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Development of a Core-Course for College Science Majors Combining Material from Introductory Courses in Biology, Chemistry, and Physics-Phase II. Final Report.

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Reported is the second phase of the development of a two-year college core science course for science majors. Materials were combined from introductory college courses in biology, chemistry, and physics. A revised lecture and laboratory syllabus was prepared incorporating improvements suggested after a pilot study of the first year course. Advantages of the combined course are that it shortens the total time spent in covering the material (by about 16%), allows flexibility in student program planning, and permits treatment of interdisciplinary topics and a spiral development of concepts. Formal evaluation focussed on the comparison of attitudes of students in the experimental and conventional courses. The results suggested that the few significant differences found may have been related to the quality of individual instructors rather than to differences in courses. Appendices include a detailed two-year course outline, a copy of the attitude test used, and a summary of the evaluation results. (EB)

FINAL REPORT
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February 1969

U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
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February 1969

Portland State College
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Portland, Oregon

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INTRODUCTION

(a) Problem, background, and related research.

The past five to ten years has witnessed an increasing concern on the part of teachers of introductory college science courses with the so-called multidisciplinary course. A common combination has been physics and chemistry, but a number of significant attempts have been made involving the biological sciences as well. [1,4,6-10, 15] The incentives underlying these developments are manifold. One can cite: (a) the rapidly growing body of interdisciplinary scientific research such as biophysics, environmental science, and molecular biology; (b) the desire to eliminate overlap among the disciplines in the teaching of certain subject matter in the face of expanding curricular demands; (c) a need to serve the science student who has not committed himself to a major, as well as the non-science student who increasingly requires a broad background in science; (d) the multidisciplinary background required of science-oriented professionals such as medical doctors and oceanographers; (e) the recent emergence of multidisciplinary high school courses, [5,12,15] which argues for a similar orientation in the training of secondary school science teachers; and finally, (f) a growing ecumenical feeling that new channels and dialogue should be created among heretofore fragmented areas of science.

Despite powerful reasons for the creation of combined courses designed for science majors, these students have not in general been the beneficiaries of the multidisciplinary fervor. Of the 520 multidisciplinary courses reported upon by Fuller, [7,8] only 51 were specifically designed to prepare students for more advanced courses. Of these only 10 are principally concerned with the three core sciences, physics, chemistry and biology. As of this writing, specific information has been made available by Fuller on only one of these programs, [15] the Tufts University course, which is now apparently defunct. [14]

Yet, the interest and rationale underlying a science major course combining physics, chemistry and biology continues. [2,9,13] It was in hopes of creating a viable program of this sort that work was undertaken under a previous grant (OEG-4-7-068468-0060). The result of that work was the creation of a syllabus for a two-year six credit-hour program combining material from the conventional introductory courses in physics, chemistry and biology. [11] This course, hereafter referred to as the "core-course", is designed to permit students to enroll in upper division work in any of these three disciplines. Three instructors were involved, one representing each of the three disciplines. It was given in its preliminary form to a pilot group of 30 students in the academic year 1966-67. In the light of that experience it became clear that a thorough revision of the program had to be undertaken before an interdisciplinary program which would serve as a viable alternative to the traditional introductory courses could be created. This report summarizes the results of this second phase of the core-course development program.

(b) Purposes and objectives.

The first year of the two-year syllabus developed under the previous grant (OEG-4-7-068468-0060) was to be thoroughly revised, and a detailed outline of the second year was to be prepared. Several desirable features suggested by the experiences with teaching the first year of the program were to be explored. These include: (1) the "cluster effect" whereby the interpersonal relationships which arise among the students of the core-course are to be expedited in other areas of their program; (2) increased use of interdisciplinary material, where appropriate; (3) the so-called "spiral approach" whereby students return to certain topics several times during the course, with increasing depth of treatment; and (4) a topical sequence which would make it feasible for a teacher to simultaneously teach in both years of the program. It was not intended that the subject matter of physics, chemistry, and biology be integrated into a thoroughly interdisciplinary course, but rather that the various topics be presented in a logically arranged sequence which would permit a student to begin a major in any of these areas in his sophomore or junior year.

A preliminary evaluatory study, principally to ascertain immediate student attitudes and performance was to be undertaken.

METHOD

(a) Syllabus

A writing committee consisting of a physicist, a chemist, and a biologist met on a regular basis during the summer of 1967 to prepare a completely revised lecture and laboratory syllabus for the two-year core-course program, as well as to complete the detailed writing of the syllabus being used with the original pilot group of students. They were aided by a biophysicist in connection with problems concerning integration of the physical and biological material, and by other members of the science departments who assisted in matters concerning scheduling, subject matter emphasis, etc. During the academic year 1967-68 the original pilot group of students continued with the second year of their program, while the first year of the revised program was administered to a new group of students. A third group of students, who began the program in the fall of 1968, will be undertaking a program also based upon the revised syllabus described in this report, with a few minor modifications. Altogether, seven professional level staff members including the original trio have become involved in teaching the core-course, and several more are expected to be enlisted in the fall of 1969.

Besides the summer development work there has been some ongoing revision which takes place during the academic year. The instructors freely attend one another's lectures and laboratories, at least until they have seen the course completely through one cycle. They meet regularly once each week for discussion and coordination of the material. In addition, response and criticism from the academic community received at various national and regional meetings has been most helpful in guiding the development of the course.

(b) Evaluation

In view of the limited statistical populations available and the relatively short period of time over which observations could be made, the evaluation program ought to be considered in the nature of an exploratory study. Results were based upon an attitude survey administered simultaneously to students just completing the first year of the core-course (experimental group) and to matched groups students just completing the conventional introductory majors courses in physics, chemistry, and biology (control groups P ,C, and B). An attempt to survey subject matter performance in these areas was abandoned upon the stringent recommendations of the various instructors, who held that in general the order of presentation of material in the core and conventional courses was sufficiently different to preclude writing meaningful comparison examination questions.

The attitude survey instrument (Appendix D) consisted of questions which can be characterized under three broad headings: (a) attitudes towards science in general (questions 1,5, and 7); (b) flexibility with respect to future plans (questions 2,3, and 6); and (c) course satisfaction (questions 4, and 8 through 15). Point values were assigned to the answers such that positive values signify effectiveness of a student's particular course (+1, maximum), whereas negative values represent lack of effectiveness (-1, minimum). The average control group scores for each question were subtracted from the average experimental group scores to yield a set of course comparison indices (see Appendix F). Indices were computed for each question and also for each of the three groups of questions. Positive values may be interpreted as favoring the core-course and negative values as favoring the conventional courses. A fourth control group (PCB) was also considered which consisted of the combined P, C, and B control groups.

The criteria by which the control group students were individually matched to counterparts in the experimental group were sex, college class, SAT verbal score, SAT math score, and high school grade point average. Matching was limited by the small size of the group from which the control students had to be selected. A large class of students who normally populate physics classes but who are not to be expected at all in the core-course, viz., engineering and applied science majors, were excluded completely in the matching procedure. The characteristics of the experimental and control groups is summarized in Appendix E.

RESULTS

(a) Syllabus

A revised lecture and laboratory syllabus for the two year core-course has been prepared. The program, as it is taught at Portland State College carries six hours of credit and runs for six consecutive quarter-length terms. This is about 16% fewer hours than would be required to complete the three comparable conventional courses. Students attend four 1-hour lectures each week, as well as two 3-hour afternoon sessions (one laboratory and one problem session during the physics and chemistry parts of the course; two laboratories during the biology parts of the course). The total amount of time allotted to each of the three disciplines is approximately the same. (See Appendix C.) No single suitable textbook is available, hence conventional texts have been used.

Appendix A outlines the general organization of the course according to major topic and discipline. Appendix B indicates the daily lecture and laboratory topics for the full two years. Detailed lecture outlines for the first year of the course as they were given during the academic year 1967-68 is available from the author upon request.

The topical coverage of the six terms may be broadly characterized as follows:

1. First term: atomic structure, including the necessary material in mechanics and electricity that underlies it at this level.
2. Second term: mainly organic chemistry and biochemistry.
3. Third term: thermodynamics and energetics - physical and biological systems.
4. Fourth term: topics in physical chemistry and in several biological areas which involve physical - chemical ideas.
5. Fifth term: mainly electrical systems and nuclear reactions.
6. Capstone topics: Chemistry - descriptive inorganic (5th term); biology - genetic and social adaptation (6th term); physics - optics, with chemical and biological applications (6th term).

There are several general features of the syllabus which should be noted: (1) The first and second year programs are coordinated so that at no time is the same discipline taught simultaneously to the two groups of students. This permits one instructor to lecture to both groups in a given discipline, if necessary, without having a doubled teaching load. It also permits the first and second year students to use the same laboratory space in each department. (2) The course incorporates at the same level all the material that normally might be expected to appear in the conventional major's-level introductory courses in physics, chemistry, and biology. The primary object is thus completeness, rather than integration; all cooperating departments can expect students of the core-course to be adequately prepared to undertake a major in their area. (3) Though the emphasis is not on integration, the course attempts to explore wherever feasible the science that lies at the interface between disciplines. A few of many examples: topics in electricity which relate physics and chemistry, topics in ionic equilibria which relate chemistry and biology, and topics in biosynthesis which relate biology and physics. (4) Though the program is designed to permit the student to postpone his choice of major until his junior year, students who so desire can begin their upper division programs in parallel with the core-course in their sophomore year. In particular, biology, chemistry, and premedical students are urged to register for organic chemistry at that time. Committed physics majors are advised to take thermodynamics and statistical physics as sophomores. Students who elect to switch from science to nonscience majors are urged to complete one full year of the course in order to satisfy part of their all-college science requirements. (5) The core-course lends itself readily to the arrangement of topics which has been called the "spiral approach".[3] Subject matter is introduced at one stage of the course, and is later re-introduced at a higher stage of complexity. In this way a concept can be reviewed and restated, a sense its implications enhanced, and more sophisticated mathematical or experimental technique can be brought to bear upon it. For instance, in physics, introductory mechanics is introduced in the 1st, 3rd, and 5th terms; in chemistry, topics in chemical equilibrium are discussed in the 3rd, 4th, and 5th terms. (6) The large number of hours which the students spend together have permitted more coordination of their programs than is ordinarily possible in a large college such as Portland State. Each student has been assigned to one of two mathematics sections. Since students must set aside two full afternoons in order to accommodate his twice-weekly biology laboratories, chemistry and physics recitations have been organized along the lines of "problem laboratories". Problem assignments are first reviewed by the instructor; thereupon students are encouraged to work together on additional problems with the help of upper class or graduate tutors.

(b) Evaluation

The results of the attitude survey is summarized in the charts of Appendix F.

The responses of the core-course students when grouped according to various categories of questions is, in most cases, not significantly different or barely significantly different from the responses of the conventional-course (control) students (see page F-1). There were, however, several exceptions. In comparison with the physics control group, the core-course students exhibited a significantly more positive attitude towards both science in general and towards their own particular course. In comparison with the chemistry control group, the core-course students were found to be somewhat more negative towards science in general. In comparison with the biology control group, the core-course students exhibited a somewhat more positive attitude towards science in general. In comparison with the overall (PCB) control group, the core-course students exhibited significantly greater satisfaction with their course.

Very few individual questions were able to discriminate between core-course and control students on a reasonably consistent basis (see page F-2). The exceptions were: question 5 on science and human affairs (core-course more negative, except in comparison to chemistry students), and question 8 on excellence of instruction (core-course more positive, except in comparison to chemistry students). In no instance did the questions which attempted to measure flexibility with respect to future plans show any significant difference between control and core-course students.

Most students seem to have positive attitudes towards their own particular course (see page F-3). Exceptions occur fairly consistently with respect to those measured by questions 2,3, and 6 (flexibility with respect to future plans), question 10 (relative difficulty), and question 13 (value of laboratory).

DISCUSSION

(a) Syllabus

Most of the goals set out in the Introduction have been attained, though continuing development is called for. The course provides a viable introductory program for students intending to major in science. Despite the warnings made by some observers that interdisciplinary courses rarely survive the first round of enthusiastic innovators,[6] the core-course program is about to enter its fourth year, with increased enrollment predicted and new teachers involved. (We proudly note a "second generation" of students: one of our freshmen is the younger brother of one of our pilot group students, now a junior). Though the statistical evidence is not conclusive (see discussion of the evaluation studies, paragraph b. of this section) there is evidence that the course provides unusual opportunities for students in the planning of their programs. This year, for instance, two premedical students decided to undertake studies in upper division physics. (Rarely are premedical students in a position to do this, since they normally postpone all physics studies until their junior or senior years.) The continuation of the program ultimately rests upon its acceptance by faculty and students; the comments which follow begin with a summary of some informal observations pertaining to this matter.

Instructors in the core-course, rather than finding the task grievously burdensome have generally come to appreciate many of the advantages. For instance, although the teaching demands are indeed very great when a teacher's particular discipline is being taught, other times are relatively free for concentrated work on non-teaching tasks such as research. Effective teaching of one of the subjects requires a period during which the instructor attends all other parts of the course. However, most of the teachers report this to be a valuable and interesting experience from both a scientific and pedagogical standpoint. Opinion as to whether the course is the best possible preparation for each particular science major is divided. The biologists generally have come to regard it as a far better alternative to the increasingly popular alternative of postponing introductory biology until a major has studied physics and chemistry. Physics and chemistry teachers sharply differ as to whether biology is sufficiently important to thoroughly expose every student to it. All teachers seem to agree that the core-course approach is desirable for undecided and premedical students. They all also agree that it allows a certain additional sophistication in presenting their own discipline: in the case of chemistry and biology by making available to the students underlying concepts from other disciplines, in the case of physics by assuring a better more uniform mathematics background due to the two-year length of the course.

Certain student attitudes, which for one reason or another were not studied in the formal evaluation study, but which are particularly pertinent to the syllabus development program might be noted here. Rather than being distressed by the shift from discipline to discipline, students in the core-course appear to welcome the change in emphasis and instructor that comes about, at the most, every six weeks. However, they seem to be perplexed, at least in the beginning of the course, by the skipping about in the text books. The ultimate solution of this problem may have to await the production of a new consolidated text. Most of the teachers seem to feel that student comraderie is higher than one normally finds in large science classes at Portland State College. This may be a result of the large number of classroom hours these students spend with one another, something which is hard to achieve at a large, non-resident campus such as Portland State College. As one might expect, students are disenchanted by some material outside their special bent. A suggested improvement which might be at least partly effective in treating this ill, lies in revitalizing the laboratory part of the course to permit flexible programs of interdisciplinary and conventional experiments individually designed for each student.

The syllabus presented in detail in Appendix B is not claimed to be the ultimate nor the only reasonable tridisciplinary course arrangement. It represents a compromise which was thought to be workable within the limitations imposed by its being taught at Portland State College at this time. At other institutions and under other conditions variations might well be called for. For instance, if teaching of a given discipline to both first and second year students simultaneously were permissable, the entire second year might be rearranged. In particular, optics ought to be given earlier in the program so as to permit meaningful discussion of a number of the modern experimental techniques in biology. The scheduling might be reconsidered with an eye towards permitting students who drop out of the core-course to enter the conventional programs with ease, although up to now each one of these cases has been successfully handled on an individual basis. Finally, some consideration might be given to designing a program similar to the core-course to meet some special or more limited objective, such as a course for pre-meds only, or as a component in an honors program for science students.

(b) Evaluation

The results of the evaluation studies ought to be regarded as preliminary. In the attitude survey, most of the results were not statistically significant, though some trends were evident. No attempt was made to evaluate subject matter achievement, mainly because the most appropriate instrument to do this at this stage of the program, which is comparative performance on subject-matter exams, was not acceptable to the instructors. In the several cases where significant differences in attitude between core-course and conventional course students were detected, there was wide variation from subject to subject, suggesting that the most important factor may be the relative quality of the individual instructors. No data was gathered on those students who dropped the course before the evaluation studies were made, though it is hoped that they made the decision to withdraw from a more knowledgeable standpoint than does the student in the conventional courses. On the whole, it may be concluded that with respect to student satisfaction, flexibility, and general scientific literacy the core-course is no worse, and very possibly more adequate than the conventional courses. It does of course retain its inherent superiority in providing a background for interdisciplinary studies, and for reducing the course-hour load for students whose program requires an intensive introduction to physics, chemistry, and biology.

The preliminary evaluatory studies undertaken here were limited by several factors. Small populations limited the effectiveness of the matching procedure and also led to large statistical fluctuations. A lack of manpower resources and time did not permit adequate control over all the data potentially available (such as a study of withdrawal and failure patterns) or more sophisticated analyses (such as individualized t-test comparisons). However, the most important consideration is that it is not clear that the long-range objective of the core-course, viz., to provide a more efficient and effective groundwork for the training of future scientists and science-oriented professionals, is actually being tested. To do this, a "long-range" evaluation study of the course is needed in which the performance and attitudes of students in the core-course and in the control groups would be surveyed during their upper division years and beyond. Factors which ought to be compared are future academic performance, course and career satisfaction, evolution of interests, and professional achievement. The survey ought to continue long enough to average out fluctuations due to individual teachers, small samples, etc. Obviously, further financial support would be required for such studies.

CONCLUSIONS, IMPLICATIONS, RECOMMENDATIONS

The main thrust of the project has been to create a single unified course which would be a viable and efficient alternative to the conventional introductory science major courses in physics, chemistry, and biology. In this regard the work has been successful. The program is now in its third year, and is expected to continue and to increase in enrollment. Many staff members from the several departments have become involved, in some cases with a good deal of enthusiasm. Much interest in the program has been evidenced by other institutions.

Further development of the syllabus should continue, especially as required to suit it to the differing needs and viewpoints of other teachers and institutions. Particular effort ought to be placed on making the course more satisfactory to students with strong and inflexible commitment to particular disciplines, perhaps through a readjustment of the laboratory program. Definitive evaluation studies would be useful, but only if conducted on more than a piecemeal and short-range basis. In particular, the long-range success of the program in providing the student with a basis for success in science or science-oriented careers, ought to be studied.

SUMMARY

In view of the increasing interdependence of the sciences and of the growing curricular demands upon students of science, a new program encompassing material from introductory majors-level courses in physics, chemistry, and biology has been developed. This core-course is a two-year sequence carrying six credit-hours per term which is designed to prepare students to undertake an advanced undergraduate program in any of these fields beginning in their sophomore year. The course appears to be a viable alternative to the conventional introductory courses at the same level, and also provides certain unique advantages. Among these are elimination of overlap of subject matter among the disciplines, more adequate preparation for interdisciplinary courses, and increased freedom of choice for students who do not have an early commitment to a particular major.

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APPENDIX A.

General outline of core-course.

Term: 1

PHYSICS
- Motion and forces - gravity, electric, magnetic.
- Conservative particle dynamics- trajectories and orbits.
- Work. Mechanical energy. Electrical potential.
- Momentum. Collisions.

PH-CH
- Rutherford experiment Bohr atom.

PHYS
- Oscillations. Stationary waves.
- De Broglie waves.

CHEMISTRY
- Electronic structure of atoms.
- Electroneg- ativity. Affinities.
- Chemical bonds. Molecular orbitals.

2

CHEMISTRY
- Acids and bases.
- Bonding in carbon.
- Organic functional group chem- istry - reactions and mechanisms.
- Carbohydrates, amino acids, and other compounds of biological significance.

BIOLOGY
- The cell.
- DNA and the synthesis of macro- molecules.
- Origin and development of life.
- Survey of present day living or- ganisms.

3

PHYSICS
- Fluid physics.
- Friction. Temperature and heat.
- Thermodynam- ics: 1st law.
- Ideal Gases. Kinetic theory.
- Sound.

PH-CH
- Thermodynam- ics: 2nd law.

CHEM
- Chemical thermo.- phys. change reactions, equilibrium.

BIOLOGY
- Cellular nutrition and respir- ation.
- Photosyn- thesis.
- Biosynthesis: energy requir- ing reaction.
- Cellular control.

4

CHEMISTRY
- Chemical equilibrium including:
- Effects of changes in temperature, pressure, concentration.
- Ionization in solution.
- Solubility.
- Buffering.

BIOLOGY
- Circulation. Transport systems.
- Gas exchange and gas transport.
- Excretion. Water and salt balance.
- Organismic control.
- Hormones, nerve systems.
- Reproduction: basics.

5

PHYSICS
- Electrostatics of conductors, dielectrics.
- Direct currents: circuits, forces and torques.
- Rotational motion.
- Magnetic effects of currents.
- Electromagnet- ic induction.
- Special rel- ativity.

PH-CH
- Nuclear re- actions and nuclear chemistry.

CHEMISTRY
- Electrochem- istry: elec. potentials, electrolysis.
- Descriptive inorganic chemistry. Metals, metal- lurgy.
- Qual. schemes.

6

BIOLOGY
- Reproduction and devel- opment.
- Genetics- classical, molecular.
- Evolution of species.
- Ecology: populations, ecosystems, communities, and the biosphere.

PHYSICS
- Alternating currents and circuits.
- E-M waves, light.
- Reflection, refraction, lenses.
- Interference, diffraction.
- Optical instru- ments and methods.

Core-course syllabus.

Week	First quarter lectures.				Labs
1	(BI-CH-PH) Introduction.	(PH) Length, time, and motion. Vectors.	(PH) Vectors continued. Velocity.	(PH) Force. Inertia. Action and reaction.	
2	(PH) Forces: gravitational, coulomb.	(PH) Magnetic force on moving charge. Quiz.	(PH) Instantaneous velocity and acceleration in one-dimension.	(PH) Kinematical relations in one-dimension.	(PH) Measurement and error.
3	(PH) Dynamics in one-dimension.	(PH) Dynamics continued. Quiz.	(PH) Electric field and force lines.	(PH) Motion in two-dimensions: parabolic trajectories.	(PH) Electrostatics. Free fall.
4	(PH) Motion in two-dimensions continued: circular motion.	(PH) Circular motion in magnetic fields: devices. Quiz.	(PH) Work and energy.	(PH) Energy continued: potential energy.	
5	(PH) Energy continued: electrical potential.	(PH-CH) Potential of point charge. Ionization potential. Quiz.	(PH) Collisions: conservation of momentum.	(PH) Collisions continued: impulse.	(PH) Collision experiments.
6	(PH-CH) Angular momentum of a particle. Rutherford experiment.	(CH) Chemical fundamentals: units, definitions, conversions.	(CH) Chemical fundamentals contd. Simple equations. Concentrations.	(CH) Concentrations contd. Introduction to atomic structure.	(CH) Glass working. Determination of density.
7	(CH-PH) Atomic structure: Bohr theory.	(PH) Periodic motions. Quiz.	(PH) Simple harmonic motion.	(PH) Mechanical waves.	(PH) Simple harmonic motion.
8	(PH) Stationary waves.	(PH) Resonance. Quiz.	(PH-CH) Bohr theory continued. DeBroglie waves.	(CH) Quantum numbers. Periodic law.	(PH) Stationary waves on a wire.
9	(CH) Ions and ionization energies.	(CH) Aufbau principle and the periodic chart.			
10	(CH) Types of chemical bonds.	(CH) Electron affinity. Covalent bond.	(CH) Electronegativity and partial ionic character.	(CH) Hybridization and geometry of molecules. Quiz.	(CH) Properties of ionic and covalent compounds.
11	(CH) Valence bond approach. Molecular orbitals.	(CH) Molecular orbitals continued. Hydrogen bond.	(CH) Exam.	(CH) Introduction to acids and bases.	(CH) Acids and bases.

	Second quarter lectures.				Labs
1			(CH) Acids & bases continued. Acid strengths. Equivalents.	(CH) Acid and basic oxides. Amphoterism. Introduction to organic chem.	
2	(CH) Structure and bonding in alkanes. Nomenclature.	(CH) Alkanes continued. Cyclic hydrocarbons.	(CH) Unsaturated hydrocarbons. Functional groups.	(CH) Alkenes. Addition reactions.	(CH) Determination of equivalent weight by titration.
3	(CH) Pi bonds and conjugated double bonds. Markonikoff's rule.	(CH) Free radicals. Aromatic hydrocarbons. Benzene and derivatives.	(CH) Alcohols.	(CH) Alcohols continued, including derivatives. Quiz.	(CH) Alcohols.
4	(CH) Alcohols continued. Phenols.	(CH) Ethers. Configurational isomerism. Organic halides.	(CH) Configurational isomerism and organic halides cont. Amines.	(CH) Amides, aldehydes. Ketones.	(CH) Ethers and esters.
5	(CH) Acetals. Some polymers. Sugars.	(CH) Organic acids and derivatives. Lipids. Soaps. Sulfa drugs.	(CH-BI) Amino acids. Peptides. Proteins.	(CH-BI) Nucleic acids. Quiz.	(CH) Organic synthesis.
6	(BI-CH) Molecular composition of a cell. Macromolecules.	(BI-CH) Proteins.	(BI) Enzymes.	(BI-CH) Nucleic acids.	(BI-CH) Chem. of proteins and nucleic acids. Enzymes.
7	(BI) DNA structure & function. Cell structure: membrane.	(BI) Cell structure: Procaryotic and eucaryotic.	(BI) Cell structure: electron micrographs. DNA replication.	(BI) DNA replication. RNA synthesis.	(BI) Monera and protists.
8	(BI) Protein synthesis and genetic code.	(BI) Biosynthesis and the capture of energy.	(BI) Origin of life.	(BI) Evolution of metabolism. Kingdoms. Viruses.	(BI) Tracheophytes.
9	(BI) Monera: bacteria.	(BI) Monera: blue-green algae. Protista: flagellates, sarcodines.	(BI) Protista: ciliates, slime molds, fungi, algae.	(BI) Protista: algae. Evolution of Metaphyta.	(BI) Radiates, acoelomates, molluscs, annelids.
10	(BI) Metaphyta: plant anatomy.	(BI) Origin of Metazoa.	(BI) Eumetazoa: origin, evolution, major phyla.	(BI) Chordata.	(BI) Arthropods, chordates.

Third quarter lectures. / Labs

	Lectures				Labs
1		(PH) States of matter. Fluid statics.	(PH) Fluid statics continued. Surface tension.	(PH) Work, heat, and energy. Temperature.	(PH) Surface tension and capillarity.
2	(PH) Heat and friction. Friction forces.	(PH) Friction and drag in liquids. Hydrodynamics.	(PH) Hydrodynamics continued. Quiz.	(PH) Heat capacity and latent heats. Thermodynamics: First law.	(CH-PH) Calorimetry and law of Dulong and Petit.
3	(PH) First Law continued. Thermal expansion in liquids and solids.	(PH) Ideal gas law.	(PH) Kinetic theory of gases.	(PH) Kinetic theory continued: diffusion. Quiz.	(CH-PH) Diffusion: Graham's law.
4	(PH) Specific heats of gases.	(PH) Speed of sound in gases. Doppler effect.	(PH) Second Law of thermosynamics.	(PH) Entropy and order. Quiz.	(PH) Velocity of sound.
5	(CH-PH) Liquid-vapor transitions. Phase diagrams.	(CH-PH) Non-ideal gases. Partial pressures.	(CH) Oxidation number. Balancing simple redox equations.	(CH) Balancing contd. Thermodynamic functions: G, H, and S.	(CH) Enthalpy of physical change.
6	(CH) Standard heats of formation. Hess's law.	(CH) Bond energies and heats of formation. Intro. to chemical equilibrium.	(CH) Gibbs free energy and reactions. Entropy & reactions.	(CH-BI) Entropy and denaturation of proteins.	(CH) Enthalpy of chemical change.
7	(BI-CH) Energy & metabolism. Thermodynamics. Respiration.	(BI-CH) Oxidation & 3-phosphoglyceraldehyde. Glycolysis.	(BI) Glycolysis. TCA cycle and generation of ATP.	(BI) Oxidative phosphorylation.	(BI) Respiration.
8	(BI) Summary of respiration.	(BI) Photosynthesis.	(BI) Photosynthesis continued.	(BI) Chemoautotrophy. Summary of energy metabolism.	(BI) Photosynthesis.
9	(BI) Biosynthetic pathways.	(BI) Biosynthetic pathways. Nutrition.	(BI) Nutrition. Digestion.	(BI) Permeases. Growth.	(BI) Nutrition. Growth.
10	(CH) Introduction to reaction rates.	(BI) Enzyme induction. Lactose operon.		(BI) Repression. Feedback inhibition.	(BI) Enzyme induction.

	Fourth quarter lectures.				Labs
1	(CH) Solutions: molarity, molality, normality.	(CH) Normality cont. Chemical equivalents. Colligative properties.	(CH) Colligative properties cont.: freezing point, boiling pt. depression.	(CH) Reaction mechanisms. Order of a reaction.	(CH) Determination of order of reaction
2	(CH) Equilibrium constant and Le Chatelier's principle.	(CH) Equilibrium calculations.	(CH) Equilibrium calculations with ionic reactions.	(CH) Quiz. Ionic reaction calculations contd. Degree of ionization.	(CH) Chemical equilibrium.
3	(CH) Polyprotic acid ionization.	(CH) Ionization of water. Concept of pH.	(CH) Acid-base indicator theory.	(CH) Zwitter ions. Quiz.	(CH) Hydrogen ion concentration.
4	(CH) Hydrolysis calculations.	(CH) Solubility product.	(CH) Solubility product cont., common ion effect.	(CH) Buffered solutions.	(CH) Hydrolysis. Titration.
5	(CH-BI) Buffering cont. Activity vs. concentration.	(CH-BI) Chem. quiz. Begin physiology: ingestion and permeation.	(BI) Digestion.	(BI) Gas exchange. Gas transport.	(CH) Solubility product constant.
6	(BI) Gas transport. Blood.	(BI) Blood, lymph, and immunity.	(BI) Blood groups. Circulatory system.	(BI) Circulation.	(BI) Digestion and respiration.
7	(BI) Transport.	(BI) Excretion.	(BI) Excretion.	(BI) Support.	(BI) Circulation. Transport. Excretion.
8	(BI) Movement.	(BI) Muscle.	(BI) Exam.	(BI) Control at molecular level.	(BI) Muscle and co-ordination.
9	(BI) Hormonal control in plants.	(BI) Hormonal control in animals.			
10	(BI) Nervous systems.	(BI) Nervous systems: comparative.	(BI) Nervous systems: human.	(BI) Sensory organs.	(BI) Nervous systems.
11	(BI) Reproduction: molecular.	(BI) Reproduction: bacteria and viruses.	(BI) Reproduction: mitosis and meiosis.	(BI) Sexuality.	(BI) Plant and animal reproduction.

	Fifth quarter lectures.				Labs
1		(PH) Review of previous e and m. Gauss' Law.	(PH) Application of Gauss' Law. Capacitors.	(PH) Parallel plate capacitor. Field energy.	(PH) Capacitance. Ohm's law.
2	(PH) Dielectrics. Resistivity.	(PH) Resistance. Ohm's Law.	(PH) Simple dc circuits.	(PH) Circuits continued. Quiz.	
3	(PH) Magnetic forces and torque on circuits.	(PH) Review of particle mechanics. Rotation.	(PH) Torque. Rotational equilibrium.	(PH) Rotational kinematics. Quiz.	(PH) Wheatstone bridge. Potentiometer.
4	(PH) Rotational dynamics.	(PH) Tops and gyroscopes. Magnetic moment.	(PH-CH) Nuclear magnetic resonance.	(PH) Magnetic field of a current. Quiz.	
5	(PH) Electromagnetic induction.	(PH) Introduction to relativity: basic postulates.	(PH) Relativity continued. Transformations.	(PH) Relativity continued. Mass-energy equivalence. Quiz.	(PH) Nuclear half-life. Measurement of e/m.
6	(CH-PH) P/N ratio. Nuclear reactions. Nuclear emmissions.	(CH) Natural series. Half life. Bombardment reactions.	(CH) Mass loss. Binding energy. Fission.	(CH) Faraday's law of electrolysis. The concept of chem. equivalent.	
7	(CH) Electrochemistry. Brief introduction to electrolytic & voltaic cells	(CH) Standard electrode potential; relation to Gibbs free energy.	(CH) Electrolysis: plating and commercial preparation of some metals.	(CH) Faraday's law contd. Common batteries.	(CH) Oxidation potentials.
8	(CH) Fuel cells. Quiz.	(CH) Halogens: electronic structure, oxidation states.	(CH) Halogens: compounds.	(CH) Sulfur, Te, Se: electronic structure, oxid, states, oxy acids.	(CH) Determin. of the Faraday. Halogens. (2 periods -no recitation.)
9	(CH) Sulfur, tellurium, selenium continued: hydrides, oxides.	(CH) Exam.	(CH) Nitrogen and phosphorous: oxy acids, hydrides.	(CH) Nitrogen and phosphorous continued.	(CH) Abbreviated qualitative analysis. (Four periods - no recitations.)
10	(CH) Alkali and alkaline earth metals.	(CH-PH) Transition metals. Metallurgy.	(CH) Metallurgy continued. Carbon and silicon: oxy acids, hydrides	(CH) Special topics.	

Sixth quarter lectures. / Labs

	Lectures				Labs
1		(BI) Sexual reproduction: tracheophytes.	(BI) Sexual reproduction: metazoa.	(BI) Embryology and development.	(CH) Abbreviated qualitative analysis. (Two periods.)
2	(BI) Embryology and development continued.	(BI) Genetics: Mendelian crosses.	(BI) Genetics: non-Mendelian.	(BI) Genetics: linkage.	(BI) Plant and animal development.
3	(BI) Genetics continued. Genetic basis of evolution.	(BI) Genetics concluded. Intro. to evolution.	(BI) Evolution: speciation.	(BI) Evolution concluded. Overview of paleontology.	(BI) Genetics.
4	(BI) Exam.	(BI) Ecology: energy flow.	(BI) Ecology: interactions.	(BI) Ecology: interactions and population growth.	(BI) Adaptations.
5	(BI) Population dynamics.	(BI) Ecological succession.	(BI) Communities.	(BI) Habitats.	(BI) Symbiosis.
6	(PH) Magnetic materials. Permeability.	(PH) Amperian currents. Permanent magnets.	(PH) The magnetic circuit. Inductance.	(PH) Inductance continued. Quiz.	(PH) Oscilloscope. Relaxation oscillator.
7	(PH) LC and RLC circuits. Transformers.	(PH) AC circuit analysis.	(PH) Electronics.	(PH) Electromagnetic waves. Quiz.	(PH) AC resonant circuits.
8	(PH) Light and Huygen's principle. Reflection and refraction.	(PH) Rays. Refraction at plane surfaces.	(PH) Mirrors. Quiz.	(PH) Spherical surfaces. Imaging.	(PH) Microscopes.
9	(PH) Lenses.	(PH-BI) The eye and optical instruments.	(PH) Interference and diffraction.	(PH) Diffraction gratings.	(PH) Grating spectrometer.
10	(PH-BI) Electron and optical microscopes.	(PH-CH) Polarization. Optical activity.		(PH-CH-BI) X-ray and electron diffraction in crystalline solids.	(PH-CH-BI) "Open" physics lab experiment.

APPENDIX C

Distribution of class hours: core-course and conventional introductory science courses at PSC.

Student class hours - Core-course:

Lectures/Labs/Recitations

Term	Biology		Chemistry			Physics			Total(Lect/other)	
1	0	0	16½	3	4	25½	6	7	42	20
2	20	10	18	5	5	0	0	0	38	20
3	14½	7	7½	3	2	16	3	5	38	20
4	25	11	16	5	4	0	0	0	41	20
5	0	0	20½	7	1	18½	6	5	39	19
6	19	8	0	2	0	19	5	5	38	20
Total:	78½	36	78½	25	16	79	20	22	236	119
Total:(Conventional course*)										
	92	61	92	30	31	92	30	31	276	183
Ratio:(Core course periods/conventional course periods)										
	0.85	0.59	0.85	0.83	0.61	0.86	0.67	0.71	0.85	0.65
Ratio:(Core course class hours/conventional course class hours)										
	0.85	0.88	0.85	0.83	0.61	0.86	0.67	0.71	0.85	0.77

Hours in class per credit hour-term:

Principles of Bio.	17.8
General Chem.	17.7
General Phys.	14.2
Core-course	14.4

Periods in class per credit hour-term:

Principles of Bio.	12.7
General Chem.	12.7
General Phys.	10.2
Core-course	9.9

* Note: Principles of Biology - 2 hour labs; Core-course - 3 hour labs.
Note also: General Physics = 5 credit hours; General Chem = 4 credit hours; Principles of Biology = 4 credit hours; Core-course = 6 credit hours (2 years).

Course________ Section_____ ID Number __________

Attitude Survey Instrument

This reaction inventory was prepared to assist the Science Faculty of Portland State College to improve its undergraduate instruction. The answers you provide will be held in strict confidence. No instructor of this course will see your response sheet. He will be provided a tally of the results, however.

Instructions: Please give your reactions to the following list of items regarding your experience in this course. Draw a circle around the letter that corresponds to the statement that most nearly registers your true feelings.

1. My experiences in this course have

   a. intensified my interest in science
   b. had no impact on my interest in science
   c. lessened my interest in science.

2. My experiences in this course have

   a. caused me to consider changing my major from science to another field of study
   b. caused me to consider changing my major from one science to another
   c. had no effect on my choice of majors

3. My experiences in this course have caused me to

   a. elect different courses than I had originally intended for next year
   b. make no change in my course selection for next year

4. To what extent has this course met your expectations with respect to improving your subject matter competence?

   a. very well satisfied
   b. satisfied
   c. disappointed

5. As a result of my experience in this course I am

   a. considerably more aware ot the impact of science on human affairs
   b. somewhat more aware of the impact of science on human affairs
   c. no more aware of the impact of science on human affairs

6. As a result of my experiences in this course

   a. I am considering changing my career choice from one which is science oriented to some other vocation
   b. I am considering changing my career choice from one science vocation to another science vocation
   c. I have not considered making a change in my choice of careers

7. As a result of my experience in this course

a. I am more aware of the interdependence of all the sciences
b. I have not changed my views about the interdependence of the sciences

8. I would rate the over all instruction I have received in this course as

a. excellent
b. good
c. fair
d. poor

(ANSWER FOR THE APPROPRIATE SUBJECT OR SUBJECTS)

9. I would rate the instruction I have received in this course as

Phys.	Chem.	Bio.	
a.	a.	a.	quite stimulating
b.	b.	b.	of average interest
c.	c.	c.	quite dull

10. I feel the course has been

Phys.	Chem.	Bio.	
a.	a.	a.	rather easy
b.	b.	b.	of average difficulty
c.	c.	c.	difficult to me

11. I consider the quality of lectures given to be

Phys.	Chem.	Bio.	
a.	a.	a.	of high calibre
b.	b.	b.	average
c.	c.	c.	poor in quality

12. I consider the assignments made were

Phys.	Chem.	Bio.	
a.	a.	a.	reasonable
b.	b.	b.	average
c.	c.	c.	unreasonable

13. In contributing to my understanding I consider the laboratory experiences

Phys.	Chem.	Bio.	
a.	a.	a.	helped significantly
b.	b.	b.	were average in their help
c.	c.	c.	helped little

14. In contributing to my understanding I consider that the recitation groups

Phys.	Chem.	Bio.	
a.	a.	a.	helped significantly
b.	b.	b.	were average in their help
c.	c.	c.	helped little

15. I consider that the examinations for the course were

Phys.	Chem.	Bio.	
a.	a.	a.	appropriate
b.	b.	b.	inappropriate

Average characteristics of test groups.

Each member of the experimental group was matched with a student from each of the three conventional courses as described in a previous report.[1] Comparisons given in this report were performed on the basis of group averages.

Group:	Experimental (Core-course)	Control (Physics)	Control (Chemistry)	Control (Biology)	Control (Combined)
Size of sample:[2]	20	24	22	19	65
Sex (+1 male, -1 female):	+0.5	+0.8	+0.8	+0.8	+0.8
Class (1 freshman, 2 sophmore):	1.2	1.2	1.4	1.1	1.25
SAT verbal:	512	492	482	504	493
SAT mathematics:	513	595	592	546	577
High school GPA:	3.11	3.14	3.11	2.86	3.03
Breakdown by major:		No data available.			
Phys. or phys/math	3				
Chemistry	3				
Biology	2				
Pre-med,-dent,-vet	6				
Mathematics	2				
Other science	4				

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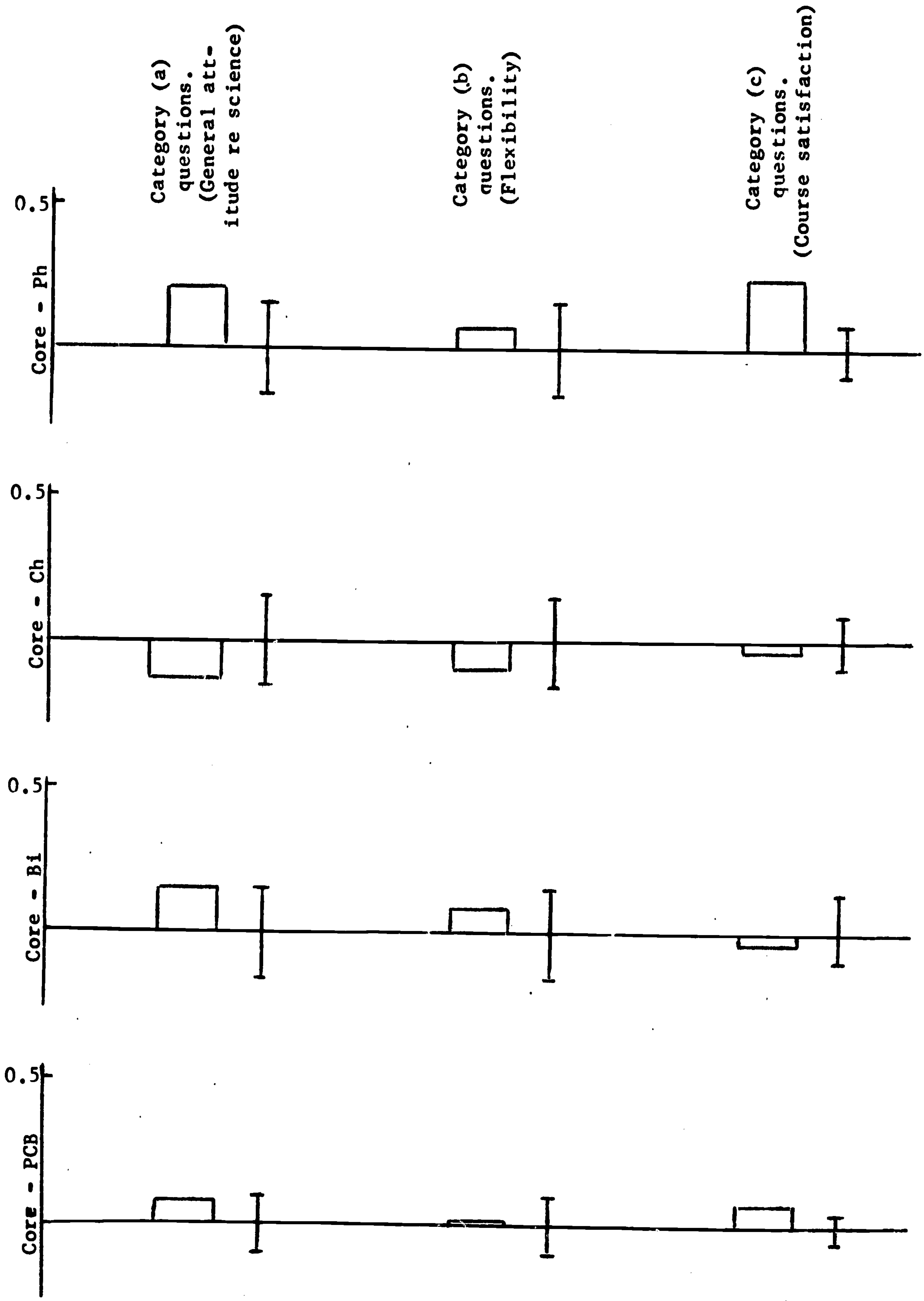
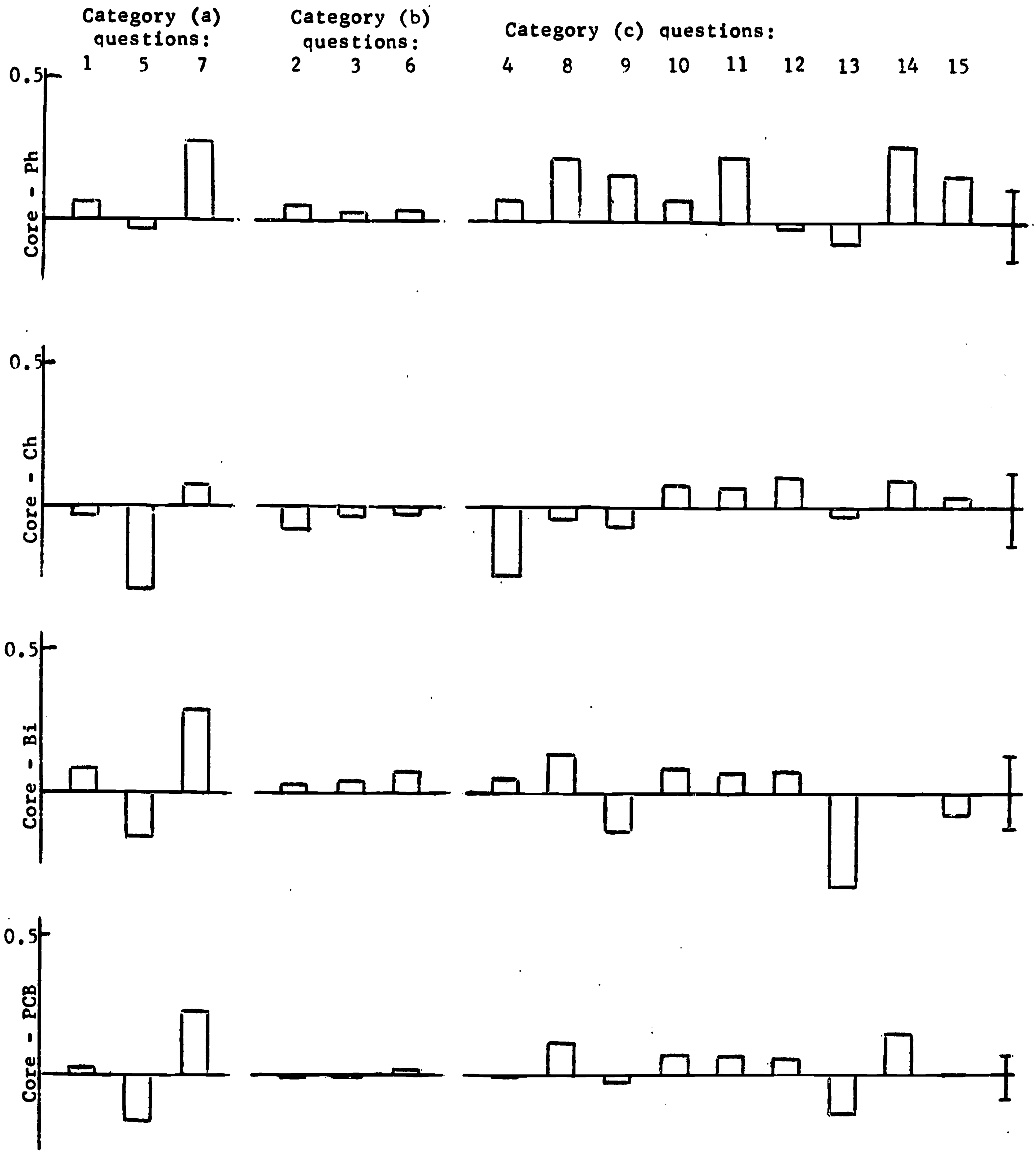
1. See page B-17, Final Report of Project No. 6-8468, U.S. Department of Health, Education, and Welfare, Office of Education. [11]

2. Due to withdrawals and absences there are slight differences among population sizes in the various groups.

Differences in average response between core-course group and various control groups - by question category. (Approximate 90% confidence intervals indicated.)



Differences in average response between core-course group and various control groups- by individual question. (Approximate 90% confidence intervals indicated.)



Average responses of various student groups, by question.
(Scores normallized to ±1. Standard deviations range from about 0.1 to 0.2.)

Question		Experimental (Core-course)	Control (Physics)	(Chemistry)	(Biology)	(Combined)
1.	(Interest in science.)	0.7	0.6	0.8	0.5	0.6
2.	(Change in major.)	-.5	-.6	-.4	-.6	-.5
3.	(Change in courses.)	-.5	-.5	-.4	-.6	-.5
4.	(Satisfaction with learning.)	.1	-.1	.6	-.1	.1
5.	(Science & human affairs.)	.0	.0	.6	.3	.3
6.	(Change to non-science.)	-.6	-.6	-.5	-.7	-.6
7.	(Interdependence of science.)	.8	.3	.5	.2	.3
8.	(Excellence of instruction.)	.5	.1	.6	.2	.3
9.	(Stimulation of instruction.)					
	PH	.4	.0			
	CH	.5		.6		.4
	BI	.2			.5	
10.	(Lack of difficulty.)					
	PH	-.3	-.5			
	CH	-.2		-.3		-.4
	BI	-.3			-.4	
11.	(Quality of lecture.)					
	PH	.5	.1			
	CH	.7		.8		.4
	BI	.3			.2	
12.	(Reasonableness of assignments.)					
	PH	.4	.4			
	CH	.8		.6		.5
	BI	.7			.5	
13.	(Laboratory effectiveness.)					
	PH	-.4	-.3			
	CH	-.2		-.1		-.1
	BI	-.4			.2	
14.	(Effectiveness of recitations.)					
	PH	.1	-.4			-.2
	CH	.2		.0		
15.	(Appropriateness of exams.)					
	PH	.9	.6			
	CH	1.0		.9		.7
	BI	.6			.7	