DOCUMENT RESUME

ED 414 835	HE 030 821
AUTHOR	Courtright, James B.
TITLE	Development of Concept Modules for the Teaching of Introductory Science to the General Student.
INSTITUTION	Marquette Univ., Milwaukee, WI. Coll. of Arts and Sciences.
SPONS AGENCY	Fund for the Improvement of Postsecondary Education (ED), Washington, DC.
PUB DATE	1995-09-30
NOTE	42p.
CONTRACT	P116811211
PUB TYPE	Reports - Descriptive (141) -- Tests/Questionnaires (160)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Academic Persistence; Achievement Rating; College Instruction; *College Science; *Curriculum Development; Curriculum Evaluation; Higher Education; *Interdisciplinary Approach; Introductory Courses; *Nonmajors; Program Evaluation; *Science Instruction; Student Evaluation
IDENTIFIERS	*Marquette University WI

ABSTRACT

A project to develop an interdisciplinary course (ARSC 10/11) for teaching science to college students not majoring in science is described. Concept modules were developed for a two-semester format consisting of three hours of lecture and two hours of laboratory per week. Important science themes were identified to promote an understanding of modern biology, chemistry, and physics. A science survey test was developed and administered at the beginning and end of the semester to students in the interdisciplinary ARSC course and in introductory biology and chemistry courses. Science topics which are potentially confusing were also identified and clarified to help avoid learning difficulties. The performance on science exams for students in the ARSC course and introductory science classes was compared. Students in the ARSC course, the School of Education, and the College of Arts and Sciences were also compared for grade point average, retention rates, and standardized achievement test scores. Appended materials include course syllabi for fall and spring semesters, the science survey test questions with year- to-year comparisons of students' scores for each question, and graphs showing testing and performance outcomes. (SW)

Project Title: Development of Concept Modules for the Teaching of Introductory Science to the General Student

Cover Sheet

Marquette University
College of Arts and Sciences
Milwaukee, WI 53233

Grant Number: P116811211

Project Dates:

Starting Date: October 1, 1992
Ending Date: Sept 31, 1995
Number of Months: 48

Project Director:

James B. Courtright
Department of Biology
P.O. Box 1881
Marquette University,
Milwaukee, WI 53201-1881
Telephone: (414) 288-1476
Email: courtrightj@vms.csd.mu.edu

FIPSE Program Officer(s): Preston Forbes

Grant Award:	Year 1	$ 53073
	Year 2	$ 83054
	Year 3	$ 70699
	Year 4	$ 0
	Total	$ 206826

Appendices.

I. Graphical presentation of student testing and performances outcomes.
II. Course syllabi for 1995/96
III. Pre/Posttest questions and the comparative year by year outcomes in summary form.

Project Title: Development of Concept Modules for the Teaching of Introductory Science to the General Student

Summary: This project identified and developed an appropriate number of concept modules based on identifiable themes that lend themselves to the interdisciplinary teaching of concepts necessary for the understanding of modern biology, chemistry, and physics. These modules were organized into a two semester course format (ARSC 10/11) so that students completing the sequence in either order would be introduced to the modes of thought that characterize scientific endeavor. This course consists of 3 hours lecture and 2 hours laboratory per week, for which appropriate lecture notes and supplements as well as related outlines of laboratory experiments have been prepared. The course has now been taught to 530 students and 60 adults registered for 3420 credit hours. This course is now entering its fifth year, enrollments are near the physical limits, and student retention levels are greater than 90%. This approach to teaching science concepts to non science students may be suitable for other colleges and universities.

Major Accomplishments:

- Major, relevant science themes and topics identified by modules.
- Lecture and laboratory outlines and exercises appropriate to each module developed.
- Key topics that are a cause of learning difficulties identified and clarified.
- Course content organized and comprehensively condensed, allowing for the science component requirement to be completed for Education majors in a 2 semester program.
- Merits of the course disseminated through First Year advising process, including advisors in the Freshman Frontiers and the Educational Opportunity Programs
- Recruitment of undergraduates science majors as cooperative and enthusiastic teaching assistants.
- Modification and adaptation of the course for adult learners in the newly established College of Professional Studies offering a BS degree in Organization and Leadership.

Grantee Organization:

College of Arts and Sciences
Marquette University
Milwaukee, WI 53233

Project Director:

James B. Courtright
Department of Biology
P.O. Box 1881
Marquette University,
Milwaukee, WI 53201-1881
Telephone: (414) 288-1476 / Email: courtrightj@vms.csd.mu.edu

2. EXECUTIVE SUMMARY

A. Project Overview:

This project started with the need to address the problems involved in teaching science as part of the core curriculum at Marquette and other universities. The teaching of nonscience students, in most instances, is a problem since 1) these students who do not intend to become science majors, 2) they have a limited interest in the rigorous reasoning processes and procedures that constitute the basis of modern science, and 3) these students, in contrast to prescience majors, have different needs in terms of historical background and breadth of content coverage.

Our project has been to develop an interdisciplinary program for the teaching of science to this general student. This has involved the development of a totally new course to the Marquette curriculum, combining lectures and learning laboratory settings. A selected number of topics suitable for this purpose has been identified, lecture and study outlines prepared, and laboratory activities developed. This course has been taught by faculty from the departments of Biology, Chemistry and Physics in combination with both graduate and undergraduate teaching assistants. Furthermore, a part time laboratory coordinator has been hired to implement the laboratory procedures and experiments.

As a means of assessing the efficacy of this approach, we have designed a general purpose science survey, collected student opinions, and correlated student performance to those of other available, independent measures of student aptitude. F.I.P.S.E. support permitted one year for developing the course program and two years for implementing the course. These objectives have been met and by many measures, this course is successful. The course has been continued with full university support for the last two years and has now been assigned to the Physics Department as a primary teaching responsibility. The university has now provided the complete funding for the course for the present and foreseeable future. Enrollments in the course are at the practical limit in terms of available rooms and resources. Student performance, both in the course and overall, is better than all other students in the college. Academic retention, as measured by continued enrollment or graduation, is greater than 92% and apparently exceeds that of any other identifiable student group.

B. Purpose.

The purpose of this project was to develop a course that would serve the educational needs of students not selecting science as a major. To help students appreciate the excitement and the analytical methods that are used in modern science, laboratory sessions devoted to both discovery and analysis would be developed. Lastly, the implementation of this course could reduce redundancy in the science offerings required for teacher certification while providing sufficient depth as to permit prospective elementary and middle school teachers an introduction to applying concepts to classroom learning activities. The focus of the course and the related laboratory activities was simply designed so that implementation at other sites could be easily implemented as desired.

C. Background and Origins.

Prior to the project, the undergraduate offerings in science for suitable for the non major were Biology, Chemistry (1 course), and Physics (five courses: General Physics, Environmental Astronomy, Environmental Physics, and Meteorology. The problem with this selection was not the diversity but the appropriateness of such offerings for the general student, who by Marquette's curriculum, was only required to take any two in any sequence. Secondarily, the content and offerings were to a large extent guided by the Wisconsin Department of Public Instruction, which required a greater breadth of coverage in recent years. Moreover, since the Physics courses would not satisfy the requirements for either the Biology major or the requirements for predental, premedical, and related preprofessional students, the audience in these courses was not as grade competitive and the science content not equivalent. Not surprisingly, these students also perceived these Physics courses as being less rigorous than the Biology or Chemistry courses. In addition, these general courses were not for the premajor and were taught by part-time, non tenure track individuals. While at Marquette, this did not present an immediate problem, the quality of these courses was dependent on our fortune in identifying capable persons and did not necessarily represent a desirable long term solution.

The major problems with this piecemeal approach to science education was that the university course offerings were to a certain extent being determined by the requirements of an external agency. Any increased curriculum demands may be difficult to satisfy easily, either at small colleges or at times with decreasing budgets and in some cases declining student enrollments. The related second problem was that a Physical-Science-only approach to the education of the nation's future citizens and teachers totally neglected most of the necessary biology and chemistry (especially organic) that are part of the modern lexicon. There should be no doubt that these students need to be more fully aware of the many biological problems presented to modern society, ranging from nutrition and agriculture to waste disposal and chemical/physical mutagens. This situation posed a problem that we felt could be changed and a curriculum that could be improved.

As described in the original proposal, our endeavor was to forge an interdisciplinary approach to teaching scientific concepts. This was done with the full support of the both previous and current Deans of the College, as well as Department Chairs, who were willing to permit released time for this effort and had the foresight to realize that F.I.P.S.E. funding would simply be the catalyst for such a change and, if successful, could be a continuing and attractive component to the offerings in the College. As originally formulated, the program was to have the continual input from the departments of Biology, Chemistry, and Physics, perhaps with joint or team taught course(s). While the success of the program would present the opportunity to secure additional outside funding for dissemination, equipment, the continuation of the program itself was not intended to be dependent on such sources and that, after the preliminary period, to be funded entirely from internal sources.

D. Description of the Project.

As students work to educate themselves for meaningful careers in a highly diverse workplace, they are inevitably divided between their individual interests and the broad, comprehensive educational goals that are the hallmark of American education. Many of these non science students are otherwise well motivated, bright, imaginative and creative and therefore should be receptive to the intriguing ideas of modern science even though they traditionally are not interested in its content. At the same time, the phenomenal successes of 20th century science and technology have advanced the scientific disciplines beyond that of a simple descriptive methodology to that requiring highly specialized terminology and increasingly complex interpretations. Our goal, therefore, has been to develop an appropriate learning environment in which students can learn about the ideas and paradigms of modern science and to provide a learning environment which allows the student to gain familiarity with scientific ideas and to apply them to an reasonable understanding of the events in their lives and in society at large.

Course Syllabus. The attached syllabus details the most recent offering of this course. To be noted is the diversity of topics and the interdisciplinary nature of the presentations.

Course Pre/Post Examinations. Two examinations, one each for the fall and spring semesters were developed. Student performances on these examinations were used as an internal control to determine the level of scientific subject familiarity and reasoning.

Laboratory Activities. Laboratory activities were primarily designed to allow students to discover new and interesting relationships. The intention of these experiments were to allow students to engage in a scientific type of experiment in such a manner that the elements of observation, communication, analysis, and testing were encouraged. Experiments were designed to avoid recipe style laboratory activities. These experiments have been and are continuing to undergo modification, based on responses from both teaching assistants and the students themselves. Activities are taking in to account the significant deficiencies in laboratory operations by first and second year students.

Science Conceptual Aids. In the process of designing and implementing this course, members of the three participating departments mutually recognized a number of topics that were conceptually troublesome to us as capable scientists. Significantly, most textbooks, even when written generalists in a discipline, gloss over these problems. Clearly, if certain topics can be potentially confusing to a practicing scientist, then one should be acutely sensitive to the problems these concepts present to the average nonscience student attempting to master them. While our (growing) list is by no means complete, some of the problem areas relate to electrochemical cells, gene action and functions, human vision, lenses and optics, nucleic acids and proteins, and simple thermodynamics. It seems likely that we have initiated steps for overcoming these learning difficulties. Perhaps importantly, these efforts have resulted identifying key areas where presentation, language, and process are critical to student mastery of relevant concepts and content. We plan on publishing articles relating to these themes and feel that these should be helpful both to students and teaching assistants in introductory science courses.

E. Evaluation/ Project Results.

1. Project Results and Comments.

A combination of cross sectional and longitudinal studies have been carried out with students who have taken the course. In all cases, we have searched for relationships between course performance, science literacy competence, university grade point average, and in one semester, performance on the broad field science examination (Educational Testing Service) which we administered in a field test. In all cases, the correlations are generally weak and interestingly, raise questions as to what are the key indicators and predictors of student college performance. Perhaps importantly, our results indicate that students who have not yet demonstrated a high level of college learning abilities on admission are able to perform adequately, if not excellently, in both our science sequence as well as in other college courses.

The one major indicator of overall success of our project is two fold: 1) for full time students, the retention or graduation rate is 91.9%, exceeding the approximate 84% of the College of Arts and Sciences. 2) the retention rate for ARSC 10/11 course students in the School of Education, the retention rate is 96.4%. The reasons for these high retention levels is not known, but student performances on our science examinations in many instances exceeds that of students majoring in either Biology or taking Chemistry courses. In addition, enrollments remain at a high level, now greater than 150 for the fall semester.

Since many in the course are pre-service education majors, the results have been further analyzed to determine if performance of these students might be significantly different from those of other students. For the criteria available, e.g. QPA (quality point average), predicted QPA, ACT, SAT, and retention rates, there is no strong evidence to suggest these students represent a different ability grouping. There was an apparent slight increase in retention of Educ8 students (93.1%), but a difference of only 2 students would have changed the outcome.

The current proliferation of student and organizational Web sites should indicate that student interest in a given topic is multidimensional and multifaceted. Furthermore, the popularity of the Internet to many students stems from the ability to focus on one topic and to branch from that topic to related ones of interest. This evidence of current student attitudes toward learning should stand in contrast to the major reductionist focus in modern science, which, despite its usefulness to the practicing scientist, is rarely relevant to the student untrained in the scientific mode of discourse. From the onset of our program, we intended to develop appropriate, interrelated concept modules, each of which could be upgraded and modified with additional intramural input from specific disciplines, as can be done readily for a research centered university. Thus, our approach was to present topics in their rich multiplicity and to offer differing viewpoints as to how science proceeds in contributing to solutions to various problems. While this approach, by its very nature, prevented us from presenting the greater depth of a given area, it did permit exploring a given theme by pointing out related major threads, with the hope that at least one of which should have appeal to most students.

One primary assumption was that there would be equal and continued contribution from the science departments. In practice, this was difficult to achieve, especially in view of the concurrent increasing demands for improvements in respective department major programs, work on first year student retention, and a need to address continued research productivity. There was substantial and continued personal commitment from the principal investigator to the success of this project, which in years 3 and 4 required coordination of the lecture and laboratory schedule, overseeing the laboratory supervisor, aiding and securing biological samples. Further, it should be noted that the fourth year implementation of the program required further inputs from the Chemistry and Physics Departments. The continued willingness and involvement of the various science departments are key to the this program and its success. Without continued support and oversight, it would seem likely that the relevant teaching department would ultimately convert the course into one more compatible with the discipline, such as Physics,

One major problem in delivering the course has been the absence of a usable and workable text. Initially Tillery's Physical Science, combined with ad hoc biological supplements, was marginally acceptable. This past year we have used Trefil and Hazen's The Sciences: An Integrated Approach but have not been pleased with its uneven and limited presentation of Biology. Our combined experience, and the student demands, of the past 4 years indicates that a suitable working text should be available. The textbook publishers have show little enthusiasm for such a book, at least on a scale that would be useful. An interim solution has been to make detailed lecture notes available to students in both printed and electronic form. With greater use of the Internet, this latter approach can now include the dynamic use of colored charts and photos, which otherwise would have been prohibitively expensive.

Lectures. Student interest in lectures has been uneven. Interested students have been able to obtain a reasonable amount from lectures, but those with weak or deficient backgrounds in science have usually found the lectures too fast paced and/or uninteresting. Student comments regarding the course, especially those that reflect on its value from a distance of time afterwards, think the course was a good positive learning experience in their Marquette experience. More immediately, students react to style and presentation techniques. Given the large size of the class at present, > 150 students in fall semesters, there may not be a simple solution.

Labs. The laboratories have two positive features that have contributed to their success as an element of the course. The first has been the personal attention provided by their small size and secondly by the undergraduate teaching assistants. These assistants have been recruited from upper level Biology and Biochemistry/Molecular Biology majors. These assistants have been uniformly enthusiastic, have enjoyed the teaching experience, have been able to put their recent mastery of biology, chemistry, and physics to practice. Many have felt that the course has been an excellent preparation for their upcoming MCAT examinations. With a singular exception, the use of graduate students has been less than desirable, primarily because the advanced standing students who would be interested in teaching a course are several years removed from cognate courses and have only been able to master the requisite background with some difficulty and with obvious reluctance. The one exception was a Chemistry graduate student, who remains enthusiastic and committed to the goals of the course.

The second strong feature has been the strong, favorable student response to these experiences. We have required in-class presentations, written work, and outside of class written reports. While this has been more work than they initially might have expected, the requirement for attendance, for deadlines, for remaining actively receptive to observation and deduction have had positive benefits. Our long range view interpretation of student comments, taken in conjunction with a separately launched Freshman Seminar and the Student Retention Services, is that an activity such as this provides as structure and a regimen and a certain level of self responsibility that is often not available in the first year of college study. Moreover, the laboratory experience with a dedicated, knowledgeable, capable and caring upperclass student provides an opportunity for intensive learning in a small group that would not necessarily be a part of the first year student's course activities.

The one small problem that has caused students' concern relates to the proper identity of the course on student transcripts (ie. ARSC 10 or ARSC 11). This is particularly a problem for students transferring to other institutions and transferring the course for science credit. Due to its interdisciplinary nature, it is neither classified as Biology, Chemistry, nor Physics. Furthermore, its listing in the catalog is as a Special Offering by the Arts and Sciences College rather than as a regular course in the Physics Department, which now has the responsibility for its delivery. These concerns are under advisement by the College Curriculum Committee.

Adult programs. Although not originally part of the program, the Marquette Continuing Education Division was changed in 1993 and a new College of Professional Studies was formed. The broad based introduction to science thinking developed with the course was ideally suited for a similar course for adult learners. We have now offered the course on Saturdays in three different quinmester sessions of 8 weeks each to more than 60 adults. The adult response to this approach has been positive and favorable and this course will be continued as part of the degree in professional studies offered.

2. Numerical Evaluations.

In addition to the percent retention noted above, we have attempted to establish correlations between various components in the course and student performance in the course as well as in other courses in the undergraduate program. In this context, we have also obtained numbers for other students not in the experimental program, allowing us to determine the relative strengths and weaknesses of the program. For this evaluation, we constructed a general purpose science survey test, which measured science content, reasoning ability, and science interest.

These pre/post tests were given both at the beginning and the end of the semester to the ARSC 10/11 students as well as to those in the introductory Biology and Chemistry courses. Two features of these tests are relevant. The first is the performance on an absolute scale, where on several questions the students in the interdisciplinary course performed better that either of the other two test groups. These performances are documented in the accompanying graphs as well as the year to year comparisons in the appendix. The second is the relative improvement in performance, as roughly measured by the total score increase as a fraction of the initial score. The overall improvements by ARSC students, as well as the number of questions in which improvements were noted generally exceeded those in other courses. These increases are also noted in the graphs and appendix charts. For ease of comparison, the results are separately reported for the Biology and Chemistry students. Not only do these results strongly suggest that students can perform at a higher than expected level, but in many instances their mastery can exceed those taught science in traditional courses. Nonetheless, the value of the pre/post testing may be questionable, both in terms of the loss of class time for administering the test, as well as the reluctance of the students to take the test seriously and conscientiously. While there are likely to be many inaccuracies in such a single dimensional instrument, these results are encouraging and suggest that modifications at the college level courses can be more aggressively contemplated than previously considered.

We have determined what correlation may exist between student performance in the course with overall academic performance. Two aspects of these results are particularly interesting, especially since they may provide an insight into an important ingredient in student college success. The first related to the pre/post testing results themselves. The initial results did not indicate any significant r^2 (where r = coefficient of correlation) between the pre/post test performance itself in terms of either grade received or cumulative QPA. The absence of a correlation also held for the degree of pre/post test improvement with regard to grades. In view of the fact that the pre/post test covered only some aspects of the course content, these results should not be particularly surprising. The fact that year to year variation for some questions was considerable perhaps can raise questions about the nature of the test content itself.

However, when the class grade itself was compared to overall QPA, there was an indication that overall college performance was positively related. When other inputs available to us were measured, the significance of these relationships increased substantially. Importantly, we looked for the relationship between course grade and QPA for those students who had taken the pretest, posttest, or both, highly significant values were observed. While there are many ways to evaluate these data, a coefficient of correlation 0.81 for students who took the tests, continued their studies, and also had some college pretesting (ACT or SAT) strongly suggests a coincident indicator that may be relevant. It seems possible that these coincident indicators reveal an aspect of students who come to class, take examinations seriously, and are trying to learn the subject matter.

While one might be reluctant to argue that performance in a lecture/laboratory course is a key determinant in college academic success, there are components to the course that provide a structure to learning that is often missing college course. The feature to the course that has remained constant (changing instructors in the lecture is the variable) has been the laboratory sessions. Attendance at these is required, class demonstrations and discovery activities are promoted, and student TAs know their students and interact well with them. This activity in itself at least provides students with a certain identity and contact with a caring instructor. It seems likely that this type of learning environment is important in the full transition to the college learning experience. In addition, the writing component, eg. microthemes, is reviewed and discussed in these classes. The commitment of the TA to the students is particularly striking, especially in the sense that many were engaged in a unspoken competition with the other TAs in attempting to get their laboratory section lecture test and grade achievements at a high level. Based on many student comments, they felt the laboratory learning experience was an important ingredient to the course. In short, the course through its various mechanisms required students to take responsibility for their own learning and to recognize what constitutes a scientific argument and approach.

In carrying out these comparisons, other comparisons have been made and most with unexpected outcomes. For example, 176 students of the 530 were pre-service education majors, all of whom need to take Educ8. For these students, there is no correlation between either the grades in the Educ8 course and the overall QPA ($r^2 \approx 0.002$). Even though attempts were made to measure associations between ACT, SAT, high school percentile, and high school size, these standings were essentially unrelated to most students performances. However, if the student participated in these precollege testings, there was an increase in college testing performance (see following table). Other factors, such as QPA and retention percentages for education students in the class differed only slightly for the ARSC class as whole. For the larger group of students, we have searched for correlations between entering performance data and QPA and generally find no association.

Table 1. Coefficient of Determination (r^2) between ARSC average grade and overall academic performance.

Comparison of ARSC and QPA (r^2)

All Students	0.494
Subsets	
Both ARSC 10 & 11	0.658
Both ARSC 10 & 11 & Pre/Posttest	0.662
Pretest only	0.527
Posttest only	0.570
Retained students	0.558
ETS Science Test taken 1995 only	0.498
ACT (taken)	0.501
SAT (taken)	0.629
ARSC7*(taken)	0.171

Notes: A given subset was defined by students who had participated in one or more of the listed activities; actual performance on these other tests was not included.
*(separate Seminar for 1st year students).

Clearly, a student's willingness to participate in optional testing, enroll in the second semester of the course, engage in precollege testing all seem to be related to overall better college performances. Hence, the marked relationship between completion of this course and general college academic success is strongly suggestive and may well indicate that we have identified at least one component of the college learning experience that may be linked with establishing good performance outcomes.

3. Administration support.

A key to the continuation of a project is its support at the administrative level; in this respect, there is every indication the administration will support continued delivery of the course. There are a variety of factors that may have persuaded the previous and current Deans to support this course beyond the years of F.I.P.S.E. support. Among the factors we can identify, the retention numbers, the involvement of undergraduate teaching assistants, the consolidation of a variety of preservice education driven courses are important. The Physics Department has assigned one faculty member (Kenneth Mendelson, part of the original F.I.P.S.E. team) to teach both semesters of the course, plus the university has provided support for one laboratory supervisor (non tenure track line, Ph.D.level). In addition, we were able to argue early and secure these monies from laboratory fees as a dedicated source of funds (in contrast to other science courses). This financial mechanism has assured a core level of support and provides sufficient monies for supplies and teaching assistants. These multiple levels of support ensure that the course is largely self-supporting and its delivery will continue for several years.

Appendix I. Graphical results of student performances.

Students in ARSC 10/11 as well as those in Biology 1/2/4 and Chemistry 1/2 (introductory first and second semester courses) were given the same pre and posttest questions at the beginning of each semester. The results are presented analyzed in three ways: first, the performances of students in ARSC, Biology, and Chemistry are given, relative to the average for all three groups. Secondly, the improvement for seach test subject of students in ARSC 10/11 are compared to those in the regular science courses. Lastly, the differences in demonstrated ability, as based on final posttest results, are separately compared to those in the Biology and the Chemistry courses.

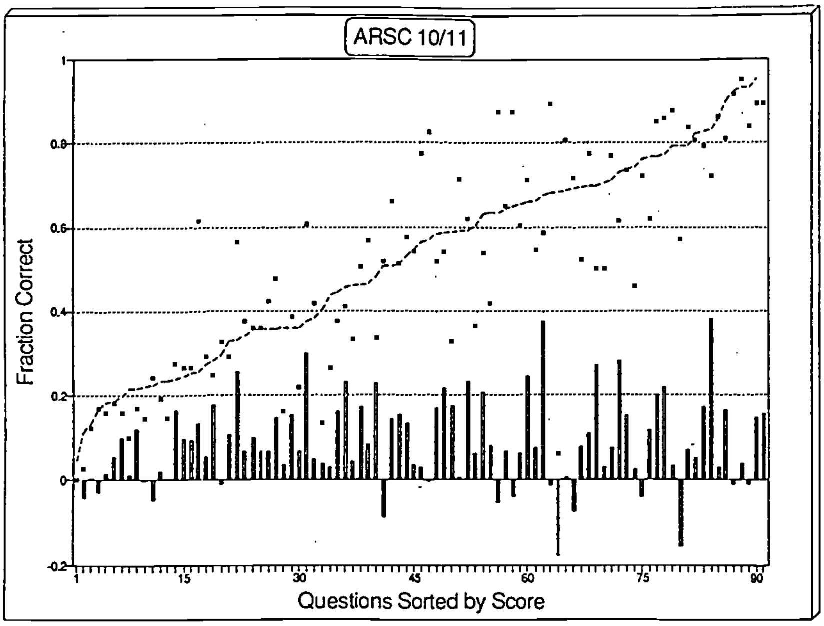
Panel I. For ease of presentation, the results for ARSC, Biology, and Chemistry test groups were averaged together. The individual results were then sorted on the basis of fraction correct answer. Differences from the average are then displayed for each tested group. On these graphs, results are also given to show the degree of improvement from pre to posttest. Separate graphs are presented for ARSC, Biology, and Chemistry courses. While the results differ from question to question, it is important to note that performance on many questions is above that of the combined average and that substantial improvement is noted for many questions that are not seen for students taking Biology or Chemistry.

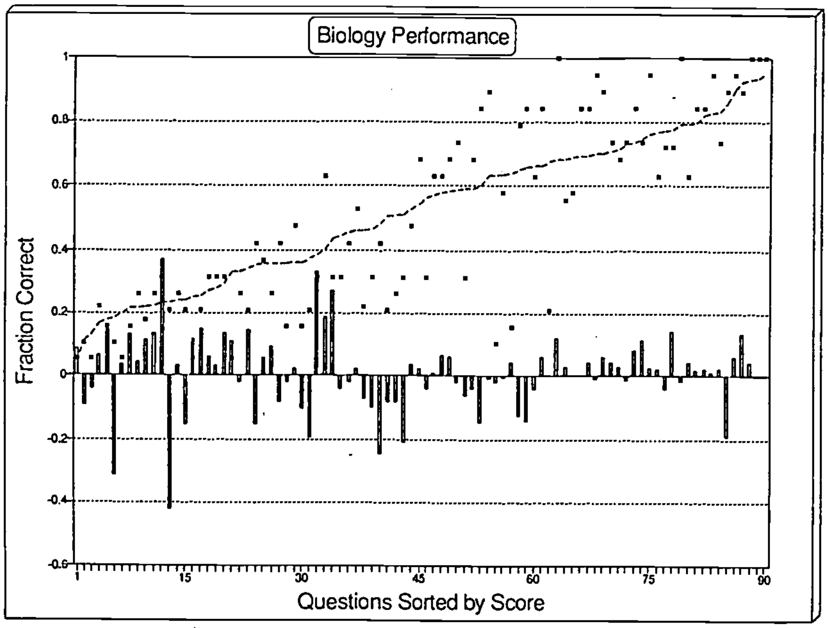
Panel II. The pre and post testing revealed a significant pattern to the improvement for students in ARSC. The results are jointly sorted first by subject matter and then by change in score for pre vs. posttest as for Panel I. Biology questions were 1-30, chemistry questions were 31-59, physics and general science questions were 60-90. Results are presented as the change from the pre test to post test. When these results ARSC vs. Biology or vs. Chemistry are broadly compared by subject matter (using same data as for Panel I), it is noted that this enhanced performance and increased improvement for ARSC students is mirrored in all major subjects tested. Although it should be noted that Chemistry students generally performed better on the pretest and therefore showed lower higher levels of improvement in the Chemistry and Physics areas than ARSC student, as should be expected. The performance of students in the introductory Biology courses, however, was not significantly different from the Nonetheless, the ARSC student performance in many instances was equivalent to Chemistry students. We feel there may be many lessons to be learned here, ranging from the comprehension by Chemistry students to the ability to learn by the nonscience students in ARSC.

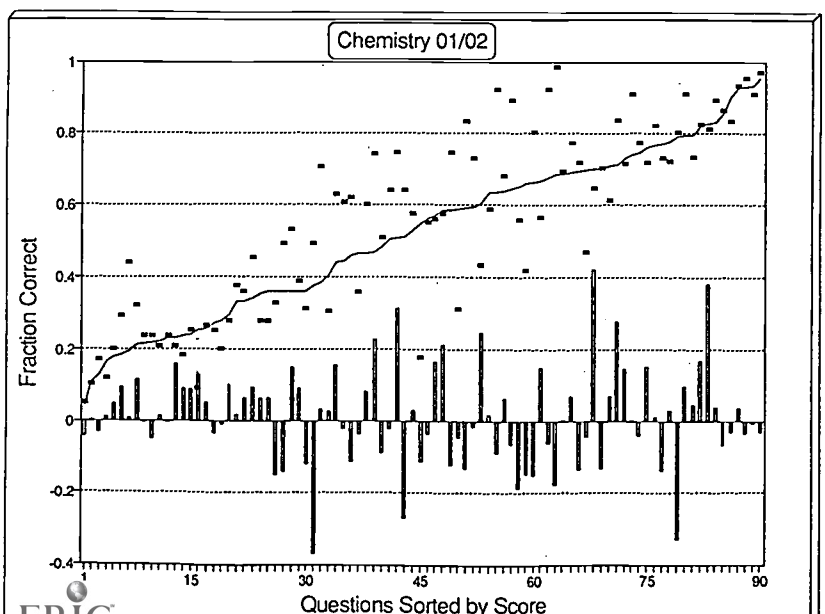
Panel III. A second comparison of the different classes was done by comparing the actual performance of the ARSC students to those in other classes. This was done by plotting the final posttest score for each of the subjects as compared to the final score for Chemistry or Biology students. There are test questions on which ARSC students performed better than those students taking these pre major courses.

Panel IV. A final comparison was made for the overall academic improvement from the semester students were enrolled in ARSC 10/11 to their last or current quality point average QPA. Approximately one third of the students showed QPA improvements (107/339). This number of students with improving QPAs and the magnitude of their improvement (0.2/student) exceeds that of the Arts and Science College as a whole and may reflect an overall improvement in academic skills.

PANEL I

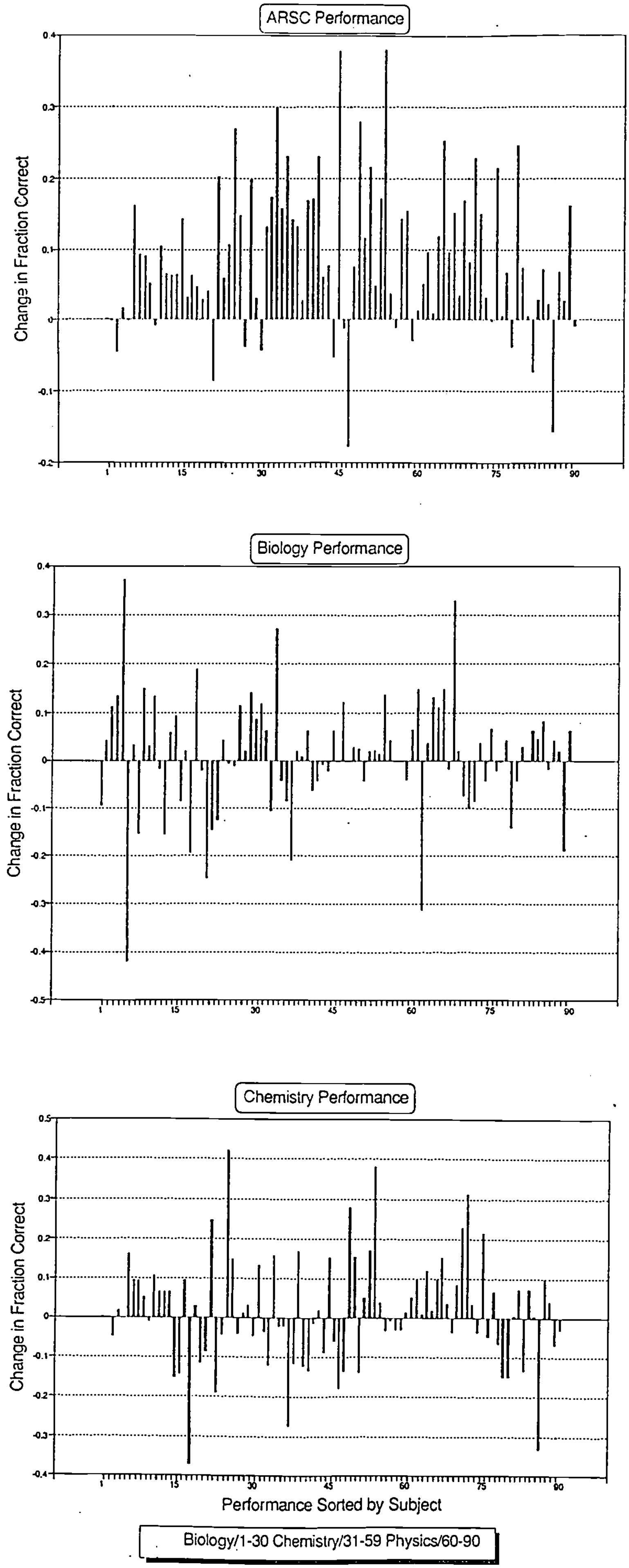


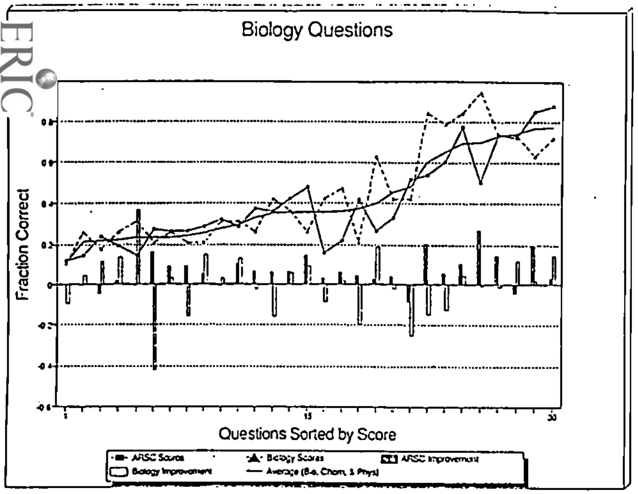


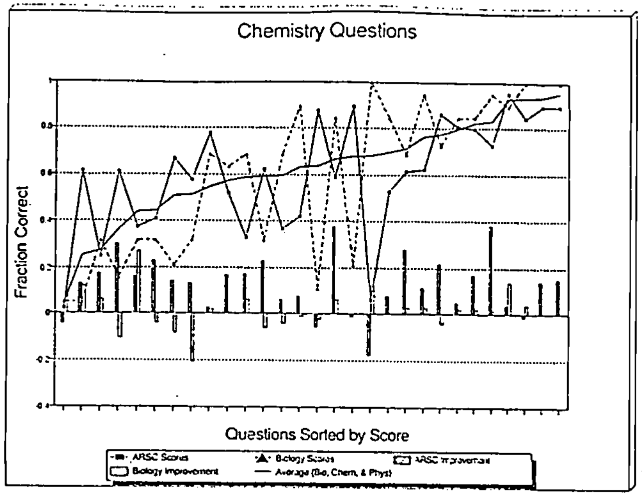


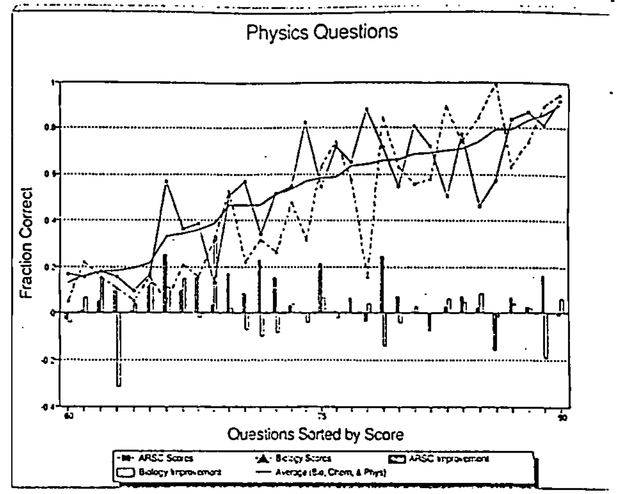
BEST COPY AVAILABLE

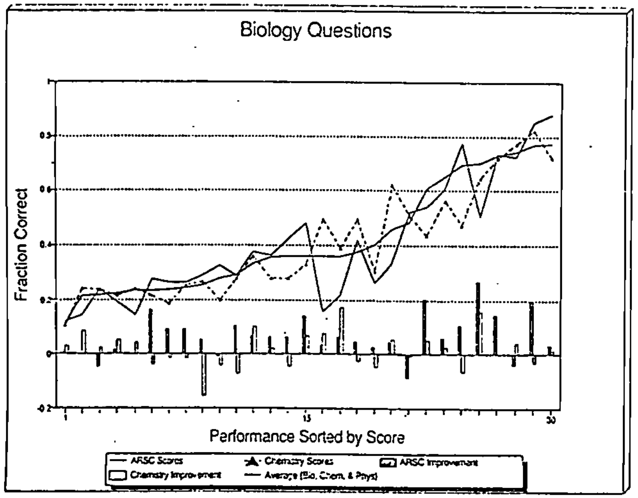
PANEL II

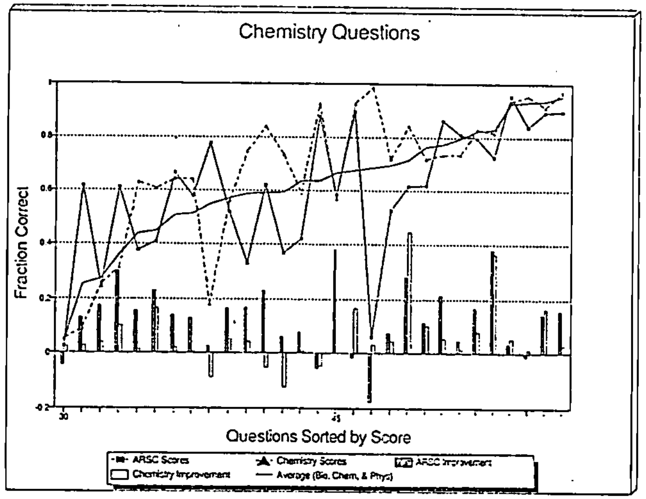

ARSC Performance
Change in Fraction Correct
0.4
0.3
0.2
0.1
0
-0.1
-0.2
1
15
30
45
60
75
90
Biology Performance
Change in Fraction Correct
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1
15
30
45
60
75
90
Chemistry Performance
Change in Fraction Correct
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
1
15
30
45
60
75
90
Performance Sorted by Subject
Biology/1-30 Chemistry/31-59 Physics/60-90

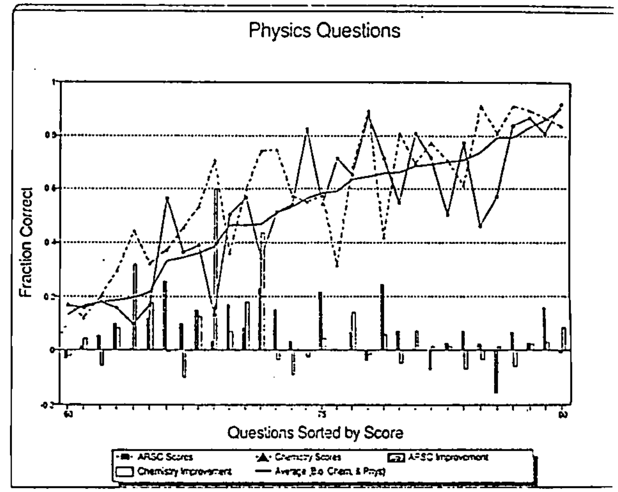




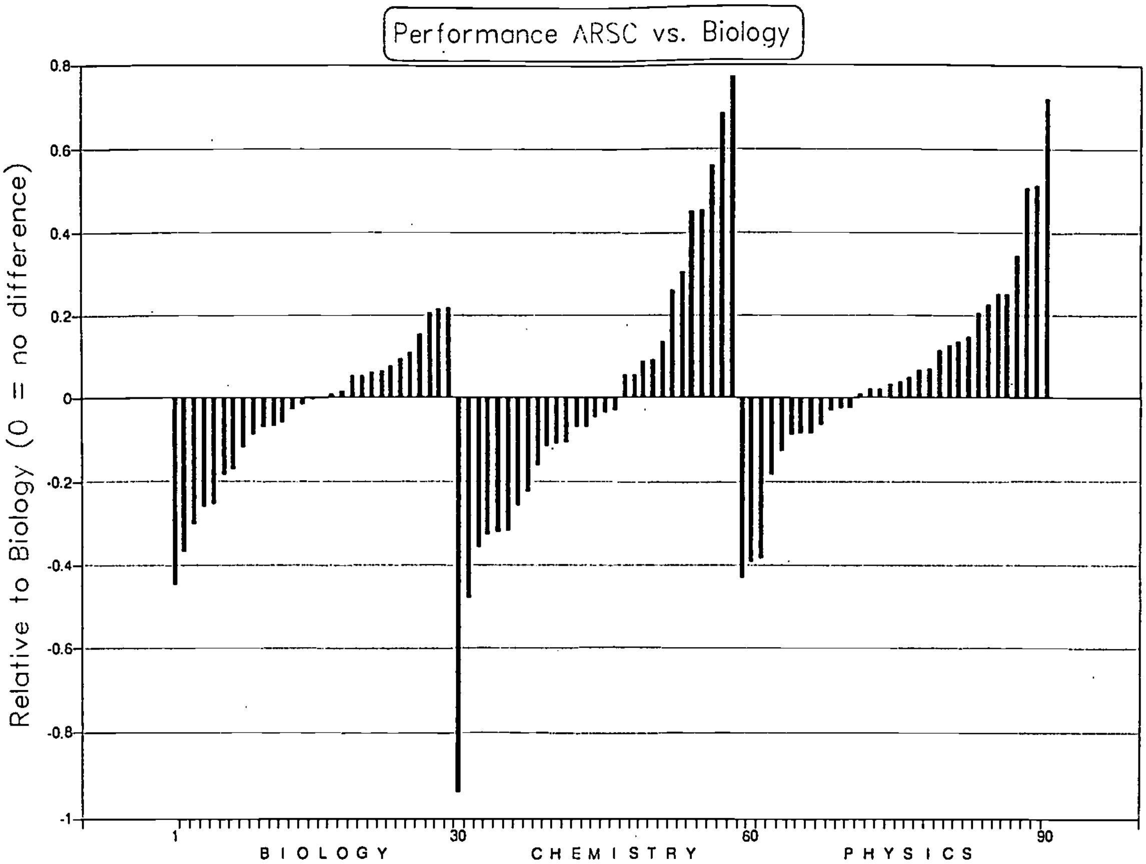




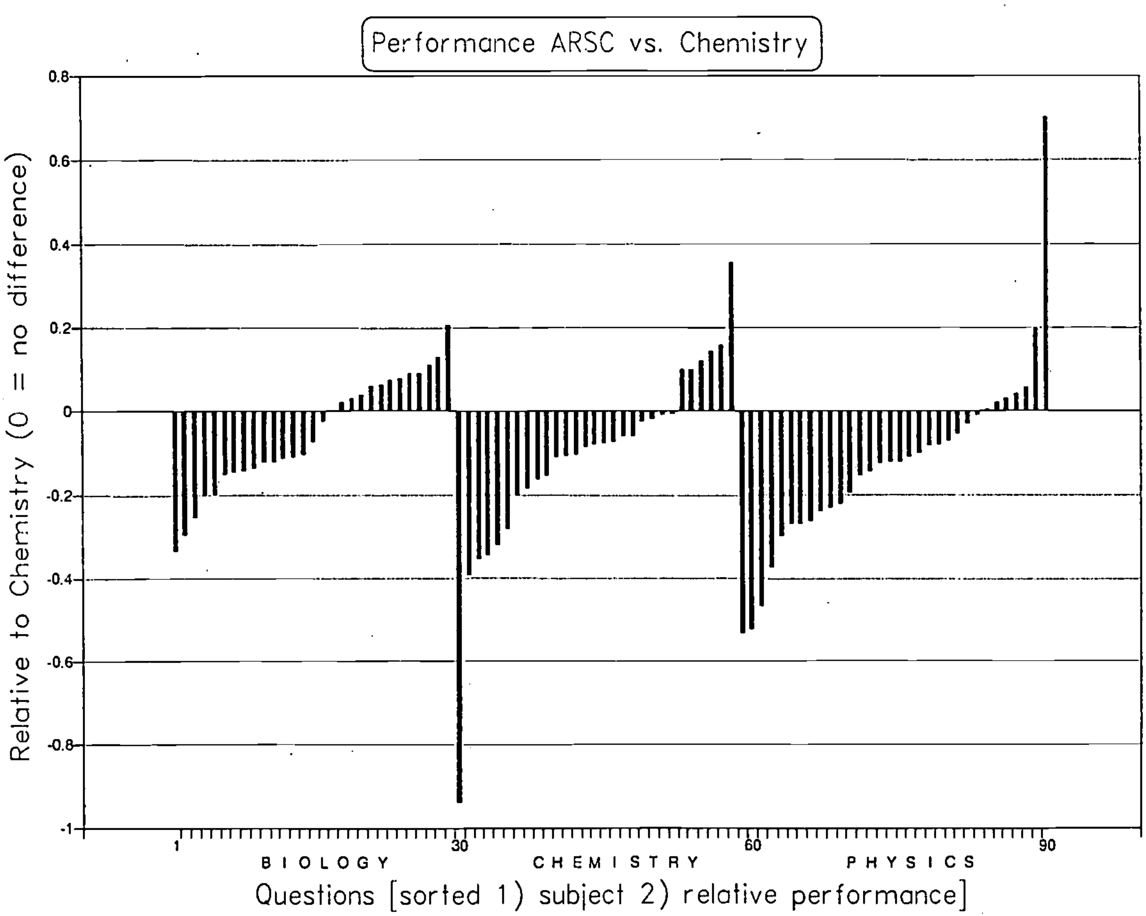




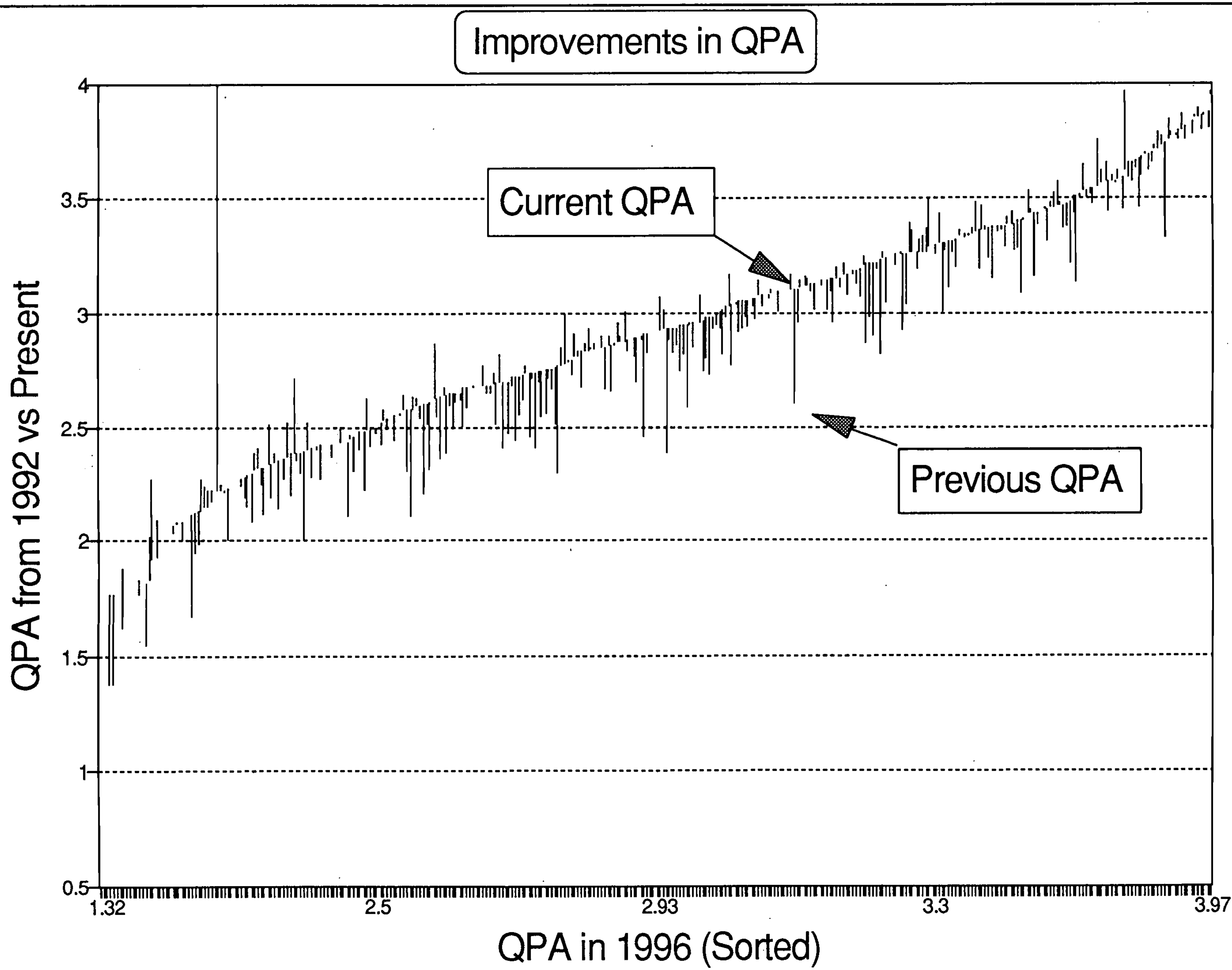
PANELS I & II COMBINED



Performance ARSC vs. Biology
Relative to Biology (0 = no difference)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
30
60
90
B I O L O G Y
C H E M I S T R Y
P H Y S I C S



Performance ARSC vs. Chemistry
Relative to Chemistry (0 = no difference)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
30
60
90
B I O L O G Y
C H E M I S T R Y
P H Y S I C S
Questions [sorted 1) subject 2) relative performance]


Improvements in QPA
Current QPA
Previous QPA
QPA from 1992 vs Present
4
3.5
3
2.5
2
1.5
1
0.5
1.32
2.5
2.93
3.3
3.97
QPA in 1996 (Sorted)

Appendix II. Course syllabi for the recent offerings of ARSC 10/11.

The content of the course and the respective reading and examination schedules for both semesters is included. Detailed study and learning keys, lecture outlines, and laboratory activities have been developed and are available for extramural use, as desired. These materials will be undergoing additional improvements and changes to reflect student input and continued problems in concept comprehension.

ARSC 010 - Schedule - Fall 1995

Day	Ch.	Topics & Assignments
Mon. Aug. 28	1	Introduction to the course. The scientific method.
Wed. Aug. 30	1	Pseudoscience. The organization of science.
Fri. Sept. 1	2	Observations of the sky.
Mon. Sept. 4		Labor Day. No class.
Wed. Sept. 6	2	The development of astronomy. **First microtheme assigned.**
Fri. Sept. 8	2	The birth of mechanics.
Mon. Sept. 11	2	Newton's laws of motion and gravitation.
Wed. Sept. 13	3	Work and power. **First microtheme due.**
Fri. Sept. 15	3	Mechanical energy and its conservation.
Mon. Sept. 18	3	Heat and conservation of energy.
Wed. Sept. 20		Test 1. Chs. 1 - 3
Fri. Sept. 22	4	Heat and temperature, calorimetry.
Mon. Sept. 25	4	Heat transfer.
Wed. Sept. 27	4	The second law of thermodynamics.
Fri. Sept. 29	4	Entropy and disorder.
Mon. Oct. 2	5	Electricity and magnetism.
Wed. Oct. 4	5	Connections between electricity and magnetism. **Second microtheme assigned.**
Fri. Oct. 6	5	Electric circuits.
Mon. Oct. 9	6	The nature of waves.
Wed. Oct. 11	6	Sound and music. **Second microtheme due.**
Fri. Oct. 13	6	Light and the electromagnetic spectrum.
Mon. Oct. 16	6	Electromagnetic waves and matter.
Wed. Oct. 18		Test 2. Chs. 4 - 6
Fri. Oct. 20		No class.
Mon. Oct. 23	7	The atom in chemistry.

Wed. Oct. 25	7	Atomic spectra and atomic structure.
Fri. Oct. 27	7	The periodic table. **Third microtheme assigned.**
Mon. Oct. 30	8	The failure of classical physics.
Wed. Nov. 1		All Saints Day. No class.
Fri. Nov. 3	8	Wave-particle duality. **Third microtheme due.**
Mon. Nov. 6	9	The chemical bond.
Wed. Nov. 8	9	States of matter.
Fri. Nov. 10	9	Chemical reactions and the structure of molecules.
Mon. Nov. 13		Test 3. Chs. 7 - 9
Wed. Nov. 15	10	Mechanical properties of materials.
Fri. Nov. 17	10	Electrical properties of materials.
Mon. Nov. 20	10	Electronic devices.
Wed. Nov. 22 - Fri. Nov. 24		Thanksgiving. No class.
Mon. Nov. 27	11	The atomic nucleus. **Fourth microtheme assigned.**
Wed. Nov. 29	11	Radioactivity.
Fri. Dec. 1	11	Applications of nuclear properties.
Mon. Dec. 4	12	The elementary particles. **Fourth microtheme due.**
Wed. Dec. 6	12	The ultimate structure of matter.
Fri. Dec. 8		No class.
Thurs. Dec. 14		Final exam. 10:30 am - 12:30pm. Chs. 11 - 12 and semester review.

ARSC 011 - Schedule - Spring 1995

Day	Ch.	Lec.	Topics & Assignments
Mon. Jan. 15			Martin Luther King Day. No classes.
Wed. Jan. 17			Introduction and organization of the class.
Fri. Jan. 19	13	1	The search for the aether wind.
Mon. Jan. 22	13	2	The special theory of relativity.
Wed. Jan. 24	13	3	The special theory of relativity. **First microtheme assigned.**
Fri. Jan. 26	13	4	The principle of equivalence and general theory of relativity.
Mon. Jan. 29	14	5	A tour of the solar system.
Wed. Jan. 31	14	6	History of the solar system. **First microtheme due.**
Fri. Feb. 2	15	7	The structure of the earth.
Mon. Feb. 5	15	8	The changing crust of the earth.
Wed. Feb. 7			Test 1. Chs. 13 - 15., Lecs. 1 - 8
Fri. Feb. 9	16	9	The atmosphere.
Mon. Feb. 12	16	10	The oceans.
Wed. Feb. 14	16	11	The solid earth. **Second microtheme assigned.**
Fri. Feb. 16	17	12	The sun.
Mon. Feb. 19	17	13	Astronomical distances and the Hertzsprung-Russell diagram.
Wed. Feb. 21	17	14	Stellar evolution. **Second microtheme due.**
Fri. Feb. 23	18	15	Galaxies and the expansion of the universe.
Mon. Feb. 26	18	16	The structure and evolution of the universe.
Wed. Feb. 28			Test 2. Chs. 16 - 18, Lecs. 9 - 16
Fri. Mar. 1	19	17	Living things.
Mon. Mar. 4 - Fri. Mar. 8			Mid-semester break. No classes.
Mon. Mar. 11	20	18	The chemistry of organic molecules.

Wed. Mar. 13	20	19	Amino acids and proteins. **Third microtheme assigned.**
Fri. Mar. 15	20	20	Carbohydrates and nucleic acids.
Mon. Mar. 18	20	21	Fats and other materials.
Wed. Mar. 20	21	22	Cells. **Third microtheme due.**
Fri. Mar. 22	21	23	Metabolism.
Mon. Mar. 25	21	24	Cell division.
Wed. Mar. 27	22	25	The rules of genetics.
Fri. Mar. 29	22	26	Chromosomes, genes, and DNA.
Mon. Apr. 1	22	27	Applications of genetics.
Wed. Apr. 3			Test 3. Chs. 19 - 22, Lecs. 17 - 27.
Fri. Apr. 5 - Mon. Apr. 8			Easter break. No class.
Wed. Apr. 10	23	28	Arguments for evolution.
Fri. Apr. 12	23	29	The theory of natural selection..
Mon. Apr. 15	23	30	Genetics and evolution.
Wed. Apr. 17	23	31	Modern evolutionary theories. **Fourth microtheme assigned.**
Fri. Apr. 19	24	32	The structures of plants and animals.
Mon. Apr. 22	24	33	Walking, running, swimming, and flying.
Wed. Apr. 24	24	34	Energy and living things. **Fourth microtheme due.**
Fri. Apr. 26	24	35	The senses.
Mon. Apr. 29	25	36	Ecosystems.
Wed. May. 1	25	37	The flow of energy and matter.
Fri. May 3	25	38	The earth as an ecosystem.
Mon. May 6			Final exam. 8:00 - 10:00 am. Chs. 23 - 25, Lecs. 28 - 38

Appendix III. Pre/posttest results 1992-1995.

The questions for the pre and posttests for the years of the F.I.P.S.E. program are given along with the changes in the fraction answered correctly in each of the funded years. The presentation of the questions is based on averages for the most recent year, which would given an indication of subject areas where students are exhibiting the current degree of scientific literacy. An approximate trend has been calculated from the averages of the respective years tested. Year to year variation in examination responses has been noted and the reasons for the variance is not known. The test was also administered in all years but for simplicity of presentation these results are not included in these data.

SORT KEY
*

Question	Q#	Subject	Semester	AVG	1992	95/96	95-92	Trend
A plant would primarily use phosphates to make:	10	Biology	Fall	21.82	26.19	12.37	-13.8	-1
The gas whose properties are likely to contribute most to global warming	15	Biology	Spring	10.84	3.77	12.50	8.7	3
Muscular contraction is best understood in terms of reactions that	13	Biology	Fall	15.93	3.64	12.50	8.9	10
One major reason for your choice in question #25 , is	26	Biology	Spring	16.72	20.75	14.29	-6.5	-3
The following data on weight gain of a certain kind of fish were obtained when the fish were grown outdoors at various controlled temperatures for one month:	43	Biology	Spring	22.24	24.53	15.46	-9.1	-2
Living systems need chemical energy for performing work at the molecular level. In	2	Biology	Fall	50.22	61.11	16.49	-44.6	-9
Most higher animals and plants have tissues with a DNA content that is	11	Biology	Spring	24.05	26.42	17.53	-8.9	-5
Nerve cells transmit signals from one end of a cell to the other	27	Biology	Spring	25.53	22.64	19.79	-2.8	0
(Salmon hatch) How does the chemical composition of the water vary from one site to another?	45	Biology	Spring	41.49	45.28	21.59	-23.7	0
If you are told that biological systems can respond to picomolar (10^{-12} M) amounts of substances, then you would most likely conclude that:	8	Biology	Spring	27.50	20.75	22.68	1.9	-1
Given our current understanding of natural history, the future evolution of species on this planet will probably	25	Biology	Spring	29.06	35.85	23.47	-12.4	-4

Which of the following statement best describes the pathways of nutrients and energy in the biosphere (the global ecosystem of atmosphere, soil, water, and living organisms)?	21	Biology	Spring	34.10	22.64	23.47	0.8	2
Which of the following symbols might best represent photosynthesis and respiration?	11	Biology	Fall	33.27	32.69	23.71	-9.0	5
Which one of the following is likely to provide the best criterion for a species classification ?	24	Biology	Spring	35.93	30.19	27.84	-2.4	-4
Vitamins are necessary :	8	Biology	Fall	47.89	68.63	28.87	-39.8	-8
Methane, CH_4, that is released to the atmosphere comes primarily from	17	Biology	Spring	40.10	32.08	28.87	-3.2	-7
Microbial life flourishes when excess phosphate (as $Na_3(PO_4)$ containing detergents are released into lakes and streams because:	7	Biology	Spring	21.85	18.87	29.59	10.7	0
No organism can live in the absence of oxygen.	3	Biology	Fall	41.76	38.18	31.25	-6.9	-1
Most people can swim 15 meters or more underwater in a single breath. This feat	44	Biology	Fall	53.85	76.36	31.58	-44.8	-12
The ability of a species to interact selectively with its environment is largely determined by:	23	Biology	Spring	34.64	33.96	32.65	-1.3	-3
A mutation is best defined as:	29	Biology	Spring	45.49	26.42	35.71	9.3	3
The human sensory system	28	Biology	Spring	48.02	30.19	35.71	5.5	-3
An ecosystem consists of	13	Biology	Spring	55.45	56.60	41.24	-15.4	-10

Imagine two cells with the same spherical shape. The diameter of one is twice the diameter of the other. The cells' abilities to get rid of wastes versus their abilities to produce wastes can be given five possible choices.	22	Biology	Spring	50.52	64.15	41.84	-22.3	-1
A toxin is a substance that	12	Biology	Fall	60.48	5.45	46.88	41.4	32
Amino acids are primarily used by living systems to make:	9	Biology	Fall	85.14	80.77	48.96	-31.8	1
Anaerobic processes are those that occur	16	Biology	Spring	60.55	83.02	53.06	-30.0	-10
Radiation from any source can have a deleterious effect on human cells.	20	Biology	Spring	59.59	81.13	61.22	-19.9	-8
When sugar is metabolized, energy is released.	31	Biology	Fall	77.54	83.64	70.83	-12.8	-8
The earth's atomsphere has not changed over time.	18	Chemistry	Spring	27.35	5.66	6.19	0.5	1
What is the difference between burning and combustion?	21	Chemistry	Fall	24.64	21.82	14.43	-7.4	1
On the temperature scale below, the following are approximately indicated as letters	45	Chemistry	Fall	32.72	51.02	17.53	-33.5	-12
An atom of hydrogen has a mass of about 1.6×10^{-24} g, what will be the mass of 200 atoms of	23	Chemistry	Fall	52.41	47.27	22.11	-25.2	-1
The formula of the compound formed between aluminum, Al, and oxygen, O_2,	14	Chemistry	Spring	30.48	37.74	23.47	-14.3	-8
The same amount of energy is released when 1 gram sugar is combusted	32	Chemistry	Fall	40.95	34.55	25.00	-9.5	3
The density of aluminum, Al, is 2.7 g/cm3, what volume will 5.4 g of Al occupy?	34	Chemistry	Fall	36.40	10.91	27.08	16.2	14

The principles required for valid and accurate measurements with a mercury (liquid)	1	Chemistry	Fall	41.76	30.91	30.21	-0.7	3
There is more oxygen than nitrogen in our atmosphere.	35	Chemistry	Fall	57.53	51.85	35.42	-16.4	1
In a typical fireworks display the color that is rendered least vividly is	28	Chemistry	Fall	58.45	60.00	36.08	-23.9	-1
Chlorofluorocarbons, CFCs, are used as:	2	Chemistry	Spring	49.46	35.85	38.78	2.9	-12
Energy (in physical sense, such as light, electricity) can be converted into chemical energy	7	Chemistry	Fall	62.00	61.11	40.63	-20.5	1
A solution is acidic if it has a pH	5	Chemistry	Spring	46.44	41.51	45.36	3.9	-10
Buffer solutions control	12	Chemistry	Spring	34.47	41.51	46.94	5.4	-16
The key property of chemical reactivity is determined by an element's	17	Chemistry	Fall	61.90	78.18	47.92	-30.3	-12
20 balloons (newly made of latex), containing about 50 ml of water, are inflated with air and confirmed not to have any leaks. 10 of the balloons are filled with air, the other 10 with CO_2. Two days later you find that all the CO_2 filled	44	Chemistry	Spring	33.73	1.89	47.96	46.1	13
All atoms of carbon contain 5 protons.	38	Chemistry	Fall	60.87	63.64	50.00	-13.6	-1
A pure chemical substance may be produced by either a biological process or chemical	40	Chemistry	Fall	66.30	78.18	52.63	-25.6	-9
Gases will expand/contract	3	Chemistry	Spring	55.29	77.36	56.12	-21.2	-11
Diamond and graphite are both forms of carbon.	39	Chemistry	Fall	86.03	98.18	63.92	-34.3	-8

Burning is an oxidative process.	29	Chemistry	Fall	77.48	81.82	67.01	-14.8	-4
Zinc, Zn, is a metal.	33	Chemistry	Fall	89.38	96.36	71.58	-24.8	-6
When sugar is combusted, energy is released.	30	Chemistry	Fall	89.25	94.55	75.26	-19.3	-6
All molecules consist of atoms in some specific arrangement.	25	Chemistry	Fall	83.88	87.27	75.26	-12.0	-5
Any atom is larger than the eye of a needle.	24	Chemistry	Fall	89.38	96.36	77.08	-19.3	-7
Chlorine, Cl, is a metal.	37	Chemistry	Fall	87.44	92.73	78.35	-14.4	-3
The weathering of rocks, i.e., their breakup, occurs by the action of	6	Geology	Spring	23.98	22.64	6.32	-16.3	-2
The earth consists of the mantle, the core, and the crust. The mantle is	4	Geology	Spring	65.73	88.68	50.52	-38.2	-9
Earthquakes, mountains, and volcanoes have all been formed by processes that begin deep within the earth.	1	Geology	Spring	86.16	96.23	86.73	-9.5	-4
Which of the following diagrams best approximates where gravity acts on a horizontal	42	Physics	Fall	82.42	72.73	4.26	-68.5	4
From the following curve, the velocity of the object is: (ft=foot)	16	Physics	Fall	45.97	14.55	7.29	-7.3	17
Which of the following statements about nuclear fission reactions is characteristic of nuclear reactors but not of bombs?	41	Physics	Spring	18.15	13.21	13.54	0.3	-4
Which of the following statements about x-rays is false?	31	Physics	Spring	35.85	16.98	16.33	-0.7	-1

According to current theory, except for hydrogen and helium, the elements were	36	Physics	Spring	24.63	18.87	21.43	2.6	1
If an unstable nucleus has too many neutrons it is most likely to decay by	39	Physics	Spring	24.44	9.43	21.65	12.2	-12
The three most important elements in fertilizers are	19	Physics	Spring	32.09	30.19	22.45	-7.7	-5
The nucleus of Np decays by alpha emission. The resulting nucleus	38	Physics	Spring	29.33	5.66	23.71	18.1	-7
A chain reaction will start in a fissionable material, such as U or Pu, if	40	Physics	Spring	34.17	11.32	24.49	13.2	3
Which of the following kinds of radioactive emission are the nuclei of helium atoms?	34	Physics	Spring	32.99	15.09	24.49	9.4	-15
The mass of a single nucleus is slightly less than the sum of the masses of the protons and neutrons that make up the nucleus. This is because	35	Physics	Spring	35.25	15.09	25.00	9.9	0
The main energy change within an electric iron is	37	Physics	Spring	44.61	64.15	27.08	-37.1	-12
Light travels as :	5	Physics	Fall	56.41	50.91	28.13	-22.8	2
In which of the following power sources is hydrogen converted into helium?	10	Physics	Spring	29.04	33.96	30.53	-3.4	-4
Which of the following best illustrates the shape of a string holding a kite?	43	Physics	Fall	54.58	47.27	33.33	-13.9	5
Suppose you start out with 2 pounds of a radioactive material and at end of two years have 1/2 pound of it left. What is its half life?	42	Physics	Spring	46.12	32.08	40.82	8.7	-1

One of the chief difficulties to utilizing direct solar power is that, although the total amount of power falling on the earth is large, the amount of power falling on a square mater is small and hence a very large area collector is needed.	32	Physics	Spring	52.38	62.26	41.84	-20.4	-11
One means of power generation is nuclear fission. Fission is	9	Physics	Spring	47.50	45.28	43.30	-2.0	-11
Visible light differs from other types of electromagnetic radiation in that	4	Physics	Fall	80.95	83.64	52.58	-31.1	-6
A typical household circuit has a 15 amp. circuit breaker or fuse. This means that the circuit breaker or fuse will be inactivated at	30	Physics	Spring	63.92	52.83	53.06	0.2	-3
By following the best practices for disposal of radioactive wastes, the present nuclear installations have prevented any danger from radioactivity.	33	Physics	Spring	77.97	83.02	57.14	-25.9	-9
Visible light originates from	6	Physics	Fall	71.43	72.73	57.73	-15.0	-2
When you exert a force on an object, the object exerts a force on you. a) true b) false	15	Physics	Fall	86.45	90.91	65.63	-25.3	-4
The momentum of a body is determined by	14	Physics	Fall	71.43	18.18	68.04	49.9	32
The mass of an object is invariant, i.e., it is the same wherever it is measured,	36	Physics	Fall	83.72	90.91	69.07	-21.8	-6
Heat and light are both forms of energy.	26	Physics	Fall	91.93	98.15	77.08	-21.1	-5
As used as a verb, "to heat" means:	27	Science	Fall	51.28	58.18	27.84	-30.3	-3
A key feature of all living systems is that	18	Science	Fall	50.36	36.36	29.90	-6.5	11

The word "because" is used to represent the connection between:	20	Science	Fall	50.18	50.91	42.27	-8.6	1
The gasoline consumption of one car is 15 Kilometers per Liter while another is measured	41	Science	Fall	71.69	72.73	52.58	-20.1	-1
Science may be defined or identified as	19	Science	Fall	57.01	64.81	54.64	-10.2	-4
There are 12 classrooms, each with a capacity of 30 students, how many students will these	22	Science	Fall	87.55	100.00	63.92	-36.1	-10

NOTICE

REPRODUCTION BASIS

☐ This document is covered by a signed "Reproduction Release (Blanket)" form (on file within the ERIC system), encompassing all or classes of documents from its source organization and, therefore, does not require a "Specific Document" Release form.

☑ This document is Federally-funded, or carries its own permission to reproduce, or is otherwise in the public domain and, therefore, may be reproduced by ERIC without a signed Reproduction Release form (either "Specific Document" or "Blanket").