterizing methods of an exact science. As a 1st example we have already mentioned the experimental determination of the force exerted on a charge in an electric field: $F \sim Q \cdot V$.

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* A field is the totality of all possible ordered effects of one single kind in space. A magnetic field is the totality of all possible ordered magnetic effects in space.

This result is more or less convincing depending on the accuracy of our experiment. The probability of a correct result, the trustworthiness of the result increases with the number of experiments yielding the same results within fixed borderlines of discrepancy. This is an example of the inductive method. The result is conclusively certain, however, when we are able to deduce: $F \cdot s = Q \cdot V$.

This last step is an example of the deductive method in physics.

2nd example for the interaction of the inductive and the deductive method, chosen from the course work in introductory electricity: we may find Kirchhoff's second law for the current intensities of parallel circuits by experiment; we may also deduce it from known premises (Ohm's law or more general the principle of energy conservation).

3rd example: We charge a plate capacitor, disconnect from the supply and then pull the plates apart. Observation: the potential difference of the plates is directly proportional to the plate separation: $V \sim s$. This result was obtained by experiment, hence by applying the inductive method. The same result may be deduced mathematically in considering the work done when pulling the plates apart: $W = F \cdot s = Q \cdot V \Rightarrow V = \frac{F \cdot s}{Q} = E \cdot s$, where $E = \frac{F}{Q}$ is the constant field strength of this charged capacitor during the operation: $V \sim s$.

I hope that I was able to demonstrate two things:

1. that this somewhat philosophical way of considering physics is often neglected;
2. that this aspect can be brought about already in the teaching on introductory level – in our particular case introductory electricity as one among many examples.

There is no question that the goal mentioned in the beginning may be attained much easier in the teaching on higher level, but that is self-evident and it was not my intention to deal with.

Discussion

The author states that he wanted to point to the importance of the presentation of physics and of the spirit behind the teaching of physics. He feels that the student ought to recognize about physics

1. Physics is man made and not god given. Knowledge in physics is gained by method, this method is based on rational thought only, the method of rational thought is limited.
2. Nature can be described by models of different complexity and completeness. Simple earlier models do not get wrong, as soon as more refined models will be created. A model can perhaps fail in some areas, but can be very useful and fit to a certain purpose, because it is easily managed.

Albert V. Baez

Innovative experiences in physics teaching: autolectures, seminars, micronotes, laboratory work with several options, films and demonstrations

Summary

Innovative experiences in teaching an introductory college physics course for non-specialists are described. The basic ingredient is the Autolecture produced by the professor. It consists of a tape recording plus about ten transparencies for the overhead projector. Several Autolectures are administered simultaneously in separate classrooms by graduate student Teaching Fellows who can, in this way, monitor and expound on a well structured lecture with a minimum of preparation and who subsequently direct the Seminars to clarify the ideas raised in the Autolectures and in other parts of the course. Micronotes, which are reduced printed duplicates of all the overhead transparencies, are distributed to the students to minimize note taking. It has been found that Teaching Fellows can also produce good Autolectures with benefit to the students and to their own teaching experience. Students can produce short Autolectures as a means of reporting on special laboratory projects and learn valuable communication skills in the process. The use of films, loops and closed-circuit TV in the demonstration lecture are described as well as their possible use in the laboratory, the Autolecture and the Seminar. Other innovations include the use of a textbook based upon a spiral approach to learning, multiple options for the laboratory and demonstration lectures with a minimum of theoretical exposition.

Maria Ferretti

Possibilities of linking the science and physics curriculum with the proposed curriculum for mathematics teaching

1. Preconference Paper (Summary)

1.1 In the last ten years it has become more and more evident that integration of science courses (at least to a certain extent) is not only feasible, but highly desirable. Up to 1970 some dozen projects were listed in the "International Clearinghouse on Science and Mathematics curricular developments".

1.2 The main reasons for this changing attitude of scientists and educators can be traced back to

a) economic reasons (saving of time and perhaps of teaching staff)
b) structural motivations (trends towards a structural unity of different disciplines)
c) environmental motivations (connected with the rapidity of the diffusion of information and the relevant mass-media processes)

1.3 A reason of type b) worth a special mention for its great importance can be found in the increasingly scientific approach in geography, as well as in other "boundary subjects" like environmental sciences, meteorology, even astronomy. With integrated courses some topics belonging to these boundary regions can be more properly treated.

1.4 Shall we expect this trend to go on and expand? Or shall we endeavour to overcome it and revert to a more specialized method of teaching, which allows a deeper insight, and to try co-ordination of specialized subjects from the outside?

1.5 Historical and philosophical background for the teaching of sciences as separate subjects (Comte); and for the modern trend towards unification. Problems connected with the teacher's training and team teaching.

1.6 Opportunity of distinguishing among: a) simple "juxtaposition" of topics coming from different science areas; b) "integration" proper, and c) "co-ordination". Syllabus patterns of the type a) are more suitable for pupils still in a pre-operational stage of thinking (according to Piaget), or at most in the stage of "concrete operations". Pattern b) applies when the "reversibility" stage is fully reached; pattern c) can be exploited to its maximum extent at the stage of "formal operations", i.e. the ability to perform hypothetical operations. Here "models" can be fully and exhaustively exploited.

"Mixed" patterns appear more likely to be put into operation, and actually are: integrated courses for physics and chemistry and for physics and biology do exist. However, the integration of biology with chemistry and physics raises some problems. In fact, the descriptive and morphological aspects of biology may be dealt with very early, whereas the study of biological functions requires rather sophisticated knowledge of physics and chemistry.

1.7 Mathematics teaching is also undergoing a revolutionary change, as it evolves more and more towards structural patterns. The increasing need of mathematical concepts for science teaching is unquestionable, and the unifying power of the methods of modern mathematics may enhance the students' ability to synthesize. One has to keep in mind, however, that the value of synthesis is based solely on the correctness of the analysis. Moreover, a strong criticism of present methods of teaching mathematics emphasizes that they somehow deprive students of the ability to do with ease the simple calculations necessary for the understanding of science.

1.8 The GIREP seminar held in Lausanne in 1967 was based on the links between mathematics and physics teaching in secondary schools. Some conclusions are perhaps worth recalling.

1.9 No matter what practical way may be chosen to link scientific subjects and mathematics in secondary school teaching, it appears important to substitute the obsolete "science hierarchy" with a more general "synthesis of disciplines", applying not only to scientific subjects, but to all fields of cultural activity. On the grounds of the structures that underlie our present knowledge in all fields, we could think of a kind of flowing link from the logical topics (mathematics, language structure) to the art-history topics (literature, visual arts, history, social science) and to natural sciences (geography, biology, chemistry, physics) to come again to mathematics. In this context, symmetries can be regarded as structural links between mathematics and structural arts, visual arts and sciences, sciences and mathematics.

2. Conference Paper

The present considerations are mainly based on the origin and the nature of the problems connected with the teaching of science and mathematics as linked subjects, rather than on practical solutions. In effect, many problems are common to all existing school systems, but solutions are locally quite different, and cannot be easily generalized.

In the last ten years, it has become more and more evident that the integration of science teaching (at least, to a certain extent) is not only feasible, but highly desirable. Just up to 1970 only, about thirty projects of this kind have been listed in the "International Clearinghouse on Science and Mathematics Curricular Development" (1). As examples, I will recall only a few of them:

The Portland Project (2) in its first attempt to integrate PSSC physics, CHEM Study chemistry and, to some extent, BSCS biology; and not in its more sophisticated pattern (age, 15-18 years)

The New Integrated and Co-ordinated Science Textbook Project (3) originated by the Science Foundation for Physics at the University of Sydney, N.S.W., Australia (integrated science, ages 12, 13, 14, 15; co-ordinated physics, chemistry, biology and geology, ages 16 and 17)

The School Council Integrated Science Project (4), at the Centre for Science Education, Chelsea College of Science and Technology, London (ages 13, 14, 15, and 16)

The Nuffield Combined Science Project (5) of the Nuffield Foundation, Great Britain (ages 11, 12 and 13).
The Scottish Integrated Science Course Project (6), Scotland (ages 12, 13, 14)
The Institute for Education in Natural Sciences Project (7) at the Kiel University, Germany (ages 10, 11, 12 and 13).
Introductory Physical Science (8) started at the ESI, Watertown, Mass., integrating physics and chemistry, ages 15 and 16.

In comparing all the existing projects, one notices that frequently the need for the integration of subjects was initially felt most by the teachers themselves, and integrated or co-ordinated projects were started on their request (as Portland Project, School Council Integrated Science Project, Environmental Studies Program openly admit in the forewords of their books); but still more frequently such an integrated approach is officially adopted for new school systems in developing countries (four such projects in Australia, one in Israel, one in Japan, Kenia, Malaysia, Nepal, Nigeria, Ceylon; the UNESCO program for Integrated Science Teaching in Developing Countries, are mentioned in the already quoted "International Clearinghouse"(1). On the contrary, in countries where the school system was established long ago - as in Central Europe, for instance - the subdivision of individual scientific subjects still persists in most secondary schools, particularly in the second cycle of secondary education.

The early specialization of subjects in schools has been originated about a century ago, and its main roots can be traced back to the positivistic hierarchy of disciplines (due to the French philosopher A. Comte) based upon the hypothesis that the sciences must inevitably develop in the order of decreasing generality and increasing complexity. Hence they appeared in the following genetic series: matnematics, astronomy, physics, chemistry, biology, sociology. Each of these disciplines depended upon those which preceded in the series. This position had a strong influence on European teaching systems at the beginning of this century.

Now, there seems to be a reverse trend: science is seen more as a way to reach a coherent description of the world, and thus the starting point could be a basis of knowledge common to all scientific subjects. But the main reasons for the changing attitude of scientists and educators seem more likely based on economical, structural and environmental motivations. Of course, the word "economical" has to be interpreted here in the broadest possible meaning: economy of teaching staff, and saving of "learning" time, which will not necessarily mean saving of money (more experimental work, more audiovisual aids are likely to be required, as well as more reference books, and so on).

Structural motivations come from a deeper insight of the modern trend towards the structural unity of different scientific disciplines (8). According to Bruner (9), to learn a structure is to learn how things are related. In a structural pattern, the methods for gaining knowledge in different scientific fields (i. e. approach to the problems, mathematical treatment of results), many basic ideas (i. e. interactions, models, microscopic understanding of macroscopical events), and some skills and techniques (i. e. observation, analysis, induction, testing, synthesis) have many common features. Moreover, considering sciences from the point of view of their evolution, we notice that subjects belonging to the boundary regions, like meteorology, astronomy, even geography, are becoming more and more structured as sciences, with an increasing adoption of mathematical and statistical techniques; at the other end, human geography is being altered by the language and thinking of the economists and the sociologists, leading to the birth of the "environmental sciences".

Environmental motivations for teaching integrated sciences stem from a double line of considerations. On one side, we have to admit that the school is no longer the only source of knowledge for the educated citizen. The increasing role of the mass-media as a source of information, the growing possibility of coming into contact with different kinds of human being, and the lowering cost of printed material, are building up a sort of permanent school that has been defined "the parallel school"(10). In this "parallel school", which cannot be ignored or underestimated, every subject is strongly integrated, not only on a scientific basis, but also regarding social problems and activities. Possibly, one of the reasons for the unease felt in conventional schools by students - and by teachers - comes from the difficulty of automatically integrating subjects that have so far been taught with rigid separations, and that teachers themselves have studied separately. On the other hand, one also has to take into account the most recent trend to overcome the purely structural considerations about the content of a course and the way the human intellect accumulated knowledge; the "other half" of the human being, i. e. how a human being feels in the learning process, in addition to how he knows, is now becoming important in the teaching process. A kind of "environmental approach" to the study of sciences is now much more appealing to students: in effect, since knowledge "per se" is no longer desired, and even its absolute value is under discussion, it appears that an integrated approach to many subjects in school can help students to build up self-confidence, and to lessen alienation(11).

On the basis of the preceding considerations, we could then assume that integrated patterns for science and mathematics teaching will gain favour in the near future: but practical difficulties to implement those kinds of curricula cannot be underestimated. First of all, it is imperative not to lower the quality of teaching by integration; and this leads to the consequent difficulties of teacher training: more in-service courses will be needed, adequate facilities, trained instructors, and tutorial help from the university faculties, both scientific and educational. But there is also the difficulty arising from the individual teacher's attitude towards other sciences and mathematics. On the average mathematicians do not seem to be very fond of looking for starting points or applications and examples rooted in natural sciences, and biologists generally dislike the special training to acquire the skill needed to treat observations with statistical methods that are unquestionable from the mathematician's point of view. Of course, this kind of difficulty increases with the advancement of the course. At the elementary level, when sciences are taught at all, they are everywhere in an integrated form; but for the terminal classes of the high school it appears almost impossible to devise a training suitable for integrated teaching.

Thus, in any integrated kind of teaching, we can recognize the need for the following distinctions:

a) the simple juxtaposition of topics, which is appropriate mostly for children in the pre-operational stage of thinking (following Piaget's terminology) or at most in the stage of the "concrete operations" - which corresponds more or less to the elementary level of teaching. A single teacher can do the job; but also different teachers can co-operate, the only difficulties being connected with the time-table scheduling. Here, the teacher's training is not a very difficult problem.

b) integration proper: such a pattern can be put into operation as soon as the "reversibility stage" of thinking has been fully reached by the pupil. Apparently this method becomes appropriate in the first cycle of the secondary education, but here the problems of the teacher training and the curriculum planning become more important, as subjects must be treated with a sufficiently deep insight. (One criticism to this approach is based on the consideration that an essential condition for appreciating the unity of science is the ability to think at a sufficiently high level).

c) co-ordination of subjects could be exploited to its maximum extent when the thinking stage of "formal operations" (i. e. the ability to perform hypothetical operations) is reached. As this will happen in average towards the terminal years of secondary education, one could take advantage of the broaded intellectual abilities of the students in order to put into operation some sort of team-teaching, with an integrated curriculum taught by teachers with different specializations. Here, the main difficulty lies in a fair distribution of teaching time among the teachers, and their personal time schedule.

Mixed patterns appear more likely to be put into operation, and actually are: integrated courses for physics and chemistry do exist, and for chemistry and biology: but here one has to consider that, whilst the morphological and descriptive aspects of biology may be dealt with at a rather early stage (say, in the first cycle of secondary teaching) the study of biological functions requires a rather sophisticated knowledge of physics and chemistry.

Probably the most complete attempt on this line is the "Messel Bible" already quoted (3): on a basis of integrated sciences (physics, chemistry, biology and geology, with some astronomy) for the junior stage, a senior stage is built, planned as a co-ordinated study of sciences, "with each science supporting and illuminating the others". A point of view worth quoting is expressed in the "Correspondence" section of the April Issue (12) of "Education in Science", by D. Duckworth. He proposes to divide the whole of science teaching, up to the ordinary level, into "physical" and "environmental": the latter would consist merely in biology (descriptive) and some geography, and should be taught in the first cycle of secondary education. Physical science (physics with chemistry) would come in years 3 and 4. Only after O-level could one think of a course in Integrated Science as a disciplined study for the ablest young scientists, through team-teaching.

Mathematics is also undergoing a revolutionary change, as it evolves more and more towards structural patterns. "New" mathematics is now largely in use in secondary instruction, and one could consider to what extent this new way of teaching mathematics is (or could be) complementary to science teaching (13). Surely the unifying power of the methods of modern mathematics may enhance the students' ability to synthesize. But not all that glitters is gold; the value of synthesis is based solely on the correctness of the analysis, and it is the long road of data collecting and critical thinking that enables significant (and not dogmatically accepted) syntheses. Moreover one criticism on present methods of mathematics teaching emphasizes that they somehow deprive students of the ability to do with ease the simple calculations needed for a first understanding of science. In any case, we can admit that the language and some particular features of "new" mathematics can be directly utilized in connection with the teaching of science, even at an early stage: examples are easily found: in number bases study, binary system can be linked with an early study of electric circuits, and the base-ten gives a clearer understanding of the metric system of units; sets language and Venn diagrams can be very useful in building up systems of classifications, and provide a check for non-ambiguous definitions. Negative quantities appear in physical measurements (electricity; temperature; etc) and vice-versa some physical quantities cannot be negative; emphasis on shapes, solids and symmetry can be linked both with arts and architecture, but also with the shapes of living things and of crystals; symmetry in particular is connected with the plane mirror reflection; statistical concepts and tools can be applied to the whole field of science observations and measurements; graphs and their interpretation can be more extensively applied to the study of linear and nonlinear relationships, to introduce the idea of the rate of change and the rate of growth(14). So, "new" mathematics can be employed very effectively in the teaching of sciences; but the reverse is also true: "new" mathematics can find in science teaching a sound background in order to give the subjects more relevance to the students, and today this is a vital need for "new" mathematics itself. New mathematics in secondary schools has been, in fact, recently attacked as an instrument of class discrimination, as it appeals more, on the average, to the children of upper classes families(15).

But, even from the standpoint of traditional teaching the opportunity of linking mathematics with sciences (via physics) has been stressed in several instances. I will not offer here any detailed mention of the numerous mixed or integrated and co-ordinated projects for mathematics and science teaching already quoted in the "International Clearinghouse"(3). But some of the conclusions of the Lausanne meeting of the GIREP in 1967 are perhaps worth recalling:(16)

" In every secondary school, at every level, the teaching of physics and mathematics has to be tightly co-ordinated. Syllabuses have to be planned accordingly. Modern mathematics should not be considered as something still more remote from physics than traditional mathematics: students must be encouraged both to recognize mathematical structures present in physics and to apply mathematical tools (in particular algebraic calculations) to physics. The concept of "model" should play a fundamental role both in mathematics and physics teaching. It is not always true that advanced physics, taught at non-specialistic level needs advanced mathematical treatment. On the contrary, a sophisticated mathematical treatment of a problem could obscure its physical meaning and implications. Statistic and probability must be introduced, in appropriate ways, in the secondary school mathematics curriculum. It is of fundamental importance that the language of the mathematics teacher and physics teacher be unified in a common language, in order to avoid confusion and mistakes when treating similar subjects (the case of vectors has been discussed as an example; generally the physicist's vector is different from the mathematician's one). And it could be of real value to stress interactions between mathematics and physics in the historical development of scientific thought. To conclude, any effort of co-ordination in the teaching of mathematics and physics should be encouraged by school authorities, and the relevant feed-back periodically examined in international meetings."

However, no matter what practical way may be chosen to develop scientific and mathematical teaching in schools, it appears important to substitute the obsolete "science hierarchy" with a more general "synthesis of disciplines" applying not only to scientific subjects, but to all fields of cultural activity. On the ground of the structures that underlie our present knowledge in all fields, we could think of a kind of flowing link from the logical disciplines (mathematics, structure of the language) to the artistic and historical subjects (literature, visual arts, history, social science) to the natural sciences (geography, biology, chemistry, physics, technology), thus linking again with mathematics. In this context, symmetry provides the structural link between mathematics and visual arts, visual arts and sciences, sciences and mathematics.

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Discussion

It is stated that, of course, the connections between physics and mathematics are close and that a good knowledge of mathematics is helpful for a physics teacher. Beyond this he ought to know, how mathematics now is taught to the students. Difficulties of linking mathematics teaching and physics teaching arise, however, by some new trends in mathematics and mathematics teaching. At present the mathematical education seems to be more concerned with fundamental questions than with calculations, the knowledge of which could be profitable for physics. Mr. THOMSEN reports that special courses of mathematics for use in physics are given inevitably to overcome this difficulty. Mr. BAEZ remarks that a physicist (and a physics teacher) ought to have knowledge of the foundation, too, not only for intellectual pleasure, but also to have profit of it. - It is regretted that physics and mathematics partially use different symbols for the same thing; the students will then not recognize it.

Until now it was only discussed about the benefits which mathematics provides for physics. On the other hand, physics gives good examples of problems for illustrating mathematics.

Mr. BAEZ feels that the history of mathematics and physics can be helpful to teach integrated mathematics and physics and to show their connections, for instance by telling how part of mathematics was invented in order to solve a problem of physics.

M. Feuchtwanger

Teaching alternating current as periodic phenomenon

1. Alternating current is a periodic phenomenon and should therefore be taught in its natural context rather than according to the history of its discovery. Periodic phenomena fascinate young and old alike. The "Hidden Persuaders" know this fact well and utilize it often. They know that a shop window exhibiting a periodically moving arrangement will attract crowds. Periodicity occurs in the submicroscopic world as well as in astronomical events and it is obvious in easily observable objects and processes like heart-beats, clocks, electrical bells, "drinking ducks" and all the oscillations demonstrated in school experiments. It has even been shown (1) that under certain circumstances the numbers of animals of two species in a prey-predator population will oscillate around an equilibrium state. The distinction between processes going on in one direction only and processes which repeat themselves periodically is quite fundamental. Therefore some understanding of periodic phenomena should be included in any science education. However, school syllabi mainly deal with one-directional processes and often consider the periodic processes only in the special feature of ideal simple harmonic motions, since this phenomenon can be described by simple mathematics.
Consequently there is no time to illustrate the rich variety of periodic phenomena and to consider their mechanism. The kinematical approach deals with the connection between SHM and circular motion with the aid of calculations or by use of shadow projection. This approach indeed makes SHM without calculus accessible to mathematical treatment, but it does not answer the basic question: how do periodic phenomena come into existence? Even if the simultaneous shadow projection of SHM and circular motion is really demonstrated - which is done quite seldom - the kinematical description deals with moving points rather than with real physical objects and is also restricted to mechanical phenomena. This line of reasoning does not enable the student to understand electrical oscillations. Therefore other physical aspects should be stressed more strongly. Restoring forces are easily demonstrated and will explain to the pupil the to and fro of SHM. The appearance of additional forces will explain damping and other phenomena, but in view of the generalisations required to understand non-mechanical phenomena the dynamical description, also, will not sufficiently broaden the students' outlook. Especially, it will not apply to electromagnetic vibrations. However we will find that energy terms are quite suitable for describing various features of oscillations like relaxation oscillations, free harmonic oscillations, damped oscillations, forced oscillations and maintained oscillations.

Systems which are capable of storing one form of energy only can perform relaxation oscillations. In an intermittent siphon for instance (fig. 1)

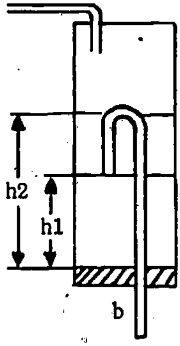

Fig. 1

water runs from tube (a) into a container. As soon as the water level raises to h_2, tube (b) will serve as a siphon. If draining runs faster than filling, the draining stops with the water level near h_1 and the whole process starts anew. Thus gravitational potential energy - and only this one sort of energy - is stored and released in this oscillatory process.

Simple harmonic oscillations, mechanical as well as electromagnetic ones, arise from periodic conversion of two sorts of energy in systems which are capable of storing two sorts of energy, like kinetic and potential energy or electrostatic and magnetic energy. Energy leakage out of the system produces damped oscillations, and in order to compensate for the energy losses we can drive an oscillatory system by another one and produce forced oscillations imposing the frequency of the driver oscillator on the slave oscillator. Maintained or continuous oscillations will arise when the oscillatory system is capable of triggering once in each period an appropriate input of energy from an external source at the right time and maintain its eigenfrequency.

We cannot demonstrate to the regular student the similarity between mechanical and electrical oscillations by the similarity of the corresponding differential equations. Nor can we explain to him the mathematics of damped or forced oscillations. But as we have seen, energy considerations will enable the students to understand the generalisations of our concepts and to classify the various sorts of oscillations. The energy notions so far used are taught or can be easily taught in schools. If we build our reasoning around some basic simple experiments we can - and I would like to say we should - introduce students into the fascinating world of periodic phenomena without limiting the teaching of oscillations to those phenomena which can be exactly described by mathematical calculations. Naturally such a course must start with mechanical oscillations. A second section, dealing with electrical oscillations can then be built on the major physical concepts introduced previously and structured as far as possible in strong analogy to the first section.

2. The main concepts relevant for the lowest of such a program are: periodic process, period, frequency, amplitude, energy exchanges within an oscillator, energy exchanges of an oscillator with its surroundings, damping, forced oscillations, resonance. Only at a somewhat higher level would we consider phase relations. We shall now outline a minimum course by indicating a selection of experiments representing the sequence of relevant concepts. We omit formulas, as these depend on the mathematical level of the class.

As a first example of a periodic process the above mentioned intermittent siphon is suggested. The graph of height (or volume) of water versus time is a simple sawtooth line composed of straight segments only. Students will observe the frequency which may easily be controlled by varying the water supply. Such a mechanical relaxation oscillation is desirable for introduction purposes. The mechanism is simple and transparent and may be used for purposes of further illustration. The oscillating parameters (height, volume) can easily and should clearly be identified. The device illustrates the way automatic flushing works. It can be quickly assembled from an open glass cylinder, a bent thin glass tube and a stopper (with a hole) fitting into the cylinder.

We will now deal with the usual examples of simple harmonic motion (damped as little as possible). The students, again, will identify the various oscillating parameters, observe frequencies and amplitudes and the factors controlling them. Restoring force and energy transformations within the oscillating systems should explain the mechanism of oscillating.

It is not essential within the context of our approach to obtain a formula for the displacement as a function of the time. Probably, the recording of an oscillation by a sand pendulum (2) or a similar device, if thoroughly worked out, will serve the students of a non-physicists course better than formal derivations.

The students then proceed to some self-criticism. They more carefully examine the former experiments and observe the inavoidable damping. In addition an experiment in which the damping is gradually increased should underline these observations. A circular disc attached to a metal rod, 12-15 cm long, is attached to the mass of an oscillating spring. We then fill with water three cylindrical vessels of various diameters, the narrowest only slightly broader than the disc. Now we let the disc first oscillate in air and then in the water. In air the damping is relatively weak and in water, the narrower the vessel the stronger the damping. (Overdamping -in glycerine- can be demonstrated also). All these phenomena should be described in terms of "frictional" forces and energy losses. It is quite natural at this stage, to consider ways of compensating for these losses. The time has come for a demonstration of forced oscillation. In a simple demonstration allowing for a wide range of frequencies, the vibrations of a loaded saw blade are driven by a rubber band which is moved to and fro by a stopper eccentrically fixed on the exle of an

electromotor. The velocity of revolution is gradually increased by changing the voltage. The blade oscillates with the frequency of the motor, and its amplitude of vibration first increases with increasing frequency and then decreases after passing a clearly distinct maximum. The experiment should be performed with various loads and/or various blades, and resonance frequencies should be measured in each case as well as eigenfrequencies. Resonance should be illustrated by as many everyday examples as possible (2, 5). In addition the film on Tacoma bridge collapse is a beautiful aid for showing the powerful accumulation of small energy inputs resulting in resonance.
Obviously each of the experiments can be replaced by an equivalent one and additional experiments or applications may be used to give the students increased familiarity with the main concepts. It is possible, but not necessary to also consider sustained oscillations which represent another way of compensating for energy losses. The frequency is that of the oscillator and the energy input is automatically triggered by the oscillations themself. The anchor escapement of our clocks represents this type of oscillation.
So far we have outlined a set of mechanical experiments and concepts which are desirable in order to set the stage for studying alternating current. Of course, the later this part of "mechanics" will be treated, the better. A reasonable timing would be to consider it after having studied elctromagnetic induction.

3. Detailed courses of alternating current are generally offered in programs for vocational schools or A-level classes. As a result of both ample time allotment and special professional or scientific aims, the topic is taught to those groups in a rather sophisticated manner. In schools with less specified goals, we can discern two types of approach. In a more traditional syllabus we find, that after having treated some electrodynamics and electromagnetic induction, the topics included are: generators for alternating and direct current, transformers, RCL-circuits, some technical applications of a. c. and finally electromagnetic oscillations and waves. Often a pure R-circuit driven by an alternating current source is first considered while capacitors and inductors appear a bit later as new elements complicating the original simple situation. The impedance formula is sometimes taught but not properly assimilated by the students. It is said to be "pure mathematics" and "hard to memorize". In the form it is usually written, it gives no physical insight into the process and turns out to be a meaningless ballast. Some modern syllabi like PSSC and Harvard Project Physics have drastically cut down on the topic of a. c. and in effect have eliminated this subject.
Apparently it was felt that the traditional treatment of a. c. in schools did not contribute very much to fundamental physics and so it was dropped. Perhaps Nuffield-O-level Physics is the only school syllabus which shows an awareness of the situation. The Nuffield program (3) suggests experiments with low frequency a. c. obtained from a hand driven generator and appropriate adaptations to the classroom situation.
Another feature of the usual instructional treatment of a. c. is its adherence to the historical sequence of physical discoveries and inventions. The a. c. generator, the commutator and the transformer were invented in the fourth decade of the last century, Maxwells' ideas grew in the seventh and Hertz' discoveries in the nineth

decade. So most courses of electricity truly reflect the historical development. Moreover, a. c. sources with variable frequency were not easily available to schools until about 15 or 20 years ago and teachers were practically bound to the frequency of the mains. So technical conditions also contributed in narrowing the scope of a. c. teaching in the schools.

It is not the aim of this paper to argue against omitting the study of alternating current circuits from the school syllabus. The total time allotted to physics in various school systems ranges from as low as 100 periods to some 500 and new topics of current interest are added. So some traditional subjects have to be dropped and no topic should be exempt from this reevaluation. Nor do we intend to ameliorate the situation by suggesting new experiments since beautiful techniques and good surveys of class experiments and lecture demonstrations are already widely accessible to teachers (1;2;3;4;5).

The question we deal with is: Provided the time is available, should we drop a. c., because it is peripheral to the fundamental concepts of physics or can we find out a set of experiments and concepts relating a. c. to basic physical notions? Hopefully such a presentation would serve a double purpose: first as a complete unit in non-specialist physics courses, and second as an introduction to a. c. in a more sophisticated program.

In order to accomplish this aim it seems to be desirable to detach the topic from its historic development and to teach alternating current in the general context of oscillations. The suggested introduction into a. c. is built around five or six experiments in close analogy to our introduction into mechanical oscillations. Hopefully, the students have learned that oscillations are connected with energy storage and release or with mutual conversion of two sorts of energy. We started the study of mechanical oscillations with a glance at relaxation oscillations since these occur in systems storing only one sort of energy. The same might be desirable in the study of electrical oscillations. A convenient example is a device for producing sawtooth voltage. A direct current is supplied to a variable high resistance in series with a variable capacitor. A neon lamp is connected in parallel with the capacitor (Fig. 2). Periodic glow is observed in the lamp.

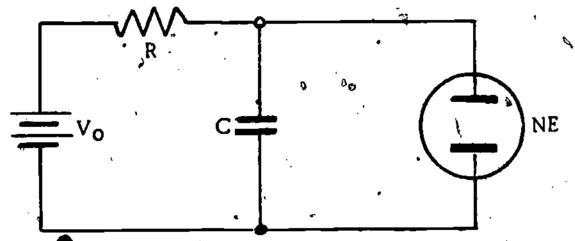

Fig. 2

The period is easily controlled by varying the resistance or the capacitance or the source voltage. This experiment introduces periodical electrical phenomena, but only one form of energy can be stored in the system: the electrostatic energy of

the charge, contrary to the oscillation circuits we are going to study later which can store two sorts of energy. Emphasizing this basic difference illustrates the important role of energy transfer in oscillations.
The second experiments, students' first confrontation with electromagnetic oscillations, should be organized in a rather spectacular manner. The students should be able to observe thoroughly the process and to discern between the main elements of the oscillating system. Therefore very slow oscillations must be set up. The circuit will contain a coil of 20000-40000 turns with a closed iron core, a condenser of 1-20 μF and a suitable meter. The condenser will be charged, then the circuit closed and at least 4-5 very slow oscillations will clearly be indicated by the meter. The frequency is about one cycle/sec and can be controlled by changing the capacitance and the inductance. The students will see that increasing L or C decreases the frequency. But first of all they will study the interplay between the storage and release of the electrostatic and electromagnetic energy and describe the process with the aid of suitable diagrams.
The oscillations quickly die out, but this might prove to be an advantage, since analogies to mechanical oscillations can be drawn in several respects. There is a storage and a mutual exchange of two sorts of energy as well as damping, which is familiar to the students from prior studies, and they know that damping means leakage of energy.
The currents and voltages which appeared in the oscillation circuit will be called alternating currents and alternating voltages. Just as in the case of mechanical oscillations we should present various ways of producing oscillations i.e. oscillating voltages and currents and also a variety of related technical devices. Some simple devices will be analyzed and clearly explained. Meanwhile the more complicated ones will be introduced as black boxes. First we show the Nuffield (3) rotating slow AC generator which is a periodic potentiometer: A flat coil resistor with two brushes rotating in contact with a coil connected to a d.c. supply of, say, 4 volt. The output voltage picked up from the brushes will oscillate between plus and minus four volt. We can rotate it by hand or with a motor. The important point is that this mechanism of alternating the voltage is simple and obvious and its understanding is not depending upon insight into electromagnetic phenomena. Then we present a somewhat more sophisticated source of a.c. voltage: a coil rotating in a suitable magnetic field or resting near a rotating magnet. Finally the sinus and square wave generator is introduced as a black box. The square wave generator is presented as an automatic switch which supplies and oppresses intermittently a d.c. voltage during equal but variable time intervals. It is advisable to use the frequency scale of the square wave and the sine wave generator as the basic timer, but the students must get some opportunity to calibrate it by comparing a few frequencies with that of the mains.
Our indicators also will briefly be explained or demonstrated. They are a loudspeaker, an oscilloscope and meters. It is highly desirable to introduce the oscilloscope in the earlier stages of teaching electricity, but if it has been omitted, it may be done now. We should also demonstrate, if possible, that with increasing frequency a milli-ammeter or a microammeter fails to respond to the oscillations while the oscilloscope does respond. Finally we provide the meter with a diode and compare again the response of both meter and oscilloscope.

Having explained these technical details we return to the main line of reasoning. So far we have observed very slow electromagnetic oscillations. We can now - in our third experiment - show the same phenomenon at more usual dimensions, in the frequency range of - say - a few thousand Herz. We have only to change L and C appropriately, to replace the meter by an oscilloscope and the d.c. source and the switch by a square wavegenerator. The oscilloscope displays all the essential features of the oscillations. Various degrees of damping can be studied and its causes be discussed. The main issue is that we can measure the frequencies. This is done by comparing the oscillogramm of the squarewave used for exciting the oscillations and the number of oscillations on the screen. The students will see again how the frequency of the oscillations varies with increasing or decreasing capacitance or inductance.

The concepts the students have been familiarized with by the first three experiments are: relaxation oscillations, electromagnetic oscillations, energy conversion during these oscillations, amplitude, frequency and damping. They are also aware that a series RCL circuit represents an oscillatory system with a natural frequency depending on L and C. As in the case of mechanical oscillations we now consider oscillations imposed on an RCL circuit by an external alternating voltage, i.e. forced electromagnetic oscillations or alternating current fed into an RCL series circuit by an a.c. supply. Of course this fourth experiment must be performed with the same circuit elements we have used in the third experiment. Assume we found an eigenfrequency of 10.000 for that system. Now we insert a suitable microammeter and an oscilloscope in parallel and drive the circuit by the sinewave generator gradually increasing the frequency from 1000 to 20.000. The students will clearly notice a maximum of current at 10.000 and will recall - or be reminded of - the mechanical resonance experiment. The energy losses by damping and the problem of compensating for them will be discussed anew, this time with respect to electrical oscillations. The driving alternating voltage source is the "driver oscillator" and the RCL circuit the "slave oscillator" (resonator) which performs forced oscillations. The varying amplitudes reflect the response and the students find that the amplitudes increase when the imposed frequency f approaches the natural frequency f_o. The students might say "the nearer f is to f_o the more energy is absorbed." They draw a parallel between the various sorts of oscillations and classify the phenomena by using energy concepts.

These considerations are not strictly conclusive, but a further experiment will do both reinforce the latter argument and connect our findings to more familiar dimensions and phenomena of alternating current. This fifth experiment introduces "tuning" and we take the opportunity of using the frequency of the mains. A coil with an iron core a variable capacitor and a bulb are connected to a 3 volts transformer. By varying the capacitance and the inductance - the latter by moving the iron core of the coil - we vary the brightness of the bulb. The students find that resonance can be established also by adjusting a circuit to a given frequency i.e. changing the circuit parameters in order to bring f_o near a given f. Furthermore the energy input of the circuit is demonstrated by the energy consumption of the bulb. So we accomplish the considerations following our previous resonance experiment.

4. We have completed our introduction into our minimum course of alternating current, but once the students have experiences with everyday appliances they can separately study the influence of the various elements of the RCL circuit and examine circuits containing mainly one of them as usually taught in school classes. They can proceed to study a. c. appliances as motors, transformers and generators. At a higher level they would study phase relations, and there are various effective ways of demonstrating the related phenomena. At a still more advanced level the mathematics of all these things can be studied. It seems to be desirable to derive the differential equations of the various phenomena from corresponding energy equations. So the mathematical theory may reflect clearly the introductory course we have outlined.

Finally a brief remark on the impedance formula which generally is written as: $Z = [R^2 + (L\omega - 1/C\omega)^2]^{1/2}$ If the students have recognized that $\omega^2 = 1/LC$ - while studying free oscillations -, we should rewrite the formula by: $Z = [R^2 + L^2 \omega^{-2}(\omega^2 - \omega_0^2)^2]^{1/2}$. In this form the formula is quite meaningful, because it is now obvious that $\omega = \omega_0$ means resonance. (Of course all this is beyond the scope of the present paper!)

The set of simple basic experiments which has been suggested used the oscilloscope and it seems indeed that sooner or later this instrument will be a standard requisit of physics teaching like voltmeter and ammeter. However, for emergency cases, it may be noticed that even without an oscilloscope resonance experiments in an RCL circuit can be performed at the range of a half to 1 Hertz. If we insert the Nuffield slow a. c. generator in the RCL circuit which we used for very slow-oscillations (with 20 uF and a 30000 turns coil with closed iron core) a maximum response of the circuit at the eigenfrequency can be observed with the aid of a suitable center zero microammeter. The resonance is quite sharp and clearly discernible.

Finally, some remarks on the literature: Recently, modern university text books began to present a. c. in the context of oscillations, but I did not find, so far, any school text or syllabus with a similar line of reasoning. This is not so surprising. The modern aim of teaching fundamental physics is based on a scheme of theoretical concepts of mathematical or otherwise sophisticated nature. As we lack the mathematical basis, we may doubt whether we can teach fundamental physics in schools, but fortunately we can replace the mathematical language by energy terms in order to unify the treatment of electrical and mechanical oscillations. In the educational literature we find a tremendous variety of definitions of the aims of teaching a. c. A new Scottish syllabus for general science claims - quite sensibly in its context - that the students should "be aware that there are d. c. and a. c.". An American doctoral thesis on the other hand concerning teachers' courses on a. c. draws our attention to 52 principles of a. c. electricity in the frequency range of 50-500. I would not like to suggest a simple formula or a set of important principles, but rather point out the desirable line of reasoning and say: In the conventional courses technical a. c. - i. e. in the frequency range of the mains - is treated outside the general physical context. The dependence of the current upon each of the various circuit elements, like R. C. L. is considered separately. The method here suggested begins with the oscillating system as a whole and studies its natural frequency and especially resonance. Alternating current in an RCL series circuit is presented as a phenomenon of forced oscillations. So a natural bridge is built between electrical and mechanical oscillations of various ranges and the comparisons may be understood. From the system we proceed to the studying of the action of the parts of the circuit as far as the level of the class allows.

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Discussion

Summary of the discussion
(In bracketts/ the replies of the lecturer).

1. In an article of D.C.F. CHAUNDY, (S. Bibliography) a similar approach has been presented.
(CHAUNDY's article has already been quoted in the bibliography of the pre-conference paper. Its underlying philosophy seems to be indeed quite similar to the one we have outlined. However, CHAUNDY only describes experiments, whilst our intention was to develop a conceptual sequence as a part of a syllabus).
2. The intermittent syphon has been described as a part of an ancient clock in the second century B.C., but my attempts to reproduce it have so far failed. Instead of intermittent behaviour a steady outflow occured (If the bend of the lower tube is smooth enough and the rate of inflow small enough the intermittencies always appear).
3. The lecturer suggests introducing the oscilloscope quite early. How can it be done?
(Two essential points must be explained. The electrostatic deflection of the electron and the time base. Various vacuumtubes for showing the deflection of electrons are available and the field between two parallel plates is investigated in most courses. The general concept of a time base of a recording instrument may easily be demonstrated by recording thermometers, barometers, and hygrometers which are found in small "weather stations" in public gardens. The special feature of the oscilloscope time base is quite attractive to students. It can be taught as explained in the present paper).
4. Why should we prefer to introduce a. c. as a special form of electromagnetic oscillations? What is wrong with the common sequence of electromagnetic induction, dynamo, alternating current?
(The answer depends on the details of the curriculum. Provided you aim at showing the existence of a. c. only, any method will suffice. But if you consider the dependence of the current in a. c. circuits upon the various parameters, the natural context is the general phenomenon of forced oscillations).
5. The lecturer has suggested restricting quite drastically the teaching of simple harmonic motion, but he uses the spring and similar phenomena in his experiments. What should be the place of SHM in school-teaching in his opinion?
(It is indeed not desirable to limit the teaching of oscillations to SHM only and to spend too much time on related mathematical calculations. However, we should begin with SHM as the simplest form of oscillations and if we are short of time or if our students are not deeply interested in mathematics, we should reduce the calculations and - instead - let the pupils see the large variety of oscillatory phenomena in our world).

6. Can pupils in school understand the basic similarity of mechanical and electrical oscillations?

(In a few pilot trials we found the pupils quite interested in this way of thinking and they displayed good understanding. However, our rather limited experience does not allow us to make a more definite statement, but it does encourage further trials).

M. Feuchtwanger

Arturo Lorio and G. Partesotti

Introduction of quantum physics (not quantum mechanics) into the secondary school syllabus

(Paper read by Arturo Loria)

In the "Annual Training Course of Teachers of Physics" (1) which is now in progress for the third year at Modena University, and in the "Summer Refresher Courses" entrusted to our Institute by the Ministry of Education, we too are aiming at studying how to introduce concepts of modern physics in the Secondary Schools.
We think that quantum mechanics proper is not in itself a suitable subject for inclusion in a Secondary School syllabus, for not only does it presuppose considerable mathematical expertise, but it also raises difficult points of interpretation. We strongly believe, however, that quantum physics can and must be treated at Secondary School level: further, we maintain that this is the first step we should take in order to achieve our aim.
As a matter of fact, at Modena we started by considering the problem of introducing special relativity into the Secondary School syllabus, because, firstly, there was considerable, widespread interest in the subject among local teachers, and, secondly, we were in the fortunate position of being able to base our work on the vast body of practical experience deriving from numerous research projects successfully carried through previously in other countries. The actual work was mainly the responsibility of Silvio Bergia, who made his teaching notes available in preprint form (2).
As for quantum physics, work was already started in Modena some time ago on teaching apparatus (3), but it was not until the academic year 1970-71 that the problem was tackled in its inherent complexity, considerable progress being made during the Summer Course held in september 1971. During this second phase we have the invaluable collaboration of Bruno Ferretti, whose lessons are now available in preprint form (4)(5): we emphasize that this material, a brief description of which follows, is meant for secondary school teachers, and not for their pupils.
It is well known that quantum physics has finally demonstrated the stability of atoms, and hence of matter. It seemed to us that the subject is of such importance and interest as to arouse the curiosity of young students, providing of course that they have been previously taught to recognize that this stability itself represents a problem, and one which cannot be solved by classical physics.
On the basis of the principle of equipartition of energy, which relies on classical mechanics and on Boltzmann's law of statistical distribution, Perrin showed that atoms in the etymological sense actually exist. However, many other experiments, notably those of Zeeman and Rutherford, were gradually building up an increasingly reliable and exact picture of an internal structure of atoms, according to which, when the principle of equipartition is applied, various experimental results are not obtainable, for example those concerning specific heats. Hence the choice between abandoning either classical mechanics or Boltzmann's law.

The experiment of Frank and Hertz, which affords direct confirmation of Planck's hypothesis, namely that energy exchanges between matter and radiation do not occur continuously but in quanta, suggests a way out of the dilemma. In classical mechanics the energy of a system of particles is a continuous quantity: that this energy should, however, be limited to a certain set of allowed values is foreign to classical mechanics, which must therefore be modified.

Taking into account the order of magnitude of the internal energy levels, and that of the kinetic energy of the atom "as a whole" at room temperature, we realize, firstly, that in the conditions under which Perrin was working the atoms behave just as if they really had no internal degrees of freedom, and, secondly, that the discrete values that the energy of the atom "as a whole" can assume are so close to one another that this energy varies almost continously. Perrin's demonstration of the existence of atoms is therefore undoubtedly correct, even if we accept, as we must, Planck's hypothesis.

It is known that classically the specific heat of the atoms is negative: e. g. the kinetic energy of the electron of H increases when the atom radiates. This would lead to a complete and, moreover, rapid collapse, with the electron falling onto the nucleus. It happens, however, that in consequence of quantization there is a minimum of total atomic energy when the electron is at a certain distance from the nucleus, and that this energy increases rapidly as the distance tends towards zero. In other words, intense repulsion occurs. In this way, the fundamental level of H originates, collapse no longer occurs, and the stability of the atom is assured.

If these new principles are accepted, and there seems to be no reason why they should not be successfully taught at secondary school level, many experimental results which were incomprehensible according to classical physics can be explained: it is possible not only to establish the correct behaviour of specific heat, but also to solve the problem of the characteristic spectra of atoms, questions which, as we have already seen, are anyway bound up with the stability itself of matter.

With Pauli's principle the periodicity of Mendeleev's table can be understood, and the atomic structure of the different elements determined. Also, the behaviour of insulators, conductors, and semiconductors is explained.

From the teaching point of view, it is particularly important to note that the homeopolar bond can be explained at an elementary level, thereby passing from the stability of the atoms to that of the molecules, and that, similarly, it is possible to understand how the laser and the transistor work.

The last part of the program sets out to develop the concept of photon by discussing the photoelectric and Compton effects, to show wave-corpuscle dualism in the light of the Janossy experiment, and to expound the meaning and some important implications of Bohr's principle of complementarity.

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(4) Lessons by B. Ferretti regarding the introduction of notions of Quantum Physics in the Secondary Schools, collected by G. Partesotti (March, 1972). The preprint may be obtained from the Institute of Physics, Modena University.

(5) A number of undergraduates working with the guidance of C. Bonacini produced degree dissertation which have made an effective contribution to our work.

Discussion

Mr. THOMSEN asks, why a choice has to be made, if to teach the theory of relativity or quantum physics. Both are important, and partly they interact.
Mr. LORIA responds that in Italy it is at present very difficult to introduce changes in the traditional curricula, because these are rigidly fixed by the State, and because time devoted to physics is so scarce that teachers hardly manage to teach what they must teach.
It is discussed about the best way to introduce quantum physics. The author prefers to start with the stability of matter rather than with the Bohr atom. Mr. BAEZ thinks a start which includes a historical view, to be profitable and enlightening. Also it is suggested to begin with the photoelectric effect.
Mr. LORIA replies that he would prefer to leave alone a model which is not only definitely obsolete, but also very far from what we believe to-day about atomic structure. He also emphasizes that one might have a quite satisfactory historical view even by following the way of the stability of matter.
The author is going to publish and to implement his educational material.

Mieczysław Sawicki

Teaching physics to gifted pupils

In 1969 an experiment was initiated in six schools which provide instruction in the field of physics and mathematics for able students. Research in question, carried out under the scientific guidance of professor W. Okoń, pertained merely to the teaching of physics.

1. Two main hypotheses were set forth:
1.1 Teaching physics to able students becomes more efficient if a special gradation and selection of content is introduced, considerably differing from that prepared for the rest of students.
1.2 Teaching physics to able students becomes efficient if the following teaching methods are introduced, i.e. teaching by discovery, teaching through research and teaching through emotional experience (according to W. Okoń).

2. Verification of the first hypothesis required a special curriculum for grades I and II of the secondary school (students aged 15-16) which was constructed according to the principle of structurizing the teaching content by means of the matrix method (Annex I). Mechanics is presented uniformly without division into classical, relativistic and quantic. The basic concepts are the following: frame of reference, transformation and invariant, while the basic law is that of conservation. Relativistic physics in a geometrical shape (Minkowski's diagrams) is introduced at the beginning, so that it can be used wherever it is possible, e.g. in electrodynamics. Although not many laboratory tasks were prepared there was much time spent for them. Important role is played by mathematical logic, theory of sets and - to a smaller degree - algebra and the theory of function. Both vectors and graphs are introduced at the very beginning.
Verification of the second hypothesis required
2.1 providing students with the opportunity to use university workshops for the freshman year,
2.2 introducing a non-rigid approach to the problem of textbooks (each student could select a textbook),
2.3 introducing a group-problem-solving method (students worked in groups of two or three),
2.4 constructing special problems for students,
2.5 emphasizing techniques of intellectual work.

3. In the course of the experiment the following research instruments of both didactic and psychological nature were used:

3.1 test measuring students' attitudes toward science (IEA, 1965) administered twice: at the stage of selecting able students, at the end of the first year of instruction,

3.2 Wechsler's intelligence test,

3.3 test measuring the understanding of basic physical concepts introduced in the course of instruction in the primary school which was administered at the stage of selecting able students,

3.4 test measuring the understanding of basic concepts and laws of mechanics, administered at the end of the first and the second year of instruction,

3.5 test measuring the understanding of basic concepts and laws of electrodynamics, administered at the end of the second year of instruction.

4. First research results

4.1 Concepts of transformation and invariants in physics are well understood by 14 and 15-year-olds.

4.2 Basic concepts and laws of relativistic physics in a geometrical representation are also well understood at this age.

4.3 Teaching basic conceptual structures, for instance, the law of conservation speeds up the learning and activates the educational process.

4.4 The experimental curriculum elicits a positive transfer of concepts and laws from the field of mathematics and especially of algebra of sets and mathematical logic.

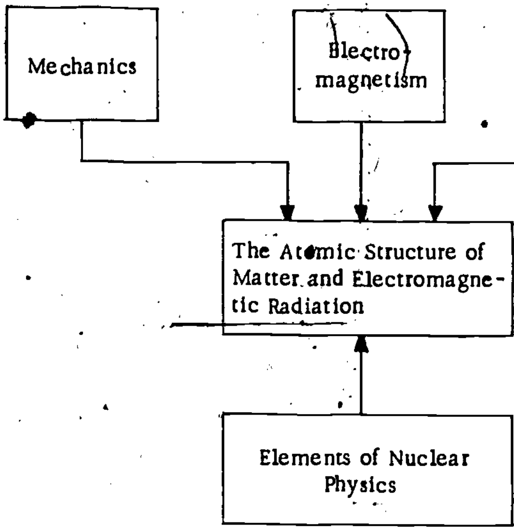
4.5 The introduction of the what-are-called general problems considerably increases the students' interest in physics.

4.6 Teaching physics to able students requires
- to individualize instruction in the field of curricula, textbooks, problems and learning speed,
- to replace lectures by individual or group work according to the problem-solving method,
- to adjust types of laboratory tasks to the level of the students' knowledge and to give them the opportunity of selection.

4.7 No correlation has been stated as between achievement and
- amount of education in parents,
- environment,
- attainment in physics in the primary school
- attainment at the entrance examination

4.8 Positive correlation has been stated as between the students' achievement and
- IQ.
- amount and type of reading,
- amount and type of independently solved problems,
- sex (girls revealed lower achievement).

Table 1: The Structure of the Curriculum for the 4-Year-Course



Annex I

Physics for talented pupils
(School of Mathematics and Physics)

1. The first year of teaching (pupils aged 15)

1.1 General structure curriculum of teaching in the first year

The subject of the first year teaching of physics in a mathematics-and-physics school is mechanics. It is no more divided into classical, relativistic and quantum.

Here the following notions are fundamental: the reference system, transformation and its invariants, field, reaction and energy. The basic laws, however, are those of conservation and symmetry.

The most popular language of didactic description is graphic representation (diagrams). It enables the students to understand mechanics as the section of physics dealing with space-time and bodies. This visual presentation of physics in a geometric style causes good transfer of general ideas of space-time into other section of physics such as electrodynamics or atomic physics.

In the process of learning the following factors are widely used: vector analysis, the language of algebra, the theory of multiplicity and mathematical logic. The new kind of problems (general ones) is being introduced and solved.

Physics laboratories enable the pupil to verify the basic laws through experiments. They make him acquainted with some simple techniques of a scientific experiment.
The wide applying of electrical methods in mechanical experiments appears to be the characteristic feature of these experimental work.

1.2 Syllabus

The third version modified after having been tested for 3 years on a sample of the population of about 200-300 pupils (the children of peasants and workers) in big industrial towns and in rural areas.

1.3 Mechanics

1.3.1 Motion and Forces (30 h).

The Scientific method. Vectors the language of Physics. Velocity and Acceleration. Some applications the fundamental ideas of kinematics. The radial component and the transverse component of acceleration (centripetal acceleration). Inertial coordinate system. The Galilean transformation. The Principle of relativity. Invariance Principles. An introduction to forces. The nature of forces. III Newton's Law. Mass and Newton's second law. Momentum of particle. Non-inertial coordinate system. D'Alembert's Law. Inertial forces. Forces in circular motion. The Coriolis force. Friction. Classification of forces.

1.3.2 Relativistic kinematics (8 h)

Michelson-Morley experiment. The postulates of the special theory of relativity. Minkowski diagrams. Space and time in relativistic kinematics. Length contraction. Time dilation. Simultaneity. The Lorentz transformation. Relations between velocities. The interval. Light cone.

1.3.3 Energy and Field (30 h)

Conservation of momentum. The relativistic mass. Work and energy. Kinetic energy. Relation between: momentum, rest energy, kinetic energy. Transformation of momentum, energy and force. Work, force and energy. Work and potential energy. Conservative forces. Hamiltonian of mechanics system. Some applications conservation laws. The potential energy graph. Potential well. Gravitational force, constant, mass. Gravitational field. Lines of forces. Total number of lines. Gauss's Theorem. The field strength. Some problems of field theory: gravitational potential energy, the escape velocity. The center of mass. The inertial mass. Weight. Non-inertial coordinate system and gravitational field. Einstein's principle of equivalence. Some problems in general theory of relativity (space-time in non-inertial coordinate system, space-time mass). The Chronometer in gravitational field.

1.3.4 Rotational dynamics (10 h)

Torque momentum. Moment of inertia. Rotational kinetic energy. Angular momentum. Conservation of angular momentum. Precession. Gyroscope.

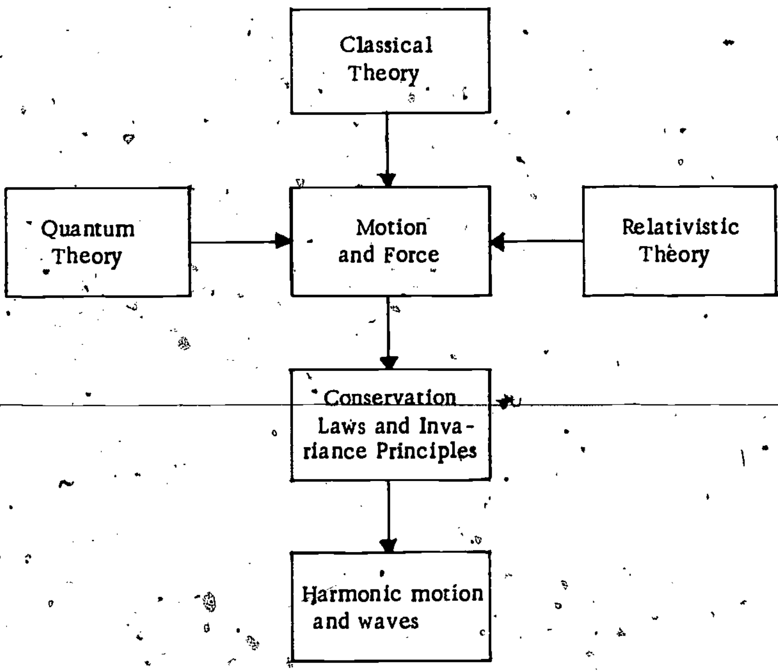
1.3.5 Practical Physics - part I (15 h)

The Vernier scale. The micrometer screw gauge. Verification Newton's Law of accelerated motion. To measure the acceleration due to gravity a free fall method. The second Law of rotational motion. Coefficient of dynamic friction for wood on wood. Maxwell's wheel (fly wheel).

1.3.6 Introduction. Hooke's Law. The equation for simple harmonic motion. The simple pendulum. The period (T). Rotational simple harmonic motion. The energy associated with an oscillating object. Damped oscillations. Resonance of oscillation. Superposition of two vibrations. Wave motion. The Phase, period frequency, amplitude, wave-length, wave front, intensity. Some other forms of travelling waves (longitudinal pulse, transverse waves). Reflection wave. Refraction. Refracitive index. The equation of a sinusoidal travelling plane wave. The Huygen's principle. The diffraction wave. Superposition of waves. A mathematical description of interference. A mathematical description of standing wave. The phenomenon of beats. The amplitude modulation of waves. Wave groups and group velocity. Dispersion. Fourier analysis. The Doppler effect. Relativistic Doppler effect. Polarisation. The application of wave theory to sound.

1.3.7 Practical Physics - part II (15 h)
Decay of oscillations of a simple pendulum. Modulus of rigidity using a torsion pendulum. Investigation of superposition of vibrations. (Use of the cathode ray oscilloscope). Velocity of sound in brass using Kundt's dust tube.

Table 2: The Logical Structure of Mechanics (First year of instruction)



2. The second year of teaching (pupils aged 16)

2.1 General Structure Curriculum of Teaching in the Second Year

Electrodynamics is another structure of notions to form the pupil's view upon the nature in the terms of phenomenology.

Here the central ideas are: the idea of the electromagnetic field and its relevant reactions.

The pupil approaches the mathematical model of that kind of field (formed by J. C. Maxwell's laws) by generalization of facts or detailed ideas.

Here the following methods of learning are used: the study of the invariance of quantities and laws, the description of some phenomena from the point of view of different coordinate systems, the use of formal analogies between the idea of a field in mechanics and electrodynamics, the graphic representation of the processes and dependence, and the frequent use of all the basic notions in mechanics.

At this stage of learning the following elements are added to the language of mathematical description: the elementary calculus of derivatives, the complete vectorial calculus and the basic methods of vector analysis. Gauss's theorem is also of a great didactic function.

The electromagnetic field is introduced as the product of relativity. Only the vector B is used.

The phenomenon of electromagnetic induction is described from the point of view of the inertial system.

The procedure of the quantization of the electromagnetic field is introduced.

The aim of the physics laboratory is to acquaint the pupil with the measuring apparata, to instruct him how to measure the electrical quantities and to make him understand the fundamental processes at the base of which lies the electromagnetic reaction.

2.2 Syllabus

The second version modified after having been tested for 2 years on a sample of the population of about 200 pupils from big cities and industrial and rural areas.

2.3 Electromagnetism

2.3.1 The electric field (54 h)

2.3.1.1 The electric field in the vacuum (12 h)

Electric charge. Coulomb's Law of Force. Intensity of the electric field. The superposition principle. Density of lines. Gauss's Flux Theorem. Examples, use of Gauss's Flux Theorem - Field of a uniform spherical shell of charge. Field of spherical charge distribution. Field in region a charged cylindrical conductor. Field out from an inifinite plane of uniform charge density. Field of an electric dipole along axis and normal to axis. Work and potential energy. The conservative nature of the electric field. Potential difference and potential. The superposition principle applied to potential. The gradient. Relativistic electric field effects.

2.3.1.2 The electric field of the presence of matter (6 h)
Dipole in the electric field. Vector D (electric displacement). Polarization vector. Boundary conditions at a Dielectric surface. Polarizability. Segnetoelectric. Piezoeffect.

2.3.1.3 Conductors and Electric Fields
Charge distributions in conductors. Vector E in conductors. Capacitance. Capacitors.

2.3.1.4 Electrostatic Stored Energy (6 h)
The energy systems of charges. Energy of the conductors. The stored - energy density.

2.3.1.5 Current and circuits (14 h)
Electric Current. The current density. Resistance, Resistivity. The Ohm's Law. Energy exchange in a circuit. Electromotive force. Kirchhoff's Rules.

2.3.1.6 Practical Physics - part III (14 h)
Fundamental electrostatics experiments. Estimations permittivity of air. To investigate the charging of a condenser through a resistor. Measurement of capacitance. Estimation of e/m Millikan's methods. The use of the potentiometer. Verification Ohm's and Kirchhoff's Laws.

2.3.2 The magnetic Field (20 h)
The magnetic force between current elements vector quantity B. The permeability of free space. Relativistic modification Coulomb's Law. Biot's-Savart's Law. Amperes circuital law. Ampere. The magnetic dipole. Forces on isolated moving charges. The Lorentz force equation. Motion of charged particles in electric and magnetic fields. The unity of electric and magnetic field. Magnetism in matter. Paramagnetism, diamagnetism and ferromagnetism.

2.3.3 The electromagnetic Field (40 h)
Induced electromotive force. Faraday's Law of Induction. Lenz's Principle. Motional electromotive force. Mutual inductance between two circuits. Self-inductance. Stored magnetic energy. Alternating - current circuits. Sinusoidal time variation. AC voltage applied to resistors inductors and capacitors. Vector diagrams (complex numbers). Series LCR circuit. Parallel LCR circuit. Power in AC circuits. The applications of induction. Oscillating circuit closed and open oscillating dipole. The LC oscillatory circuit. Maxwell's equations. Electromagnetic waves. Tuning and detecting radio waves.

2.3.4 Practical Physics - part IV (20 h)
Verification Biot's-Savart's Law. Estimations the Magnetic Force between current elements. Estimation of e/m using the "magnetron effect" and by a deflexion method. The use of the ballistic galvanometer. Electromagnetic induction. The self-induction of a coil. Investigation of RC, LC, RLC oscillatory circuit. The characteristics of a diode and triode. Resonant feedback oscillator. Tuning and detecting radio waves.

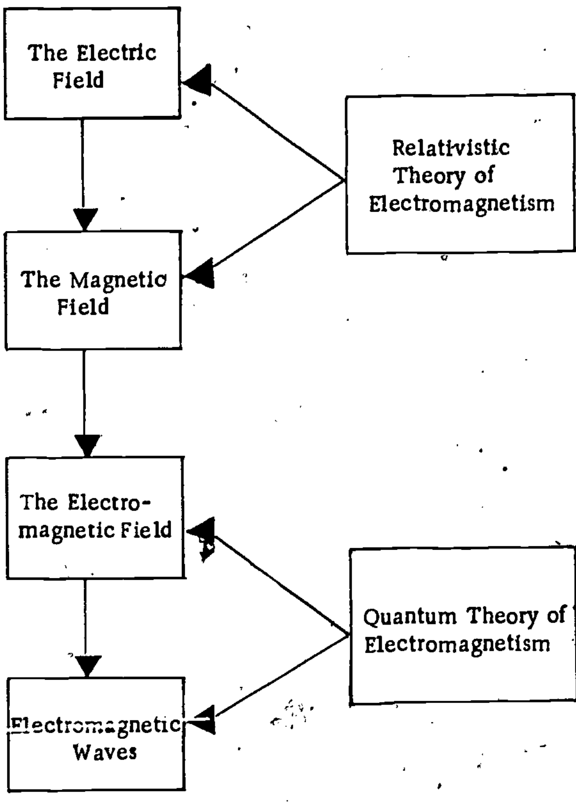
3. <u>The third year of teaching</u>

3.1	- Introduction to thermodynamics	- 10 h
3.2	- Elements of statistical physics	- 15 h
3.3	- The atomic structure of matter	- 20 h
3.4	- Solid state	- 30 h
3.5	- Liquids	- 20 h
3.6	- Gases	- 20 h

4. <u>The fourth year of teaching</u>

4.1	- Radiation and matter	- 35 h
4.2	- Nuclear physics	- 20 h
4.3	- Practical physics	- 50 h

Table 3: The Logical Structure of Electromagnetism
(Second Year of Instruction)



V. On the evaluation of science teaching

John P. Keeves

The IEA science project

1. Background Paper

The completion of the IEA Mathematics Study (Husén, 1967) contributed to an understanding of the relationships between inputs and outcomes of the educational process. This knowledge and experience could now be applied to studying such relationships in other areas. Hence the IEA project entered Phase II.
In the autumn of 1966, IEA formed an international committee for the IEA Science Project which was chaired by the English representative, Mr. L. C. Comber, who had recently retired from the position of one of Her Majesty's Inspectors. Professor Karl Hecht of the Federal Republic of Germany was a member of this Committee, supported by seven other committee members from different countries which were taking part in the project.
At the same time each research center participating in the study formed an IEA National Science Committee. The competencies represented on each committee were expertise in Science, in the teaching of Science in schools, and in test construction. Table 1 lists the countries taking part in the IEA Science Project and shows the levels at which testing took place in each of the countries. It will be seen that not only were most of the countries of Western Europe represented, as well as the United States, Australia, New Zealand, and Japan, but four developing countries, Chile, India, Iran and Thailand were also involved.

The importance of the inquiry to science education

The inquiry was planned at a time when in many parts of the world the nature of Science education and its contribution to a general education, as distinct from a specific training, were being closely examined. The traditional patterns of science teaching, affecting both subject content and methods of learning, were giving way to new programs, often under the stimulus of curriculum projects organized on a large scale and employing new approaches to curriculum reform. It is true to say that the inquiry was made at an important stage in the history of Science education and that the results obtained will be viewed with great interest and may influence considerably the direction of future progress.
In this changing pattern certain aspects stand out:

- Traditional content is frequently being pruned away, and new and sometimes untried topics are being substituted.
- Methods are changing, too. From quite an early age a spirit of inquiry and investigation is being infused into the work. As a result the methods of study and the attitudes developed are considered to be least as important as the knowledge acquired.

Changing methods are linked with the nature and extent of the practical experience provided in the laboratory. Countries and schools within countries would appear to differ markedly in their emphasis on laboratory experience. The outcomes of these differences in practice, which stem from financial considerations and the level of technological development in the area or country concerned as well as from an approach to Science education, are of considerable pedagogical importance.

It is clear that although the IEA study was made at a time when Science education was in a state of flux, which imposed serious difficulties when the procedures for a large-scale, objective, comparative study were being worked out, it came at a time when the findings of such a study would be most valuable.

The construction of the instruments for the science project

For the construction of the cognitive tests in Science, it was first necessary to obtain as complete a view as possible of the curricula in Science in the participating countries at the three levels of testing: 10-year-olds, 14-year-olds, and the pre-university grade. The International Committee prepared a tentative grid of content areas and objectives and circulated this to national committees, asking them to extend it on either axis and to complete it according to what was taught at the actual pre-university grade and at the modal grade level for the cases of the chronologically defined populations. Four methods of content analysis were suggested for preparing the national grids:

- of the major text books,
- of national examinations where they existed for the target populations,
- of the subject content which groups of teachers (for example, in schools of different types) said they taught, and
- of national or regional syllabuses.

The various national grids were merged into a total international grid. A set of ratings for each cell was then obtained from each national committee, concerning the amount of emphasis given to the cell in the teaching of Science for the target population in question. At the same time the hypotheses that were of particular interest to the International Science Committee were formulated to give a focus to the investigation.

On the basis of the ratings and the hypotheses advanced for testing, the International Science Committee, in collaboration with the national committees decided which cells to test. Items were then supplied from existing tests or were written by members of both the national committees and the International Science Committees. All items from existing tests proved to be in need of editing by the International Committee. Particular emphasis was placed on producing items measuring the higher cognitive skills (See Bloom, 1956) and those testing special abilities such as the design of experiments or the handling of scientific apparatus.

Items were first selected from the point of view of their coverage of the subject area to be tested and, as far as possible, with equal representation from the contributing countries. The final decision for the inclusion or exclusion of an item depended in each case on whether the item, in the Committee's opinion, was potentially a good one. All the items to be used were then put into a multiple-choice form with five alternative responses, and new items were devised to fill in the most obvious gaps in subject area coverage. Rough drafts of these initial tests were then sent to all national centers for comment. After replies were received, pre-test versions were prepared. In all, just over 1600 items were pre-tested in order to construct the final tests which contained about 400 items.

Pre-testing of items was carried out by sixteen countries early in 1968. The testing load was kept manageable by rotating among countries the different parallel forms of the trial tests. Before undertaking the pre-testing, national centers were given advice on how to deal with difficulties of translation, the use of popular and scientific terms and units, and the substitution of local plants, animals, and materials for any in the items that would be unfamiliar.

The students' responses from this pre-testing, which was carried out on judgment samples of 100-200 students for each population and sub-test, were analyzed by national centers and submitted to IEA Headquarters where they were collated. The final selection of items and their arrangement in the tests was carried out by the International Science Committee at a meeting in July 1968. The items for each cell to be tested were selected in terms of their face validity and their statistical characteristics which were obtained from the item analysis. In the final tests, there were eleven items that were common to Populations I and II and twenty that were common to Populations II and IV.

It was felt that the International Science Committee should make an attempt to assess the students ability to understand the nature and methods of Science. To this end, a test which drew heavily on the TOUS test developed by Cooley and Klopfer (1961) was compiled and pre-tested in late 1968. Comments were received from eleven countries and full pre-test results, including item analyses, from eight. On the basis of these data, it was decided to include in the test battery tests on "Understanding the Nature of Science" for use with Populations II and IV respectively.

One of the major differences between countries in their approaches to the teaching of Science was in regard to the place accorded to practical work in the laboratory or field. Many of the new developments in Science education are concerned with the question of the nature and extent of the first-hand experiences that are considered desirable during the study of Science at school. In fact, one of the most important hypotheses to be tested by the Science project was that students learning Science through actual enquiry and by sound scientific methods would achieve higher total Science scores than students being taught by traditional methods.

Since administering laboratory practical tests would have created difficulties in many countries, because of the demands on time, equipment, and space in the schools, it was decided to incorporate, in each of the cognitive tests for Populations II and IV, paper and pencil items aimed at measuring the results of practical experiences. Laboratory tests requiring a minimum of apparatus were also prepared, but it was optional for countries to administer these tests to their samples of students.

As well as a total score for Science, for Population II for example, there were also sub-scores available as follows: Theoretical Science, Biology, Chemistry, Physics, and Practical Science. Furthermore, there were also sub-scores on the behavioral objectives: (a) functional information, (b) comprehension, (c) application, and (d) higher process.

Attitude and Descriptive Scales

The project also attempted to assess certain non-cognitive outcomes of Science education - in particular, interest in Science and engagement in scientific activities, attitudes concerning the place of Science in the modern world, and attitudes towards schooling. In addition, items and scales were prepared to assess emphasis on laboratory work, on investigation and inquiry, on the use of the textbook, and to measure aspects of the school environment. Unfortunately these attempts to assess non-cognitive features of Science education proved for one reason or another to be rather unsatisfactory.

The Questionnaires

The most important tools for obtaining information on the inputs into the educational system - the teaching objectives, the classroom practices, and background of the students - were the questionnaires. It was decided that all students would be asked, among other things, to give information on their home backgrounds, subjects being studied at present, and outside activities; teachers of Science in each school would be questioned about their training, use of teaching time, organization of material, and other teaching activities; and school principals would be requested to supply information about school organization, enrollment, finance available, and so on. These questionnaires were pre-tested in 1968 and final forms were produced in 1969.

In addition, a National Case Study Questionnaire was devised to be completed by each national center. Each country was requested to submit appropriate parts of the questionnaire to experts in national educational policy, economics, sociology, and demography. The data from each country could thus be examined in relation to the social, economic, and cultural milieu from which they were obtained.

Data Collection

To make the whole study which involved assessment in six subject areas practically manageable, the work was split into three stages: Stage 1 was the instrument construction described above, Stage 2 was the international testing in Science, Reading Comprehension and Literature, and Stage 3 was the testing in French and English, as Foreign Languages, and Civic Education. Each national center appointed a National Technical Officer to be fully responsible for the day-to-day administration of the program.

Manuals were written by the staff of the IEA Headquarters for National Technical Officers, school coordinators, and test administrators, detailing the exact steps to be taken in carrying out the testing. MRC (Measurement Research Council) answer cards were prepared and national centers given the choice of having students answer directly on the cards, which could then be read by machine, or answering in the test booklets and then having the answers transferred to punched cards at the national centers. All instruments and the manuals for school coordinators and test administrators had to be translated by the national centers. A check on the accuracy of the translations of these instruments was kept by requesting back translations of certain sections.

A dry-run was held on judgment samples with Stage 2 instruments to test administrative procedures and to detect any unforeseen problems. Appropriate adjustments were then made and work begun on the main testing. Stage 2 main testing was carried out between January 1970 and February 1971, and Stage 3 between February 1971 and February 1972.
The schools and students to be tested were selected by the national centers by means of stratified probability sampling. The object was to have the standard errors of sampling for national mean values as small as possible at the least cost. Sampling plans were devised so that every student in the defined population had a specified non-zero chance of entering into the sample. All sampling plans were checked by an international sampling referee, and then the schools chosen were approached. Each national center had available a secondary list from which to supply replacements for those schools which declined to participate.

Data Analysis

The data were edited, sorted and filed by the IEA New York data processing unit. Total scores and sub-scores for each student for all criteria were then computed. Unfortunately, in one or two instruments and for one or two population levels, scoring errors occured, with the result that some of the Science classroom descriptive scales and the Test on Understanding Science at Population IV level had to be dropped from any further analyses.
For each population, country by country. weighted means, standard deviations, and frequency distributions were produced. Weighting was applied for each stratum employed in the sampling plan to allow for any shortfall of schools or students within the stratum.
A report on the cognitive test scores for each school, comparing their results with those for similar schools in the country and with all schools within the country, was sent to each of the participating schools by its national center. Furthermore, item analyses were produced for each test for each country.
For each population tested, student, teacher, and school files were prepared in New York and sent to Stockholm where the main work of the bivariate and multivariate analyses was carried out. The necessary transformations on all variables were undertaken. and between-students and between-schools correlations were computed using existing pairs. Whereas the data for students were weighted for the student univariate and bivariate analyses, in the between-schools analyses initially unweighted data were used, but subsequently the data were weighted.
In carrying out the regression analyses, essentially two types of analysis were made. In the first set of analyses characteristics of students, teachers, and schools were examined in relation to achievement test scores, using students as the unit of analysis. In the second set of analyses the same variables were examined, using schools as the unit of analysis.
The first step in the between-schools analyses was to form a weighted composite of six variables representing the long-term home effects. This composite included the variables: father's occupation, father's education, mother's education, number of books in the home, use of a dictionary in the home, and size of family, scored negatively. Thus in the between-schools analysis this composite variable indicated

the socio-economic and cultural level of the community in which the school was set.
The effects of this composite score, referred to as a School Handicap Score (using a yachting analogy), were regressed out from the zero-order correlations between the independent variables and the total Science criterion score. In a second step standardized partial regression coefficients were obtained making allowance for the Type of Educational Program provided by the school or for the Type of School involved. In this way the schools were given a handicap, using regression analysis procedures, according to the nature of the community the schools served and the type of program they offered. A school was to be judged in terms of the factors contributing to the achievement of its members after allowance had been made for the home background of its students and its type of program.
A reduced list of predictor variables was produced for each population for each population for each country, containing those variables having large partial regression coefficients, when errors of measurement arising from the size of sample employed and other sources were borne in mind. A distinction was also made between variables that were found to be important for all countries and variables that were unique to specific countries. For each population these variables were clustered together to form meaningful composites, using national weights based on the size of the partial regression coefficients after the effects of the School Handicap Score and Type of Program had been allowed for.
The variables or cluster of variables were then grouped into blocks in a predetermined order. The general strategy was to enter into the regression analysis first the long-term home variables, then the type of school and type of program variables, followed by the learning conditions, including the student characteristics, the teacher variables, and the school organization variables, and with the kindred or allied variables entered last.
In the multiple regression runs, a variable was permitted to enter the analyses if its level of significance exceeded a prescribed value ($F = 2.0$). Furthermore, the increase in variance accounted for by each block variables was computed, as well as the standardized partial regression coefficient for each variable which entered the regression equation. The main results of interest are of course the regression coefficient for each variable and the variance accounted for by the blocks of variables that were entered into the regression equation in a causal or logical order.

2. Paper given at seminar

I wish to talk today about some of the results of the IEA Science Project. We were interested in carrying out a survey across countries to try to determine the factors in the educative process which influenced the achievement of students in Science. While for some specific purpose objective tests may have severe limitations, we considered that for survey work they were the most effective and efficient means of obtaining information about student performance, provided the tests were both valid and reliable. With a project of the magnitude of this study, it was essential that the responses of the students should be machine scored and this was only possible with objective tests.

Table 1: Country-by Population Participation in the IEA Science Project
Numbers of Students and Schools with Total Science Scores (Actual Sample Sizes) 1970-1971

	Australia	Belgium FL	Belgium FR	Chile	England	F R G	Finland	France	Hungary	India	Iran	Italy	Japan	Netherland	New Zealand	Scotland	Sweden	Thailand	U S A
Population I																			
Schools		32	33	81	162	68	97		152	176	53	264	250	60		105	98	27	259
Students		715	764	1470	3556	1742	1290		4860	2662	1623	4508	2407	1622		2158	1982	1822	5431
Population II																			
Schools	221	31	21	103	144	83	77		210	155	33	327	196	49	74	70	95	29	137
Students	5292	697	562	1268	3490	2231	2267		6942	2845	1020	7363	1946	1202	1959	1980	2328	1924	3398
Population IV																			
Schools	194	18	42	72	69	80	76	141	39	124	34	242		38	69	69	139	15	110
Students	4194	467	941	1947	2181	1989	1725	3523	2828	3040	1051	1579		1138	1676	1321	2754	724	2514

OPTIONAL TESTS EMPLOYED FOR DIFFERENT POPULATIONS (X) indicates data not as yet processed

	Australia	Belgium FL	Belgium FR	Chile	England	F R G	Finland	France	Hungary	India	Iran	Italy	Japan	Netherland	New Zealand	Scotland	Sweden	Thailand	U S A
Population III					X		X										X	X	
Population IVS	X			X	X										X	X			
Practical																			
Population II					X								X						
Population IV					X														

Sometimes we felt that the project had become overwhelmingly large, since Science was only one of the six subject areas tested, but involvement in more than one subject area had clear advantages for the development of an understanding of the school systems of each country concerned. Although we tested students at the 10-year-old, 14-year-old and terminal secondary school levels, this discussion will refer mainly to Population II - the 14-year-olds, and Population IV - the group in their last year of secondary schooling.

Cross-national studies have two unique contributions to make to an understanding of educational phenomena. On the one hand, we are interested in parallel analyses within each country, in which case the countries serve as replications of an experiment and provide an opportunity to test in a broader context relationships that have been observed previously in single national systems. On the other hand, these studies make possible comparisons across countries, examining in what respects countries differ in their level of performance, and attempting to understand those differences in terms of the characteristics of the countries involved. The kinds of analyses to be presented today will sometimes be comparisons between countries, and on other occasions will involve replications of relationships from one country to the next.

In the analyses the individual countries will be identified, but it is not our purpose in this inquiry either to applaud or to point the finger at any one country with respect to its level of achievement. We are interested only in understanding; and in this context it is the nature of the country and its economic, social and educational system that we are trying to relate to the achievements of the student at school.

Included in this study were four developing countries, Chile, India, Iran, and Thailand, and their lack of economic development or of a background of universal education showed up very dramatically in their performance on the tests. The level of performance of the students in these countries was, in general, a full student standard deviation below the performance of the students in the other countries taking part in the study. This relationship was also evident in the results of the Reading Comprehension testing, suggesting that some students in these four developing countries may have had difficulty in reading the questionnaires. Consequently, their erratic answers to questionnaire and attitude scale items are likely to confound the results of certain sections of the investigation. We now face the rather serious question, in interpreting the findings for these countries, of whether the questionnaires were adequately completed by the rather limited readers who had to answer them.

Although we had doubts about the responses given by the students to some of the attitude scales and to certain items in the student questionnaire, we were more confident of the tests, particularly the Science tests. The reported reliabilities were satisfactorily high for the full tests, and indeed for many of the sub-tests, except perhaps in the developing countries where the score distributions heaped up at the lower end of the scale.

Table 2 records for the different countries at the Population II (14-year-old) level the standardized scores for the total test and the four sub-tests: Biology, Chemistry, Physics and Practical. These scores show the extent to which a country is above or below the grand mean for the developed countries, with the average

Table 2: Science Standardized Sub-test Scores for Population II (Weighted Scores by Students, Corrected for Guessing)

Number of Items / Country	Biology	Chemistry	Physics	Practical	Total
	19	19	22	20	80
Australia	0.14	0.18	0.09	0.22	0.19
Belgium (FL)	−0.29	−0.07	0.15	−0.17	−0.10
Belgium (FR)	−0.49	−0.43	−0.41	−0.54	−0.58
England	−0.16	0.04	−0.23	0.11	−0.08
F.R.G.	0.13	−0.15	0.22	0.16	0.12
Finland	0.09	−0.03	−0.27	−0.21	−0.15
Hungary	0.73	0.56	0.35	0.24	0.58
Italy	−0.20	−0.28	−0.20	−0.38	−0.33
Japan	0.46	0.62	0.77	0.49	0.75
Netherlands	−0.31	−0.56	−0.16	−0.14	−0.38
New Zealand	0.12	0.20	0.01	0.21	0.16
Scotland	−0.25	0.07	−0.13	0.07	−0.07
Sweden	−0.08	−0.07	−0.07	0.05	−0.05
United States	0.12	−0.07	−0.11	−0.11	−0.06
Standard Deviation	3.33	3.55	4.44	3.48	11.83
Developing Countries Below Grand Mean	−0.85	−0.65	−1.06	−0.69	−1.04
Chile	−0.12	−0.13	0.01	0.03	−0.07
India	−0.35	−0.03	−0.17	−0.13	−0.20
Iran	−0.17	−0.11	−0.18	−0.14	−0.19
Thailand	0.64	0.26	0.34	0.25	0.47

standard deviation for these countries being used as the scale unit. In a similar way Table 3 gives the standardized scores for the total test and the four sub-tests which are calculated from the data collected at the terminal secondary school (Population IV) level.

The four developing countries have been separated from the developed countries in both Tables 2 and 3 and it is seen that the mean scores for these countries are about a student standard deviation below the mean scores for the developed countries.

In discussing these results I would like to focus attention on the data for three countries. Our hosts today live and work in the Federal Republic of Germany, so we are particularly interested in this country's performance on the Science tests. We are also interested in the level of educational achievement in the United States, because developments in this country have during the past decade had a profound impact on Science education throughout the world. In addition, I have chosen to consider the results for Australia, because Australia is my home land and because the Australian results show a very uniform profile, slightly above the average for the developed countries, but without any marked differences in level of perfor-

Table 3: Science Standardized Sub-test Scores for Population IV
(Weighted Scores by Students, Corrected for Guessing)

Country / Number of Items	Biology	Chemistry	Physics	Practical	Total
	16	16	16	12	60
Australia	0.27	0.44	0.23	0.28	0.39
Belgium (FL)	−0.45	−0.24	−0.17	−0.30	−0.36
Belgium (FR)	−0.63	−0.31	−0.46	−0.38	−0.57
England	0.1[illegible]	0.09	0.10	0.42	0.23
F.R.G.	0.80	0.23	0.52	0.37	0.61
Finland	0.32	−0.32	−0.07	−0.27	−0.12
France	−0.26	−0.32	−0.20	−0.02	−0.26
Hungary	0.27	0.29	0.17	−0.13	0.21
Italy	−0.34	−0.52	−0.25	−0.53	−0.51
Netherlands	0.18	0.32	0.28	−0.08	0.24
New Zealand	0.60	0.77	0.45	0.79	0.82
Scotland	−0.14	0.34	0.18	0.31	0.23
Sweden	−0.21	−0.20	−0.12	−0.02	−0.18
United States	−0.55	−0.60	−0.68	−0.44	−0.73
Standard Deviation	2.92	3.27	3.75	2.60	9.86
Developing Countries Below Grand Mean	−1.16	−0.69	−0.97	−0.86	−1.17
Chile	0.12	−0.12	−0.16	0.05	−0.05
India	−0.58	−0.26	−0.10	−0.18	−0.34
Iran	0.26	0.08	−0.04	0.00	+0.09
Thailand	0.19	0.31	0.29	0.13	+0.31

mance between the four sub-tests for either Population II or Population IV (See Figures 1 and 2). For the United States, at the 14-year-old level (Population II) the profile is close to the international average, except for Biology which is slightly above average. However, at the terminal secondary school level (Population IV), the profile for the United States is always well below the international average, being highest on the practical subtest. The profiles for the Federal Republic of Germany are, in general, at both Population levels above the international average. Although this seminar is particularly concerned with the teaching of Physics, it is interesting to note that the level of performance in Germany for both Populations is somewhat lower in Chemistry than in the other branches of Science.

These results lead us to examine the reasons for such differences in the performance of the students in each country and to consider their nature and origin. It is not for us to pass judgment on the level of achievement of the students, whether it be good, bad or indifferent, but to report the relationships we observe, and to suggest to Science educators in each of the countries engaged in this inquiry that they may wish to re-examine the provision for the learning of Science in their schools in the light of these findings.

Figure 1: Science Standardized Sub-test Scores for Population II

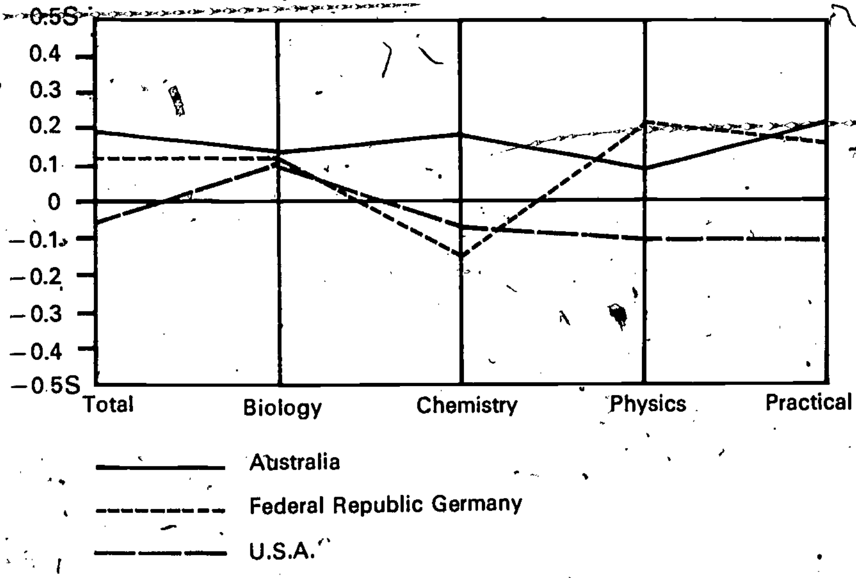
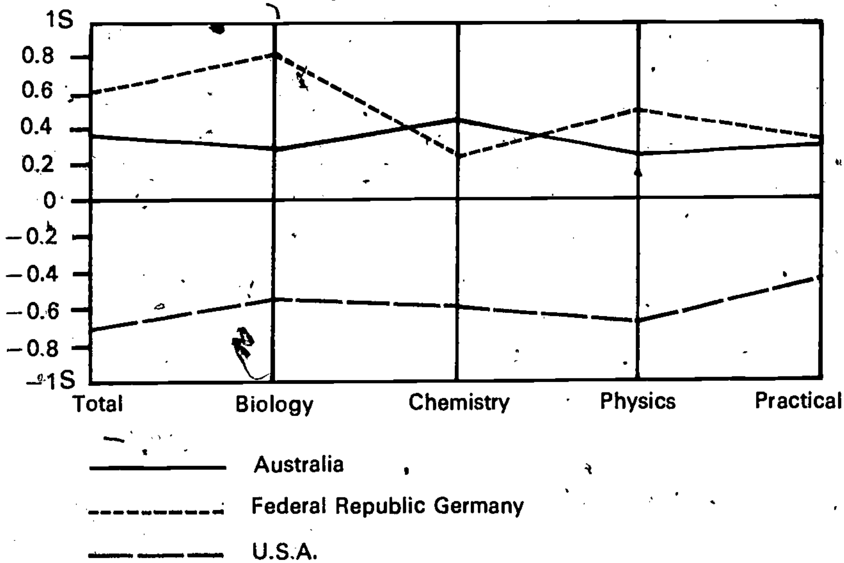


Figure 2: Science Standardized Sub-test Scores for Population IV



Opportunity to learn

In addition to testing their students, the science teachers in each school were asked to come together at about the time the testing took place to consider whether the students in their school who were answering the tests had had an opportunity to learn the content of the items. The teachers as a group were asked to rank each item on a five point scale if the following proportions of the students had covered the topic embodied in the item:

A. All students	Score: 4
B. More than 75% of the students	3
C. Between 25% and 75% of the students	2
D. Less than 25% of the students	1
E. None of the students.	0

From these scores for each school an average score per item was calculated for the test as a whole. The scores obtained for the schools in each sample were added and averaged to provide a measure of opportunity to learn the content of the Science tests for the sample.

In Table 4, the opportunity to learn scores are recorded for the Population II samples together with the total Science scores and the estimated proportions of the age group at school in each of the countries concerned. In Figure 3 a graph has been plotted of the total test scores in Science aggregated by school against opportunity to learn the items in the test. It is apparent that although considerable care was taken in checking the suitability of the test items by trial runs, the tests were more difficult than anticipated. Nevertheless, there is an approximately linear relationship between level of performance in each country and opportunity to learn the content tested. Some of the developing countries did not provide opportunity to learn scores and these countries have been excluded from the figure. In addition French-speaking Belgium had only a very small sample of 21 schools, and it is not surprising that this country does not lie close to the "line of best fit". For the remaining countries however, there would appear to be a clear relationship between the level of performance of the students in Science and the provision made for them to learn the content of the items included in the tests.

Although this relationship may reflect the nature of the tests which were constructed, indicating that they were more appropriate for use in some countries, such as Japan and Hungary, every effort was made to sample items which would represent the courses in Science in each of the countries concerned. Consequently, it must be suggested that this relationship arises from a difference in emphasis given in each of the countries to the teaching of Science at the 14-year-old age level.

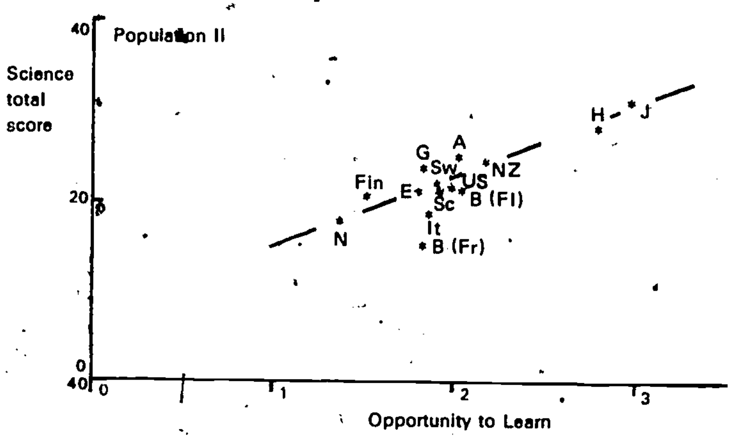
The three countries discussed earlier, Australia, the Federal Republic of Germany and the United States, are placed centrally among the other countries, both with respect to level of performance and opportunity to learn. The countries in the more extreme positions would appear to place greater or less emphasis on the learning of Science in their schools, thus providing their students with greater or less opportunities to learn, which leads in turn to a higher or lower level of performance.

With regard to the level of performance of the students in the three countries under discussion at the terminal secondary school level we have taken the examination

Table 4: Science Test Scores and Standard Deviations for Populations II and IV with Scores on Opportunity to Learn, Holding Power and Social Bias

Country	Population II				Population IV				
	Science Total Score		Opportunity to Learn	Holding Power	Science Total Score		Opportunity to Learn	Holding Power	Index of Social Bias
	Mean	S.D.			Mean	S.D.			
Maximum Score	80		4	100	60		4	100	
Australia	24.6	13.4	2.03	99	24.7	10.7	2.57	29	3.5
Belgium (FL)	15.3	8.8	1.83	90	17.4	8.1	2.02	47	2.4
Belgium (FR)	21.2	9.2	2.03	90	15.3	7.9	2.88	47	1.8
England	21.3	14.1	1.79	99	23.1	11.5	2.07	20	7.6
F.R.G.	23.7	11.5	1.82	94	26.9	8.9	3.15	9	37.7
Finland	20.5	10.6	1.51	99	19.8	9.8	2.65	21	4.8
France	–	–	–	99	18.3	8.7	2.60	29	–
Hungary	29.1	12.7	2.78	83	23.0	9.0	3.03	28	3.9
Italy	18.5	10.2	1.86	55	15.9	8.8	2.50	16	2.1
Japan	31.2	14.8	2.96	99	–	–	–	70	–
Netherlands	17.8	10.0	1.37	98	23.3	11.1	2.42	13	6.1
New Zealand	24.2	12.9	2.15	99	29.0	11.6	2.88	13	4.7
Scotland	21.4	14.2	1.90	99	23.1	12.1	2.17	17	9.9
Sweden	21.7	11.7	1.88	99	19.2	10.2	2.75	45	2.4
United States	21.6	11.6	1.98	99	13.7	9.5	2.13	75	1.3
Mean	22.3	11.8	1.99		20.9	9.9	2.56		
Chile	9.2	8.9	1.48	71	8.8	6.0	2.69	16	7.9
India	7.6	9.0	1.48	25	6.0	6.0	1.85	14	1.0
Iran	7.8	6.1	–	25	10.2	5.6	–	9	0.8
Thailand	15.6	8.1	–	40	12.4	6.1	–	10	10.4

Figure 3: Teachers' Estimates of Opportunity to Learn as Related to Science Test Scores for Population II



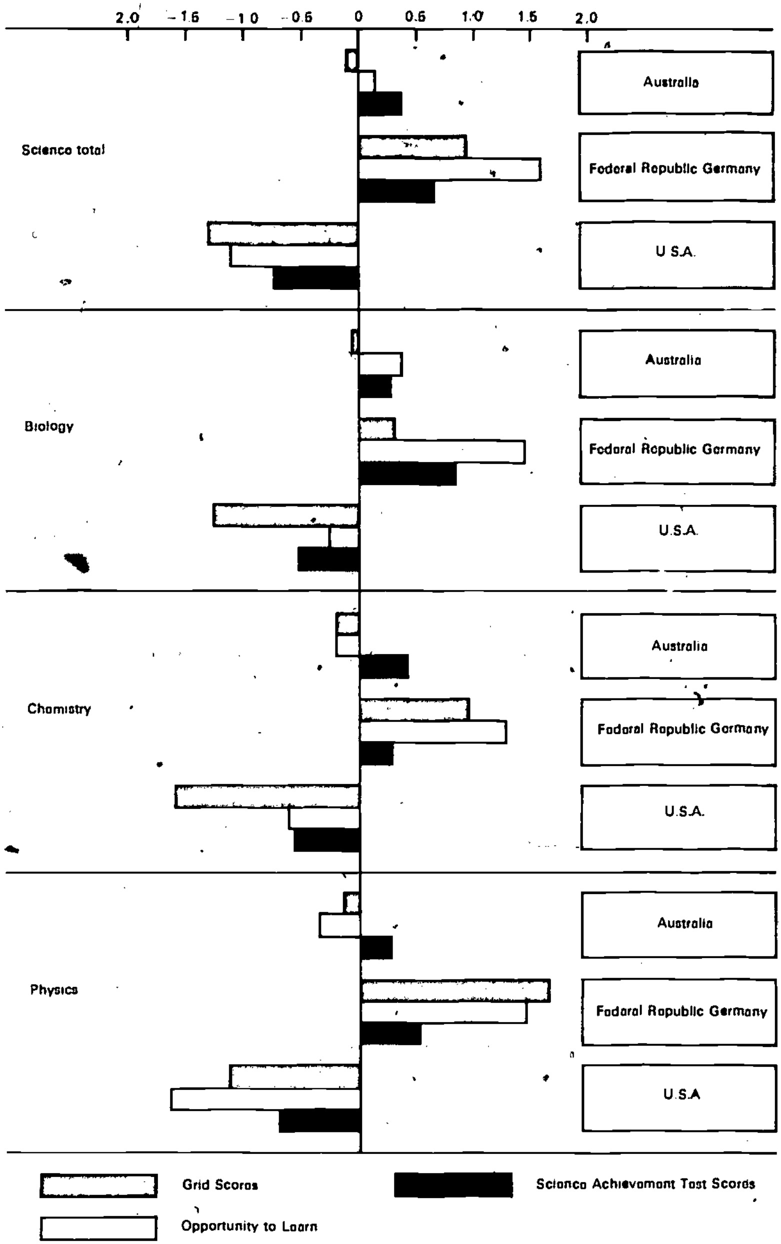
of the evidence available a step further. Not only did we have information on opportunity to learn the content tested, which was obtained from the teachers in the schools, but we also collected data on syllabuses and courses in Science at this level. Prior to the construction of the tests a grid was prepared with content along one axis and behavioral objectives along the other. The content axis was divided into the main subject areas of Earth Science, Biology, Chemistry, and Physics and further divided into topics, while the behavioral axis was subdivided into four sections: functional information, understandings, applications and higher processes, including analysis and application as outlined earlier. Each national center engaged in the Science project was asked from a consideration of syllabuses, text books and current examination papers to assign to each cell in the grid a rating for the emphasis given to Science as taught in their country. Three categories of response were used for these ratings: no emphasis - 0, moderate emphasis for some students - 1, clear emphasis for all students - 2.

From the ratings it was possible to calculate a score, assessing the emphasis given to the different branches of Science in each of the countries. These scores were standardized and have been recorded together with the test scores and opportunity to learn scores in Table 5. In Figure 4 these scores have been plotted side by side for the three countries we are considering, Australia, the Federal Republic of Germany and the United States. For the three countries concerned, there is a general level of correspondence between the three sets of scores, the grid scores assessing the prescribed curriculum, the opportunity to learn scores assessing the

Table 5: Sub-Test, Grid and Opportunity to Learn Scores for Selected Countries (Populations II and IV)

Population II Test Scores	Total	Biology	Chemistry	Physics	Practical
Australia	0.19	0.14	0.18	0.09	0.22
F.R.G.	0.12	0.13	−0.15	0.22	0.16
United States	−0.06	0.12	−0.07	−0.11	−0.11
Population IV Test Scores					
Australia	0.39	0.27	0.44	0.23	0.2[illegible]
F.R.G.	0.61	0.80	0.23	0.52	0.37
United States	−0.73	−0.55	−0.60	−0.68	−0.44
Grid Scores					
Australia	−0.12	−0.05	−0.17	−0.15	–
F.R.G.	0.90	0.30	0.95	1.65	–
United States	−1.33	−1.30	−1.65	−1.17	–
Opportunity to Learn Scores					
Australia	0.18	0.36	−0.17	−0.37	0.53
F.R.G.	1.60	1.45	1.25	1.49	1.70
United States	−1.15	−0.21	−0.65	−1.65	−1.47

Figure 4. Sub-test, Grid and Opportunity to Learn Scores for Selected Countries Population IV



actual curriculum, and the test scores which assess the outcomes of Science teaching. The results indicate in general terms that level of achievement in Science is related to what is taught in the schools. Nevertheless, it does not answer the question of why in different countries there should be clear differences in the prescribed Science curricula, in the actual Science curricula of the schools, and in the level of achievement of the students.

Staying longer at school

The question must now be asked, "Why is there this marked difference in opportunity to learn and in the content of school Science courses between the three countries at the pre-university level: Australia, the Federal Republic of Germany, and the United States?" These three countries differ in the percentage of an age group remaining at school to the terminal stage. In the United States the proportion of the age group attending school, given as holding power in Table 4, is high (75%). In Australia there is a lesser proportion (29%), and the Federal Republic of Germany, where only those students attending a Gymnasium were included in the sample, the proportion is 9%. It should be noted, however, that in the Federal Republic of Germany a further section of the age cohort are engaged in other forms of education, but are not following academic courses in preparation for university entry.

Where a large proportion of the age group is still at school, a different kind of education in Science must be provided. The differences between countries in prescribed curricula, opportunity to learn and level of achievement in Science indicate that groups of students of different ranges of ability are being considered in the different countries. In the Federal Republic of Germany an academic élite is being taught in the Gymnasia with highly advanced courses. In the United States the group is of lower ability and the courses in Science are necessarily more general. In Australia the pattern of relationships suggests that the ability of the group lies somewhere in between and the Science courses are designed to suit this group.

It is also of considerable interest to examine (See Table 4) the differences across countries in social class composition between the 14-year-old students and those remaining at school to the pre-university level. Because of the difficulty of finding an internationally valid occupational scale to indicate social class, each country used a national set of occupational categories. Nevertheless, it was possible to collapse categories for all countries into four major groups: unskilled and semi-skilled workers (D), skilled workers (C), clerical workers (B), and professional or managerial workers (A). An index of social bias was calculated using the proportions in the highest and lowest occupational groups by means of the following formula:

Index of Social Bias =

$$\frac{\%\text{in Group D for Population II}}{\%\text{in Group A for Population II}} \times \frac{\%\text{in Group A for Population IV}}{\%\text{in Group D for Population IV.}}$$

In Table 4 the proportions of an age group at school at the 14-years-old and pre-university levels are given. The marked differences between the developing countries and the developed countries should be noted, as should the differences between countries at the pre-university level. The column of figures on the extreme right-hand side in Table 4 gives the indices of social bias, and shows some quite striking differences between countries. As might be expected from the proportions of the age group remaining at school to the pre-university level the index is low in the United States, higher in Australia and very high in the Federal Republic of Germany. This index reveals the nature and extent of differences in the level of equality of educational opportunity across different occupational groups in each country up to the end of secondary schooling. It must be noted, however, that differences in the definition of the target population at the pre-university level account in part for the differences recorded between countries in their index of social bias.

It is often argued that, by extending the ability range at the pre-university level and by having a higher proportion of the age-group remaining at school to the terminal secondary school stage, there is not only a lowering of the average level of achievement of the group as might be expected, but that the performance of the most able students also suffers. It is suggested that expanding the numbers at school at the upper secondary level leads to a decline in standards and that "more means worse".

Table 6 records the data for each country and shows the percentage of an age group

Table 6: Level of Performance of Various Percentages of an Age Group in Science in Final Secondary School Year (Population IV)

	% in school	overall mean	overall s.d*	top 1% mean	top 1% s.d	top 5% mean	top 5% s.d	top 9% mean	top 9% s.d
Australia	29	26.1	11.5	51.5	3.2	44.0	4.7	39.9	5.9
England	20	24.4	12.4	51.6	3.2	41.6	6.5	35.5	8.5
New Zealand	25	30.8	12.6	55.1	2.0	48.3	4.3	44.4	5.6
Scotland	17	24.4	12.9	50.7	3.8	40.6	6.4	34.4	8.7
U.S.A.	75	14.2	9.9	45.8	2.8	36.8	5.5	33.1	5.9
Fed.Rep.Germany	9	28.4	9.6	45.0	4.1	35.3	6.2	28.4	9.6
Finland	21	20.8	10.5	46.0	4.1	35.7	6.4	30.7	7.4
France	29	19.1	9.1	40.5	3.5	33.3	4.4	29.9	5.1
Hungary	28	24.0	9.6	48.0	3.8	39.0	5.4	35.0	6.1
Sweden	45	20.1	10.9	49.5	3.4	41.2	5.3	37.0	6.2
Belgium (Fl)	47	18.1	8.5	39.8	3.7	33.0	4.0	30.5	4.2
Belgium (Fr)	47	16.0	8.3	36.2	2.0	30.9	3.1	28.4	3.7
Italy	16	16.5	9.2	38.2	4.7	27.4	6.5	22.7	7.3
Netherlands	13	24.4	12.0	47.1	3.6	37.2	6.5	30.3	9.4
Chile	16	9.3	6.3	23.5	3.8	16.8	4.3	13.6	4.8
India	14	6.3	6.1	20.8	3.7	12.8	4.8	9.5	5.2
Iran	9	10.8	5.9	21.9	3.6	14.8	4.4	10.8	5.9
Thailand	10	12.5	6.1	23.3	2.4	17.4	3.6	13.6	5.3
Rank order r*	1.00	0.07		0.35		0.40		0.57	

* Rank order correlation between percentage in age group in school and the mean scores for the various groups of students.

in school at the pre-university level, together with the means and standard deviations for the samples tested. In addition, the means and standard deviations for the top 1%, 5%, and 9% of the age group in the countries concerned have been given. In the calculation of these figures it is assumed that the students still at school would perform at a higher level in Science than those not in school. If, on the one hand, we compare the evidence presented for Australia, the Federal Republic of Germany and the United States, it is clear that the larger the percentage still in school, the lower the level of performance. On the other hand, if we examine the data for the top 1%, 5% and 9% of the age group for the Federal Republic of Germany and the United States, the performance of these groups is much the same in the two countries, but is slightly greater in Australia.

Other factors are almost certainly involved in accounting for the differences observed. The evidence from other analyses carried out indicates that the proportion of the group at school studying Science, the number of years during which the students have studied Science, whether or not they have studied or are studying all branches of Science, and the time spent currently studying Science all contribute to achievement in Science at the terminal secondary school stage.

By carrying through a higher proportion of the age group to the pre-university level and fostering the study of Science at this level, the number of persons in a country with a knowledge of Science is increased. Such a result is not unexpected. It is, however, important to note that this rise in productivity of the school system with respect to scientific knowledge can be undertaken without a marked decline in the level of performance of the more able top 1% of the students. Where the students in a country perform well in Science and where the level of achievement of the different percentage groups is relatively high, for example in New Zealand and Australia, we must seek an explanation in terms of emphasis placed on the teaching and learning of Science at the upper secondary school level in the countries concerned.

To assist in the identification of factors contributing to level of achievement within each of the countries engaged in this inquiry, regression analyses have been carried out using both the schools and the students as the units of analysis. The identification of important variables contributing to variation in achievement in Science, both between schools within a country and also between the students within a country, depends in part on the manner in which the school system is organized and how its organization influences the amount of variation that exists. For a discussion of the results of these aspects of the investigation, the reader is referred to the published report on the project (Comber and Keeves, 1973).

In conclusion, it must be emphasized that in this inquiry an immense body of potentially valuable data have been gathered, far more than can be summarized in a brief discussion. It will take many years to sift through the evidence available and I hope that from time to time attention will be drawn to valuable findings emerging from this study.

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Discussion

QUESTION: Did the translation of the question influence the results of the tests?
J. R. KEEVES: replied that the questions were originally written in English and then translated into other languages. Using the item analysis data, the items were examined for marked differences between countries. A marked difference was observed between countries in the item characteristics for one item at the 10-year-old (Population I) level, and it is possible that a translation problem was associated with the different patterns of results for this item across the different countries. The items will be published in full in the final report, with some data on the item characteristics.
QUESTION: Have the students within a country at the Population I and II levels had equivalent periods of education?
J. R. KEEVES: explained that Populations I and II were really age groups, not grade groups, except in Japan, where there are definite promotion procedures, with all the 14-year-olds being located in one grade. Consequently, in most countries the students tested may have had different periods of education.
QUESTION: Was television viewing found to influence achievement in Science?
J. R. KEEVES: Yes, in the United States where for example, the viewing of TV programs associated with history, travel, nature and scientific development was found to be positively related to achievement in Science, after the effects of home background and type of school had been taken into account. Information on this variable was not available in the analyses carried out for the Federal Republic of Germany, since Germany did not administer the Reading Comprehension tests.
QUESTION: What steps were taken to ensure that the questions used would be fair to students in all countries?
J. R. KEEVES: replied that in the construction of the tests representatives of 9 countries were involved in editing and selecting items. In addition, all countries engaged in the study were asked to submit items for the tests, and draft forms of the tests were given a trial with representative samples of 200 students in 16 countries. Unfortunately no representatives from any of the four developing countries were engaged in the construction of the tests, and not all of the developing countries were involved in the trial testing. Students in these countries clearly found the tests very difficult.
QUESTION: Were the geographical differences within a country, for example in Italy, considered in the analyses?
J. R. KEEVES: replied that in Italy the sample was stratified between the north, the center and the south. In the regression analyses the type of school variable made a distinction between the northern, central and southern schools, and when entered into the analyses was found to be significant.
QUESTION: What influences does the study show as important in regard to performance on the Science achievement tests?
J. R. KEEVES: replied that although work on the regression analyses was still in progress the evidence to date suggests that at least three factors are important, if the contribution of the schools is considered after allowance has been made for

home background and the type of school attended or tape of program followed. These three factors were:

1. The time devoted to learning Science both in terms of hours per week and years over which Science had been studied.
2. Time spent on homework, both in all subjects and in Science itself.
3. The opportunity to learn the content tested.

John P. Keeves

Elizabeth A. Wood

The American National Assessment of Educational Progress in Science

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1. Preconference paper

What NAEP is

The National Assessment of Educational Progress (NAEP) is a very large project designed to obtain census-like data concerning the learned knowledge, attitudes, and skills in various subjects possessed by Americans at various age levels. By repeated sampling, our progress, or lack of it, may be discovered. According to Dr. Frank Womer, Staff Director from 1967 to 1971, "the purpose behind National Assessment is to improve the educational decision-making of legislators, board-of-education members*, professional educators, and others vitally concerned with improving American Education. It is assumed that decision-making is improved by providing information pertinent to the decision-making."

History

The concept of this vast undertaking was first proposed by Dr. Ralph W. Tyler, Director Emeritus, Center for Advanced Studies in the Behavioral Sciences at Stanford, California, in 1963, during a meeting of laymen and professional educators concerned with strengthening American education. The Carnegie Corporation of New York, a private foundation, granted funds to start the project and appointed the Exploratory Committee on Assessing the Progress of Education (ECAPE). This committee then sought advice on the design and conduct of the project, consulting teachers, administrators, school board members, and others. The aim was to be constructively helpful to the schools and to avoid possible injuries that might arise from comparing one school or school district with another. The committee also studied ways of assessing national achievement and developed a detailed plan for conducting the assessment. These tasks required four years for completion.
In 1968 the Exploratory Committee handed the results of its work to the Committee on Assessing the Progress of Education (CAPE) which then undertook to implement the recommendations of the Exploratory Committee.
National Assessment is currently funded almost entirely by the United States Office of Education, a government organization, but is not in any way governed by this office. A concern expressed by some with the governance of the project was the

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*In the United States, local School Boards or Boards of Education guide the administration of most of the schools. Such boards are commonly made up of private citizens, usually parents of school children, who serve without pay.

self-perpetuating aspect of CAPE: the fact that CAPE members were not responsible, directly or indirectly, to the people of the nation. In consideration of that concern, the Education Commission of the States was approached and asked to consider becoming the governing body for the National Assessment. In July of 1969, the ECS assumed this responsibility. The Education Commission of the States is a new and growing organization composed of seven representatives from each state which is a member, assembled to work together on educational problems of mutual concern. At present, 41 states and two territories belong to the Commission.

The present Staff Director of NAEP is Dr. J. Stanley Ahmann, formerly of the Psychology Department of Colorado State University. Requests for NAEP reports or for further information should be addressed to the Public Information Office of the National Assessment for Educational Progress, 300 Lincoln Tower, 1860 Lincoln Street, Denver, Colorado 80203, USA.

The first assessment, begun in 1969, includes ten areas: reading, writing (written expression), science, mathematics, social studies, citizenship, vocational education (career and occupational development), literature, art, and music. Other areas may be added in the second round. The present paper will focus attention on the science assessment.

Objectives

Major objectives for educational achievement in each field were outlined by groups of scholars, teachers, and curriculum specialists. The statements of objectives were chosen with three criteria in mind:

(1) reflecting accurately the contributions of the particular field,
(2) being objectives which the schools are seriously seeking to attain and
(3) considered desirable by thoughtful lay citizens.

Sample questions, called "exercises", were provided for each objective. The objectives and exercises were subsequently reviewed by eleven panels of laymen (not scholars, teachers or curriculum specialists) in various parts of the country, and very minor modifications resulted. This combined involvement of scholars, teachers, and laymen was for the purpose of ensuring that every objective toward which progress was being assessed met the three criteria given above.

The Primary Science Objectives so determined were:

a. Know fundamental facts and principles of science
b. Possess the abilities and skills needed to engage in the processes of science
c. Understand the investigative nature of science
d. Have attitudes about and appreciations of scientists, science, and consequences of science that stem from adequate understandings.

Illustrative categories

Illustrative categories were identified under each Primary Objective and a statement was made of what should be the knowledge in each category expected of 9-year olds, 13-year olds, 17-year olds, and young adults (26-35). For example, under Objective 2, one of the categories and its statements of expectations were as follows:

"Ability to obtain requisite data"

Examples of abilities which would fall within this category are the ability to assemble and use laboratory equipment in a logical sequence and the ability to make observations

Age 9. These children should be able to collect data based on simple direct observations as well as elementary experimental situations with proper direction and guidance.

Age 13. These students should be able to make direct observations of phenomena as well as some measurements of such dimensions as distance, weight, volume, and time. They should be able to make these observations or measurements under proper guidance and also independently in familiar areas.

Age 17. These students should be able to proceed independently to make reasonably careful observations and/or reasonably precise measurements in several areas following a data-collecting procedure of their own design. They should have some facility in the use of rulers, balances, and stopwatches as well as such more specialized apparatus as microscopes, electric meters, and compasses.

Adult. Adults should be able to observe phenomena directly or make measurements with simple commonly-available apparatus. These observations and measurements should be appropriately relevant and precise.

The exercises used in the assessment were chosen to test these expectations.

The nature of the exercises

A science exercise frequently consists of a question with multiple-choice answers. The data show the percentage of respondents choosing each of the possible answers.

Reporting the data

The results are not individual scores. The record of names of the assessees (the respondents) were never removed from the school building in which the exercises were administered and have now been destroyed by the principal (director) of the school. Records have been kept of various characteristics of and influences on the assessee for the purpose of grouping the data in various categories. These are as follows:

- Age
- Sex
- Region of the Country (Northeast, Southeast, Central, West). No finer division is used so that one state for example, cannot be compared with another.
- Size and Type of Community (Large Cities, above 200.000 population; Inner City Areas; Urban Fringes; Middle-sized Cities, 25.000-200.000; Small Town and Rural Areas, below 25.000; Extreme Rural Areas).
- Socio-educational Status (Various ways of determinating this without invading the privacy of the family were tried. The one used was to ask the respondent to state the highest level of education of either parent). The great concern of contemporary

society with the education of the disadvantaged young people makes it highly desirable to gather information about the knowledge and skills of that group as they exist today, so that we may evaluate future progress.

Color (for correlation with the above category and for some of the same reasons indicated in that category).

The Group Results do not, on the whole, surprise anyone. They show that older people know more facts than younger people; that males do better in most science exercises and females do better in most writing exercises, this difference increasing with age; that students in the northeast do better than students in the southeast; that children in expensive residential regions ("Urban Fringes") do better than children in poor districts of cities ("Inner City Areas"); that children whose parents had more education do better than children whose parents had less; that black children do not do as well on most exercises as do non-black children. However, the fact that the results are not surprising does not mean that it was not useful to collect the data.

Assessment repetition

The first round of assessment has now been completed. The results are like a single point on a curve. They can tell us nothing about Educational Progress. A second round of assessment will occur three years after the first round (in the academic year 1972-1973). Since the age groups are separated by a period of four years, none of the assessees of the first round will be assessed in the second round. This is an assessment of the population, not of individuals. Only 40% of the first-round exercises have been made public. The intention is to re-use the remaining 60% in the second round, in order to have data on exactly the same exercises.

In the second round, new exercises will be added. Prior to the second round, a thorough review of the administration of the first round will result in modifications of approach to National Assessment. A slightly revised set of Objectives has been written.

Some problems of attempting national assessment

Techniques of administering exercises to assessees

In order to minimize the effect of reading difficulties, the exercises were read aloud to the assessees. (It was found that this resulted in an increase of more than 25% in ability, by "low achievers", to perform the exercises.) Here, however, we come up against the problem of distractions due to the personality, voice, and appearance of the reader. Therefore the reading was recorded on tape, using a radio or television announcer with a "national television" accent, which was found "just as effective" as using a school teacher with a local accent.

Since the grouping was by ages, students had to be taken from various classroom groups and assembled in a special room for the administration of the exercises. Both the school and the individuals cooperated on a voluntary basis.

In order not to require too much time away from other activities, each "package" of exercises was limited to 50 minutes in length. Therefore, in order to sample a broad range of abilities and subject matter, twelve different packages were designed for each age level. Each assessee responded to only one package, but every exercise was used for at least 2.000 assessees. In all, about 90.000 assessees participated in the first round of the National Assessment.

A number of exercises were used for more than one age level. Sometimes this necessitated slight changes in wording of the exercise to make it more appropriate for the chosen age level.

Some decisions required preliminary trials. For example, as a result of preliminary experimental administration of exercises with and without the optional choice of "I don't know", it was decided to include this choice. Adults chose it more frequently than did any other age group.

Sampling

Since the beginning of the project, National Assessment has benefitted from the consultant services of Dr. John W. Tukey of Princeton University, internationally known statistician.

His advice has been of value, not only on ways of treating the great mass of numerical data accumulated, but also on problems of sampling. The sampling problems are of three sorts:

1. sampling of exercises from the infinite number of possibilities
2. sampling of four age groups from all possible ages
3. sampling of individual assessees from within the enormous number of people in each chosen age group

Limits were set on the total number of exercises because of limited time, which, in turn, was a result of limited funds.

The age levels were chosen to represent significant stages in the educational development of the individual. For "young adults" the age 26 was chosen as an age when most adults have completed all of their formal educational work. The age 17 was chosen as the age, when most students have completed what is know as "high school" in America, and are about to go into college. At age 13 most students are completing "elementary school", where a set program is usually followed by all students, and are entering high school where more freedom of choice is permitted and initiative is expected of the student. At age 9 most students are beginning to use books as a major educational source and are developing from being children into being students.

Sampling of the individuals within each age group was done by selecting sample areas of the country, then sample schools within these areas, then sample individuals within these schools, all with extremely conscientious effort toward randomizing of samples and assuring the statistical reliability of the results. Similar care was taken in sampling the "young adult" population, which had to be assessed at home. The samples may be confidently taken as representative of the defined populations.

Teaching toward national assessment

In the United States there is no Ministry of Education, no body which determines a national curriculum. Although some states choose textbooks for use throughout the state, others leave this choice to each school and the school may leave the choice to the teacher. Most educators feel that heterogeneity of education in the nation is a source of educational strength. When the National Assessment was proposed, fear was expressed that its exercises would become teaching goals, toward which students would be directed by their teachers. However, this possibility has been avoided by not making public those exercises that will be used in future rounds of the National Assessment. The publicized educational objectives are so broadly stated and so widely agreed upon by educators and laymen that they can hardly be considered as restricting educational freedom.

Sources of learning

Some have questioned whether the National Assessment really assessed the efficacy of our educational system. The school is not the only place where knowledge, skills, and attitudes are acquired. National Assessment exercises were not designed to distinguish between the influence of the school and the influences outside of school, of which the television is becoming increasingly important in the United States.

Interpretation

The National Assessment Staff has acted as information collectors and not as interpreters of results. They have organized the data in a variety of ways to make it digestible by scholars and educators and they have invited these people to interpret it.

The interpreters, in their turn, should avoid the temptation to make broad generalizations on the basis of isolated observations. However, there is much of interest in the great body of collected data. For the teacher, the greatest interest in the first round of results lies in answers to specific exercises, especially the wrong answers. Why would the majority of 13-year olds be unable to select, from diagrams, the correct set of objects to be used in determining the boiling point of water? Perhaps most students are not understanding diagrams in textbooks! Why did 69% of the 9-year olds indicate that mixing equal quantities of water with temperatures of 50° and 70° Fahrenheit would give water with a temperature of 120° Fahrenheit? Did the word Fahrenheit frighten them into just reading "Add 50 and 70"? Perhaps we are preventing them from relying on familiar experience when we use an unfamiliar word.

Even though we must wait for the next set of results to discover whether we are making "progress", there is information now available from the National Assessment of Educational Progress that can help us improve our teaching

2. Conference paper

The National Assessment of Educational Progress (NAEP) is a very large project designed to obtain census-like data concerning the learned knowledge, attitudes, and skills in various subjects, possessed by Americans at various age levels. By repeated sampling, our progress or lack of it may be discovered. In my pre-conference paper, I gave the history of the project and described the way in which the test instruments were constructed and administered to those chosen for testing. The sampling procedures and statistical methods are as good as our best statisticians can make them.

About 90,000 individuals responded to the questions in the first round of the National Assessment. Not all of these responded to science questions. Other areas investigated were Citizenship (knowledge of current affairs) and Writing (in the sense of written expression). Subsequently assessment has been made of Art, Music, Literature, Vocational Education, Reading, and Social Studies.

Today I shall show you samples of the questions in Science, which the National Assessment people call "Exercises". (I should say, parenthetically, that I am not on the staff of the National Assessment. I am an independent scientist, invited to evaluate their results.) Exercises have been administered to 9-year-olds, 13-year-olds, 17-year-olds, and young adults, but I shall emphasize the results from the 9- and 13-year-olds, because I think they are of more interest to this group. In discussing the exercises, I want to point out the implications I see in them for teachers of the physical science in our country.

Finally, I shall show you Group Results; comparisons between city children and country children, boys and girls, blacks and non-blacks.

The science questions were designed to assess education in four major categories, identified as worthy objectives by teams of scientists, teachers, and laymen. Briefly stated, these objectives were:

That the individual should

I. Know the fundamental facts and principles of science
II. Possess the abilities and skills needed to engage in the processes of science
III. Understand the investigative nature of science
IV. Have attitudes about and appreciation of scientists, science, and the consequences of science that stem from adequate understanding

The National Assessment staff wanted nearly equal numbers of exercises in the four categories, but the professional testing services producing the questions produced most of them in the category of facts and fewer in the important later categories where the difficulty of writing good exercises increases. There will be more exercises in the later categories in the second round of assessment.

Let us begin with three exercises administered to 9-year-olds, to test their knowledge of the facts and principles of science.

Excercise 104:

All of the following can be burned in the fireplace EXCEPT

Age 9		
89%	●	iron
2%	o	leaves
2%	o	paper
6%	o	wood
0%	o	I don't know
1%		No response
100%		

The students are asked to choose the one substance that cannot be burned in the fireplace. They are permitted to choose "I don't know".

Note the manner in which the results are presented. There are not scores of individuals, as in most examinations. No permanent record is kept of performance by individuals, or even by schools. In order to ensure the cooperation of the schools, it was essential that they not feel any anxiety about being held up for public comparison.

The results show the percentage of the whole group that chose each of the possible answers. Remember that this exercise, like all the others, was performed by at least 2.000 children.

In the reported results, the correct answer is marked by a black dot. It is significant I think, that 10 percent of the respondents chose substances that can be burned in a fireplace; 6 percent of them choosing the commonest, wood. This suggests to me a habit of careless reading. The student glances quickly at the words "burned" and "fireplace" and checks "wood", because he has learned that he must give quick answers. How long does a teacher wait after asking the class a question? One or two seconds of silence is about all that most teachers can bear. How often is a student given unlimited time on an examination? Perhaps these ten percent who gave wrong answers are being pushed too fast and are learning to jump at any answer rather than take time to think.

There is another possible interpretation. Some of the children had never seen a fireplace. When a group analysis was made of this exercise, it was found that the percent of inner city children (children in the city slums) who answered this question correctly was 28 percent below the national average.

Exercise 109:

Nearly all rocks on the Earth's surface are

Age 9		
5%	o	gas
6%	o	liquid
84%	●	solid
4%	o	I don't know
0%		No response
100%		

One could hardly think of a simpler question that to ask whether a rock is gas, liquid, or solid! But 15 percent of our 9-year-olds did not give the right answer.

Is it possible that some of the children are just guessing the answers at random or mischievously checking wrong answers since they know they will not receive grades for these examinations? Probably not, since the percentage answering some questions correctly is very high. For example, in a question about where a baby comes from, 92 percent of 9-year-olds chose the correct answer, that it comes from its mother's body. So we need to seek further concerning the rock answer. If "gas", "liquid", "solid" and "rock" are words that 9-year-olds do not understand, text book writers should keep this in mind.

Turning to the 13-year-old group, let us look at the results of an exercise on kinetic theory of heat.

Exercise 49

Which of the following is true of hot water as compared with cold water?

Age 13	Adult		
9%	6%	o	It is denser
3%	2%	o	It is easier to see through
61%	49%	●	Its molecules are moving faster
9%	4%	o	It has more free oxygen dissolved in it.
6%	5%	o	It has more free hydrogen dissolved in it.
12%	32%	o	I don't know
0%	1%		No response
100%	99%		

This exercise was also administered to young adults (26-35). In nearly all exercises, we find the adult group is more willing to say "I don't know" than in any other age group - especially the 17-year-olds.
Only 49% of the adults chose the correct response in this exercise, but 61% of 13-year-olds chose it. Is it a cause for rejoicing because we are teaching the coming generation better than their elders were taught? Not when we discover their answers to the question, "Why do we think that matter is made up of atoms?"

Exercise 224

Why do we think that matter is made up of atoms?

Age 13		
41%	o	We can see atoms with a microscope
1%	o	We can see atoms with our unaided eyes.
2%	o	We can see atoms with a magnifying glass
34%	●	Matter behaves as if it were made up of atoms.
10%	o	A famous wise man said many hundreds of years ago that matter is made up of atoms
11%	o	I don't know
0%		No response
99%		

We find that 41 percent of them think that you can see atoms with a microscope and another 3 percent think you don't even need a microscope! When will we learn to postpone the teaching of the unobservables until senior high school or even college? Rote learning about kinetic energy is worse than meaningless for these students. It teaches them the habit of accepting authority in science and this gives them a false concept of the nature of the scientific enterprise. In the early years science teaching should mean teaching careful observation and critical evaluation of one's observations; the process of asking simple questions for which one can make simple, testable hypotheses. This is the essence of science and a slow, careful training along such lines will be the best foundation for a scientist or a liberally educated citizen in today's world.

Consider, next, some exercises to test the abilities and skills needed to engage in the processes of science.

Can the students interpret a simple table? From a chart listing the weights of various chemical elements found in a 100-pound man, the students are asked to choose the one found in smallest amount

Exercise 4 Weights of some Chemical Elements

Found in a 100 pound Human

Calcium	2 pounds
Carbon	18 pounds
Hydrogen	1P pounds
Oxygen	64 pounds
Phosphorus	14 ounces
Sodium	2 ounces
Sulfur	4 ounces

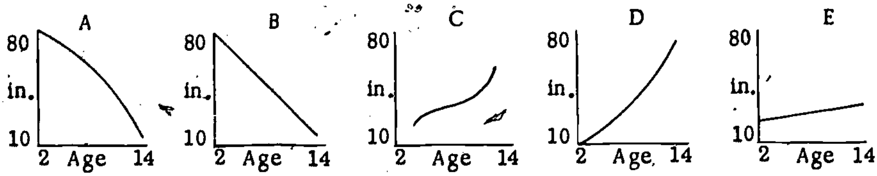
From the chart above, which of the following chemical elements is found in the SMALLEST amount in the body?

Age 9	Age 13		
14%	3%	o	Calcium
5%	3%	o	Carbon
8%	4%	o	Hydrogen
54%	81%	●	Sodium
7%	6%	o	Sulfur
11%	2%	o	I don't know
1%	1%		No response
100%	100%		

This exercise was administered to both 9-year-olds and 13-year-olds. We see that at 9 years old, 14 percent chose the first low number (2 pounds) instead of the lowest weight (2 ounces) and 12 percent found the table too difficult to try. For the 13-year-olds, the percentages were 3 and 3. Remember, these are not the same children, grown older. Both of these groups were tested three years ago. Will the 13-year-olds being tested this year do better or worse? That is one of the things the National Assessment wants to find out. This exercise will not be used again, but another of similar type will be used. Sixty percent of the questions used in the first round of assessment have been kept secret for re-use in the second round. The forty percent that have been made public will not be re-used. Otherwise some teachers might be tempted to drill their students in the answers to these questions instead of educating them in the spirit of scientific enquiry.

Exercise 44

Which of the following graphs could show the average height in inches of a group of children growing at a normal rate plotted against their age in years?



Age 13	Adult		
16%	6%	o	A
14%	9%	o	B
27%	39%	●	C
16%	18%	o	D
10%	9%	o	E
16%	16%	o	I don't know
0%	3%		No response
99%	100%		

Can the students interpret a simple graph? In this exercise they are only asked to choose the graph that shows normal human growth rate. The ordinate is height in inches; the abscissa is age in years. The first two graphs show height decreasing with age. About a third of the 13-year-olds chose these. And so did 15 percent of the adults!

Before you use graphs to simplify information for publication, you might test your own country's adults with such an exercise.

Another exercise designed to test skills involved actually working with a balance. The respondent had to place a sliding weight in the right place to achieve balance and tell where it was placed. 64 percent of 13-year-olds gave the correct answer; 75 percent of 17-year-olds and 74 percent of adults. I hope that my butcher was not among the 26 percent of the adults unable to perform this simple task.

An exercise given only to 17-year-olds and adults described a situation in which a population of rabbits lived by eating grass and were in turn eaten by hawks, birds which caught them and ate them. The respondents were told that some disease resulted in greatly reducing the rabbit population and asked to choose one of five possible effects on the grass and hawks, one of which was that the grass would grow taller and the hawk population would decrease. 68 percent of the 17-year-olds chose the correct answer but only 52 percent of the adults. Now here was a question that required no technical training - just the ability to reason that if there were fewer rabbits to eat the grass it would grow longer. I would like to see science courses that gave the students experience in the rational approach to a broad range of situations and confidence in their ability to use it successfully.

How do 9- and 13-year-olds measure up to the objective of understanding the investigative nature of science?

Exercise 1

Scientists would have most trouble testing which of the following?

Age 9	Age 13		
12%	6%	o	I have a fever
6%	2%	o	I weigh 101 pounds
14%	4%	o	I am 62 inches tall
13%	8%	o	I can lift a 20-pound box
38%	73%	●	My dog is better than your dog
16%	7%	o	I don't know
1%	0	o	No response
100%	100%		

In this exercise they are asked to choose the statement that scientists would have most trouble testing. I find some encouragement in seeing that 38 percent of the 9-year-olds and 73 percent of the 13-year-olds correctly chose the value jugdement as one that would be difficult to test.

Attitudes are hardest of all to assess, and there were very few exercises in this category. One attitude exercise for 13-year-olds stated that women can be successful scientists and gave the students the choice of stating that they believed this statement, did not believe it, or didn't know. I am happy to report that 94 percent of 13-year-olds believed this statement.

I have emphasized the wrong answers because, as a teacher, it seems to me that we have most to learn from them. The exercises were intentionally designed to include those which nearly everyone would get right and those which very few would get right, as well as the usual middle group. But there were surprises at both ends.

Now let us consider the Group Results. Information collected at the time of administering the exercises has enabled the National Assessment staff to group the results into categories. In each case the median performance of a particular group is compared with the national performance. We learn, for example, that respondents of all ages living in the southeastern part of our country give significantly poorer performance than the median for the country as a whole. Others whose performance is significantly below the median are those whose parents did not finish school; those living in extremely rural areas, far from any town; those in "inner cities", the poorer sections of big cities; and blacks. The reason for selecting blacks as a special group is that a special effort is being made to improve the quality of their education and we need to know whether we are making any progress.

Are the differences entirely the result of the factor identified? Parents with higher education are likely to live in the affluent suburbs, rather than in the inner city, for example.

The statisticians have used a method called "balancing" to try to take account of the interaction among the various factors identified. They freely admit that the process is full of approximations and assumptions. There is no sure way to disentangle the complex influences on people.

However, when balancing is applied, the differences among the groups in each category do decrease; though they still exist, and in the same order of rank. Perhaps, if we knew how to adjust for all the influences on individuals, the differences in performance resulting from any one influence would almost disappear.

Finally we compare males and females in two areas: science and writing. Unlike the other cases, this one does not make comparison with the national average. The sexes are compared with each other. At all ages the males do better in science and the females better writing. The differences increase with age.

When you consider the difference between the toys that are given to little girls and the toys that are given to little boys, it is surprising that the boys' advantage in science is not even greater at the age of 9. At 13, girls are sent to sewing and cooking classes when boys go to the carpenter shop. At 17, boys find a girl more attractive if she pretends not to understand science. And so it goes, getting worse and worse for the girls in science as they get older, judging from these results. Among young adults, society requires that the man understand machines and electrical equipment, and that the woman write the invitations and thank-you letters. The social pressures are strong and deep.

The National Assessment is providing us with a great deal of retrievable information that we have never had before. The later rounds of the assessment will make possible a variety of interesting comparisons. However, as a teacher, I see much in the individual exercises of the first round that can be put to immediate use to improve our teaching of science.

Further information can be obtained from: The National Assessment of Educational Progress, Education Commission of the States, 300 Lincoln Tower, 1860 Lincoln Street, Denver, Colorado 80203, USA. Report number 1 gives all the science exercises that have been released for publication from the first round of exercises, with percentages of population giving each answer, as in this paper. It includes some summaries of results. Report number 4 gives group results for sex, region, and size of community. Report number 7 gives group results by color, size and type of community, and parental education. These may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, USA. (No. 1, \$ 1.75. No. 4, \$ 1.00. No. 7 will be available soon from the same source.)

Discussion

The discussion deals with the various results of NAEP separately.

Exercise 104

Mrs. WOOD points to the fact that 6% of the pupils believe that wood cannot be burnt in a fireplace. She explains it by rapid, careless reading of the exercise and, as regards the group of poorer people, a lack of appropriate experience within everyday life. Mr. BAEZ and Mr. ROGERS consider the formulation of the question to be confusing and misleading by the use of the word "except". "I have 120 dollars except the 100", Mr. ROGERS says. Besides wood will not be burnt completely. He suggests to change the wording from "can be burnt" to "can burn". They propose a new formulation "some materials of the following can burn, some cannot. Which cannot burn?".

Mrs. WOOD answers

1. that she did not formulate the questions (she is no member of NAEP, but an independent scientist invited by NAEP to interpret the results),
2. that the writing of examination questions is difficult and that all the questions are under constant attack and revision by NAEP itself, but
3. she feels, nevertheless, that students ought to be able to understand such a sentence.

Exercise 224

41% of the 13-year-olds had answered that one can see atoms with a microscope. The audience suggested two additional explanations:

1. Brownian motion was possibly shown to the pupils, which they understood as the motion of single molecules
2. Text books perhaps contain informations about field emission microscopes.

Exercise 4

Some people doubted that abilities and skills are more necessary - as NAEP felt - for the solution of this exercise than the knowledge of facts. As regards the relatively poor results, it was commented that

1. the amount of reading required for this exercise is great,
2. it might be confusing during the stress situation of the exercise that not always the same weight unit is used.

Mrs. WOOD feels that reading a table of data predominantly demands abilities and skills, not knowledge of facts; she points out that this table of data is a real-life example. In English-unit countries, weight is commonly given in both pounds and ounces.

Group Results

Mrs. WOOD comments that at the age of 17 it was intended to have 2 groups, the drop-outs and those ones who are still in school. As NAEP got very few drop-outs to to take the exercises, they felt that it was not a statistical sample, and so they only interpreted the results of the ones in school.
It is considered that a modification of the way of teaching during the last years might have influenced the results of the various age groups, not only the age of the students by itself. Mrs. WOOD feels that the first influence was comparatively small.

VI. Experimental psychology and science instruction

Werner Kroebel

The concepts of physics in the view of cybernetics

Through cybernetics we have got the knowledge that everything which pupils learn on new things is an information for them. The concept of the information is the concept of a countable set. Every information necessarily consists of physical marks or signs, respectively, and in reality the informations are counted by counting these physical marks.

If one receives informations, for instance by reading a manuscript, then the physical marks to which the contents of the informations are associated are equal to the types of our alphabet.

There are 26 types. This number is the repertory of the chosen physical marks. Therefore we can associate 26 different informations with this quantity.

If we have to give more informations, then we have to combine several types or signs with one another. So we combine two, three, or more types on two, three, or more places to construct one mark. In this way the physical mark for one information is given as a combination of types of our alphabet. And if we combine n types to one word, we have 26^n different possibilities to do so, i.e. 26^n different physical marks for 26^n informations.

But from all these combinations - being mathematically possible - from types to words, words to sentences, and sentences to a longer text, only a restricted number of combinations really exists. For instance no meaningful word exists, which consists of three types "d" as "ddd". So we have to learn, which arrangements of types are equivalent to an existing word of our language. A feeling for the proper usage of such combinations can only be learnt by a lot of exercises, by reading manuscripts or books or by learning a talk. We may call it the syntax of types to words, furthermore of words to sentences, and sentences to texts. This syntax heavily reduces the mathematically possible number of arrangements of types, words, and sentences.

The simplest repertory of marks is a binary system. Its physical representation may be given by O and 1. The number of informations which can be associated with these marks is given by

$$N = 2^n ,$$

where n means the number of news or informations, respectively, 2 is the number of different marks within the repertory, and n the number of places within a complex mark, i.e. the "length of the word". We call n the number of informations in bit.

When we read a text, then informations flow into our mind. We measure this flux of informations in bits/sec.

In measuring this flux of information during hearing or reading, we find 90 bits/sec on an average. But many investigations show that we can only pick up 16 bits/sec in our consciousness. If we read a text with a velocity of 90 bits/sec and understand it, we must therefore know about 74 bits/sec in advance. Consequently we have to separate the text which we read into two parts: one which is known before reading and one which is unknown before. Only the latter part is called an information and they both together a news.

This fact implies that the number of marks, which we know before reading, must be reduced by a process of fusion of several marks or types, respectively, to a new mark or a new word showing a higher degree of abstraction. We call it a supermark. The capability of reading and simultaneously understanding at a flux of news of 90 bits/sec provides the capability of developing supermarks, which can be attained by an intensive training of our mind. Thereby it is important simultaneously to train the association which exists between a certain supermark and the single marks, from which it is derived.

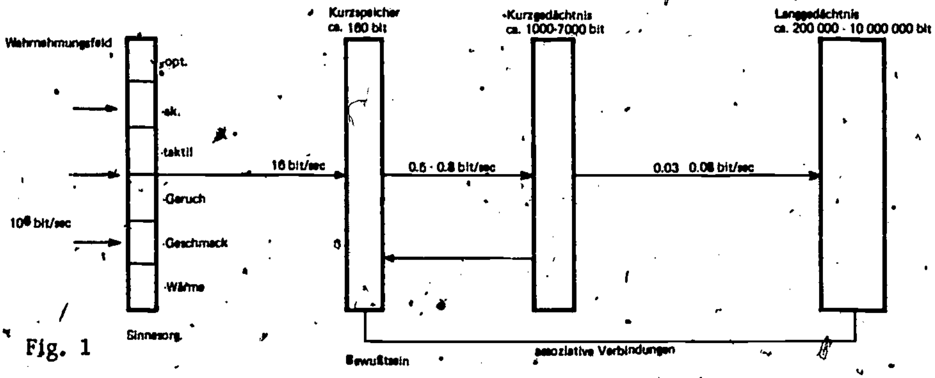


Fig. 1

Helmar Frank (1) developed a simple model to explain these facts which is shown in figure 1: The possible flux of informations into our mind only amounts to 16 bits/sec which is stored there about 10 seconds.

So we have about 160 bits of informations in our conscious mind which we can simultaneously survey; they are equivalent to 30 up to 35 concepts or imaginations. This number of concepts or imaginations, however, is not sufficient for our processes of thinking. The conscious concepts and imaginations must continously be exchanged against other ones being accumulated in our memory.

Therefore we need a method or a path, respectively, between the contents of our memory and or instant consciousness. When we think in physical laws and concepts, this path is given by means of associations between the known concrete physical phenomena, their single marks and simple concepts, and the corresponding supermarks.

The physical world in which we live shows us a vast field of very different, single, and individual phenomena. To know all these phenomena requires a vast experience. But not all phenomena which are possible from the view of mathematics exist in reality. The physical world is severely ordered by physical laws and natural facts. Therefore the development of a system of concepts, as we have it e. g. in the theory of mechanics containing the concepts of velocity, acceleration, kinetic and potential energy, the principles of mechanics etc., allows us a far reaching reduction of the great number of concrete phenomena, for instance, of all the kinds of motions. Then the concept of a velocity allows us to use this sign of motion for the infinite diversity of all the possible motions. So the concept is a supermark of a high degree of abstraction. Therefore this concept cannot directly be understood from its definition, but a knowledge of physical concepts must be attained in advance. It is a supermark which first of all has to be associated by the learning process with the above mentioned aspect of motions, which is derived from a vast field of concrete motions of very different kinds. Now we have as a basis this vast field of imaginations of concrete motions which are associated with the concept of a defined velocity or the supermark of a physical velocity, respectively. On this basis the reduction of the flux of informations, that means the reduction of the number of bits/sec, which must be perceived during the reading of a word, becomes possible.

That is why the reading of a text or book does not only require the knowledge of the definitions of the concepts of velocity, acceleration, etc., but - in analogy to a chain - requires the knowledge of each single link of the development from single marks to combined marks or supermarks, respectively, of increasing degree of abstraction.

The velocity, which a pupil has in reading a physical text he tries to understand, must be controlled so that the flux of information amounts to about 16 bits/sec. In this way we get an additional method of research to study the learning process of a pupil: by measuring his velocity of reading the marks, supermarks, etc. of a physical text before and after a lecture on this topic.

Results of such studies by Kroebel (2) are given in figure 2. It shows the dependence of the reading velocity on the text for 5 lines. The text is written left of the coordinate Z. v_r, the reading velocity, refers to one type of the read text. We have

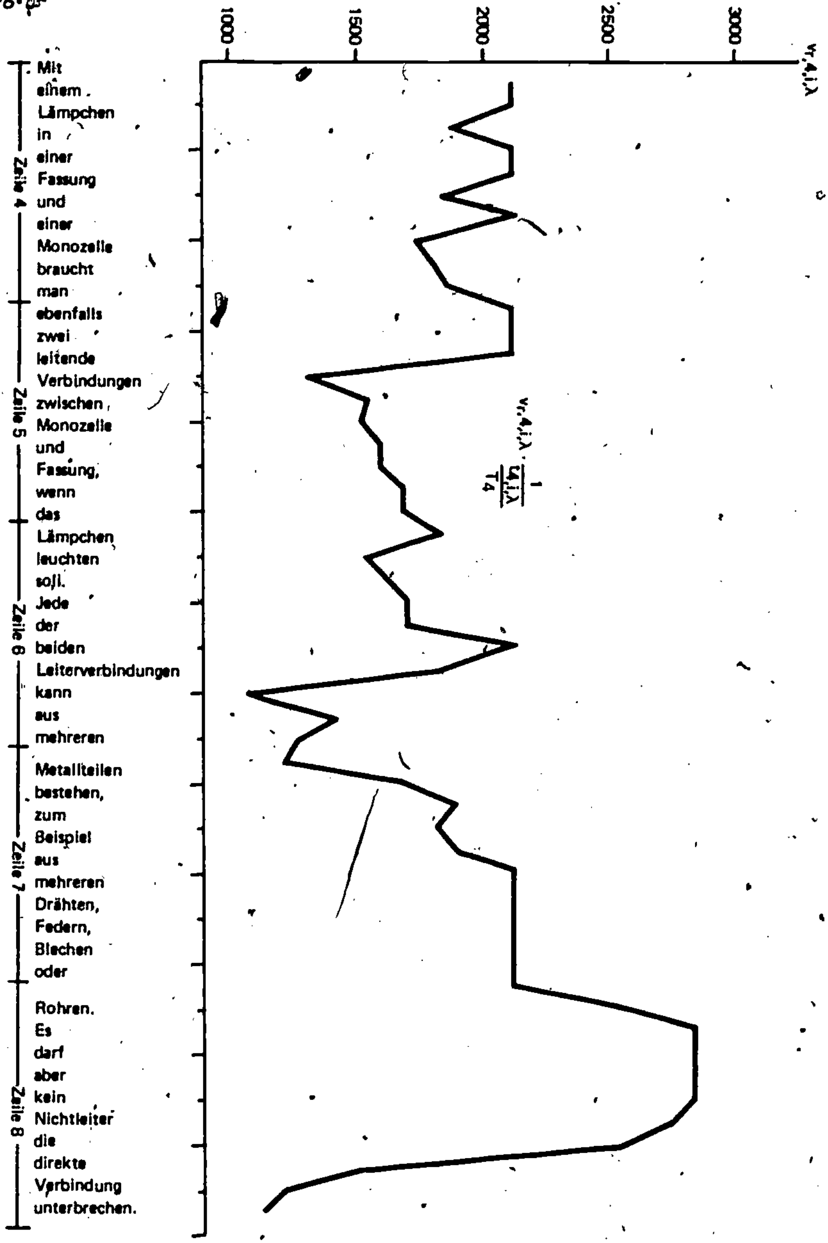
$$V_{r,4,i,\lambda} = A_\lambda \cdot \frac{1}{\frac{t_{i,4,\lambda}}{T_4}}$$

with the following meaning of the indices: r points to relative velocity, 4 is the code number of the pupil, i the number of the read line (in this figure: from 4 to 8), λ the number of types of the read word, which is equivalent to the length A_λ of the word. The time t_i is the time needed for reading the line i, T_4 the time required for reading the whole text by the pupil 4.

The figure shows a reduced velocity of reading per letter at the words "Lämpchen", "Fassung", "Monozelle", and - very intensively - at "leitende Verbindungen" and "Leiterverbindungen", because these words required a particular attention, and much more at those supermarks such as "Verbindungsleitungen", especially if conclusions are combined with them as e. g. in that sentence containing "leitende Verbindungen".

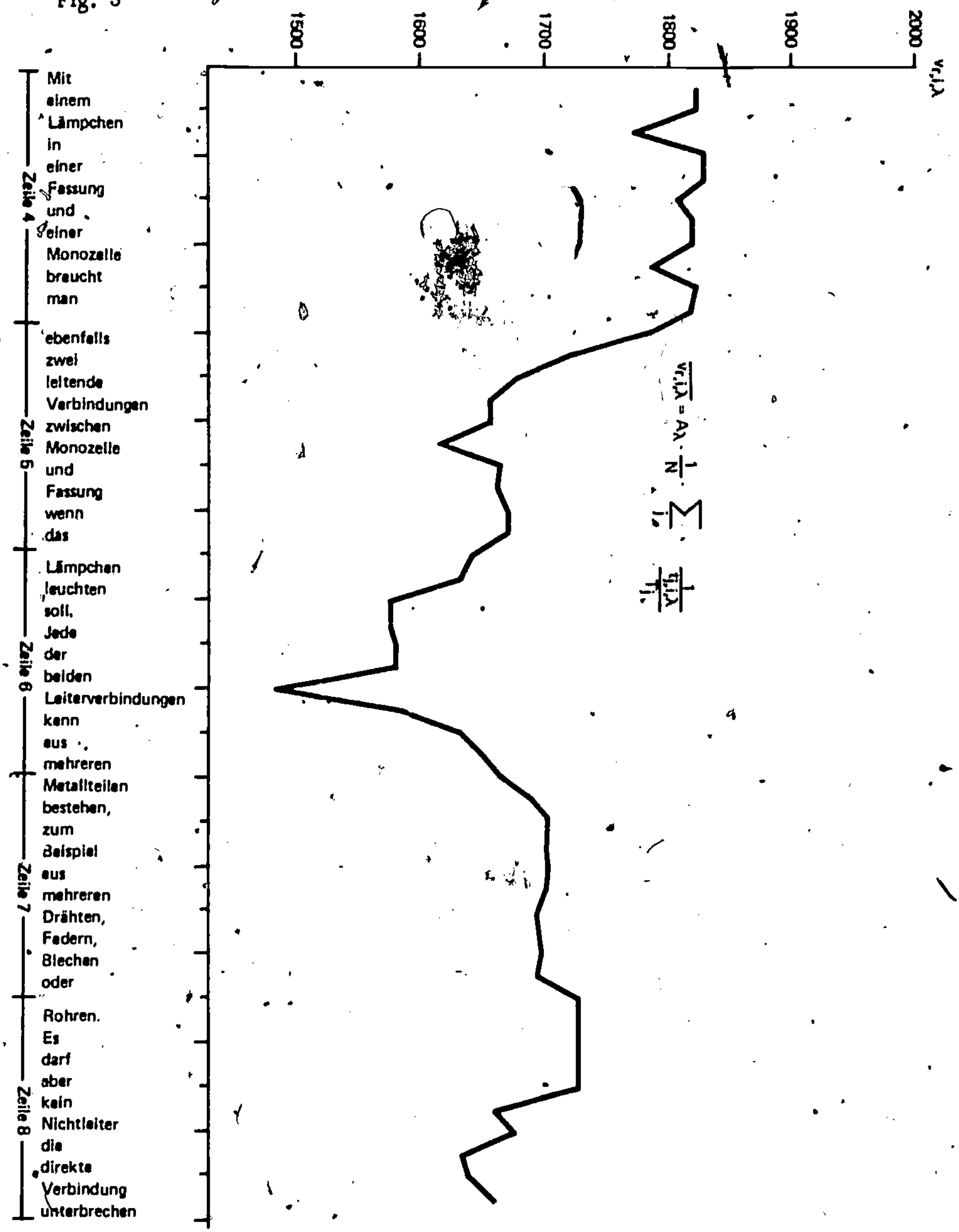
Figures 3 shows this result very clearly. The average of the reading velocity of N = 37 pupils j demonstrates it for the word "Leiterverbindungen" in line 6 and

Fig. 2



1000
1500
2000
2500
3000
Vr,4,i,λ
Vr,4,i,λ · 1/(L4,i,λ/T4)
Zeile 4
Zeile 5
Zeile 6
Zeile 7
Zeile 8
Mit einem Lämpchen in einer Fassung und einer Monozelle braucht man ebenfalls zwei leitende Verbindungen zwischen Monozelle und Fassung, wenn das Lämpchen leuchten soll. Jede der beiden Leiterverbindungen kann aus mehreren Metallteilen bestehen, zum Beispiel aus mehreren Drähten, Federn, Blechen oder Rohren. Es darf aber kein Nichtleiter die direkte Verbindung unterbrechen.

Fig. 3



1500
1600
1700
1800
1900
2000
vr,i,λ
vr,i,λ = Aλ · 1/N · Σ ti,λ/ti
Zeile 4
Mit einem Lämpchen in einer Fassung und einer Monozelle braucht man
Zeile 5
ebenfalls zwei leitende Verbindungen zwischen Monozelle und Fassung wenn das
Zeile 6
Lämpchen leuchten soll. Jede der beiden Leiterverbindungen kann aus mehreren
Zeile 7
Metallteilen bestehen, zum Beispiel aus mehreren Drähten, Federn, Blechen oder
Zeile 8
Rohren. Es darf aber kein Nichtleiter die direkte Verbindung unterbrechen

for the end of the same sentence, respectively. The formula for the average reading velocity of a group of pupils is

$$V_{r,i,\lambda} = \frac{1}{N} \cdot \sum_{j} \cdot \frac{1}{\frac{t_{j,i,\lambda}}{T_j}}$$

The fact that the appearance of a conclusion in the text reduces the reading velocity becomes obvious in the lines 5 and 6.

All supermarks must be constructed from simple marks. Therefore the physical concept of a velocity cannot be understood by a pupil from the defining formula v-ds/dt. At first he has to get acquainted with the vast range of different motions which happen in the real world. Then one has to develop the ability to reduce this variety of motions by the creation of supermarks. The theory of mechanics is designed so that the supermarks can be connected like the links of a chain. So a very important learning process will happen, namely the learning of all the associations which belong together. In the same way one has to put together the the supermarks of a lower rank to supermarks of higher and higher ranks. Doing so one succeeds in understanding the physical world from the concrete phenomena up to the concepts of the highest degree.

A study on the velocity of reading a physical text and on the question, how much of the content is understood, can increase our knowledge about the processes of learning.

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Discussion

At first some details of the procedure of measurement are discussed. The author reports that the velocity of reading a line is measured, and the velocity of reading a word is calculated afterwards. As the aperture of the apparatus is rather large, the recorded data are smoothed to some extent. Nevertheless, the data are sufficiently characteristic for an interpretation.
It is difficult to define an accuracy of the measurements. A certain text may be read by a certain subject only once or very few times. Otherwise the inevitable process of learning will change the results. It is only meaningful to average the results of different subjects, but the individual fluctuations are great. Each subject reads many texts. It is controlled by tests whether the person understood the text.
It is asked whether anything is known about the training of the eyes. For instance, a man, who reads proofs professionally, is forced to do it very quickly and yet to understand the text (to a certain measure). The author replies that further investigations are planned. No measurements about this topic have been made until now.
It is stressed that the amount of unknown content of a text must be considered. The author reports that before the reading some lectures on the content of the text are given to the subjects and that their knowledge is tested. Only then the reading is performed. The measurements indicate that persons, who had shown a good knowledge of the contents, read rather uniformly, whereas these persons of a smaller knowledge, but with a good carefulness, read with a widely varying velocity. A third group consists of students having poor knowledge and a small interest, who read fast and uniformly, but understood little.
It is asked how the level of complexity of a mark can be measured or estimated. The author responds that it will be sufficient in the beginning to construct some crude categories.
The audience is astonished about the low number of informations which flow into the long memory. The author points to the fact that even this small number amounts to 2×10^7 bits within 10 years. He adds that many things are learnt without cooperation of the consciousness, e. g. the ability of seeing three-dimensionally. It would be interesting to know how the informations are selected for the long memory.

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