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Abstract Approved:
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This study investigated the relationship between safety knowledge and student perceptions of classroom-laboratory safety practices of secondary school science teachers.

Two data-collecting instruments were developed: (a) *Teacher Knowledge of Laboratory Safety* (T-KOLS), and (b) *Student Perception of Laboratory Safety* (S-POLS). Each instrument consisted of one hundred objectively scored items divided into ten safety areas. An *Instructor's Resource Guide* prepared by the Council of State Science Supervisors (CS^3) in conjunction with the National Institute for Occupational Safety and Health provided criteria for the safety areas and topics.

A three-round Delphi exercise was conducted to ensure content validity, provide feedback on the test items, and the *best* response alternatives. Over forty members of the Delphi panel consisting of CS^3 members, science educators and safety professionals responded to each round.

Independent pilot studies were conducted on each instrument prior to field testing in the State of Oregon. Cluster sampling was used to provide a population of 145 science teachers who responded to T-KOLS. S-POLS was administered to 8003 students in 372 science classes taught by the teachers.

Spearman-Brown full test split-half reliability coefficients of .64 and .77 were obtained for T-KOLS and S-POLS respectively.

Correlation coefficients for matched T-KOLS and S-POLS scores were not significant ($P<.10$) and failed to refute the study hypothesis of no relationship between teachers safety knowledge and student perceptions of the teachers' classroom laboratory safety practices. Significant differences between the knowledge and practice scores obtained by application of a paired *t*-test further supported these findings.

Significant ($P<.10$) F-ratios between mean T-KOLS scores and self-reported safety-related demographic factors were found for (*a*) amount of safety instruction in college science courses, (*b*) amount of in-service safety instruction, (*c*) amount of personal reading related to safety, (*d*) years of teaching experience and (*e*) size of school system. Three demographic factors, (*a*) amount of personal safety reading, (*b*) number of teacher accidents and (*c*) teaching specialty, were found to produce significant F-ratios using mean S-POLS scores.

Some parallel was shown between these findings and those reported by other investigators. The findings have implications for the safety training needs of science teachers.

STUDY OF THE RELATIONSHIP BETWEEN SAFETY KNOWLEDGE AND STUDENT PERCEPTION OF SAFETY PRACTICES OF SECONDARY SCHOOL SCIENCE TEACHERS

by

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Preface

A fatal accident on the 7th November 1973 in a secondary school science classroom-laboratory in Brisbane, Australia, inadvertently inspired this study. At that time, the science teaching community was stunned by the death of a student and his twenty-one year old teacher during a laboratory demonstration. Of thirteen boys in the classroom at the time of the accident, only one escaped without injury. One of the injured boys lost one hand and half of the other in the explosion. An ambulance driver with ten years of experience described the incident as *the worst they had seen*.

What had started out as a routine laboratory exercise, possibly designed to stimulate the interest of pupils in the concepts of laboratory science, turned into a holocaust as the *makings* of a rocket exploded during packing. At the subsequent inquest into the cause of the tragedy the coroner indicated that apparently the teacher was unaware of the potential danger of using the chemicals potassium chlorate and sulfur in the manner in which they had been used.

As acting science subject mistress in a neighboring Brisbane high school at the time of the incident, I along with fellow science teachers and administrators, sought answers that would prevent the re-occurrence of such a disaster. The science curriculum in Brisbane in 1973 included courses of study developed in the United States in addition to Australian versions of *hands on* laboratory activities inspired by the American curriculum writers of the sixties. For this reason, it was naively assumed that the answers sought in relation to laboratory safety would be found in the United States. As the Introduction to the present study will show, this was found not to be the case.

At this time I applied for, and was granted, a one year leave of absence by the Queensland Department of Education in order to pursue graduate studies in the United States. At the end of 1974 with a Master's degree in Science Education but few answers forth-coming regarding the concepts of laboratory safety, I resigned from my position in Brisbane and commenced a doctoral program that would include research in the area of laboratory safety. A proposal was submitted to the National Safety Council in 1975 (through the Department of Science Education at Oregon State University) for the Howard Pyle Safety Award. Had this been successful the proceeds were to have been used for the preparation of science safety materials. The fact that an award was not granted for this purpose possibly points to the low priority held by most safety experts at this time regarding the urgency of a safety program for secondary school science teachers.

During this period, however, the efforts of Franklin Kizer, former Science Specialist in the state of Virginia and presently Executive Secretary of the Council of State Science Supervisors, were more successful. The suggested in-service training program for science teachers described in this study was without a doubt the result of his personal endeavors. Co-operatively developed by the Council of State Science Supervisors (CS^3) and the National Institute for Occupational Safety and Health (NIOSH) the resulting Instructor's Resource Guide was the first real indication that laboratory safety in the science classroom should be a necessary part of science teacher education. Plans for in-service workshops were undertaken in many states in response to this publication, and it is gratifying to know that efforts are still continuing in this direction.

Following publication of this Guide, the next step appeared to be the development of some means of teacher evaluation, and the fulfillment of this phase of the work is incorporated in the present study. In this regard, it was only through the untiring efforts of Ray Thiess (Science Specialist, Oregon State Department of Education) and N.J. Berberich Jr. (National Institute for Occupational Safety and Health) that the present project was initiated and reached final fruition. In this endeavor, an incredible number of man-hours went into the refinement of instruments by members of the three groups serving on the Delphi panel. In some cases individual contributions of time and energy must have encroached heavily on personal time.

The interest of science teachers in the project was apparent from the voluntary involvement of so many both in review of preliminary materials and participation in pilot studies. Teachers in classrooms both here and overseas have repeatedly expressed the need for information consistent with a safe and productive laboratory program. It is vital that such safety information be made available to all practicing science teachers and their supervisors and that these materials be continually up-dated to enhance their usefulness.

It is my sincere hope that the efforts involved by so many in bringing the concepts of laboratory safety in school science to the fore will not have been in vain. Much work still remains to be done in this direction. Records show that lives and man-hours are unnecessarily lost in industrial accidents. In both the professional and home environment disabling accidents are reported with startling regularity. Quite apart from the need to maintain a safe school laboratory, the subject area diversity of the science classroom provides one of the most appropriate venues for students to learn those safety concepts that are basic to their future needs--whether in industry, the research laboratory or the home.

In retrospect..... for a teacher to live to face his students after an accident such as that described above would be intolerable. Ironically, the responsibility for such a tragedy does not rest with the single individual involved, but must be shared equally by all science educators. It is my earnest plea that the death of this young teacher--and others killed or maimed in similar manner--will not have been in vain, and that efforts to improve the safety of science instruction will continue without abate.

STUDY OF THE RELATIONSHIP BETWEEN SAFETY KNOWLEDGE AND STUDENT PERCEPTION OF SAFETY PRACTICES OF SECONDARY SCHOOL SCIENCE TEACHERS

CHAPTER I

INTRODUCTION

> No cause, not even the highest and purest, can prosper in our day without making education its ally.
>
> Horace Mann.

These words, spoken in 1857, were carried in the *Foreward* to the *Eighteenth Yearbook of the American Association of School Administrators* (1940). This volume was devoted entirely to safety, and is recognized as an important milestone in the Safety Education movement. The school safety program serves a vital function to society, and the words spoken by Horace Mann convey an important message. The growth of safety education has paralleled the needs of an industrialized nation; to keep abreast of present technological progress it must continue to be assessed and modified to meet the needs of modern schools.

This study deals with safety in science education. It is concerned specifically with the safety knowledge of secondary science teachers, and student perceptions of safety practices in the science classroom-laboratory. *Chapter I* provides a brief account of the history of safety education and its neglected role in the school science laboratory. A discussion of the need for such a study, statements of hypotheses to be tested, working definitions, and an outline of the research design follow.

Safety Education

The school safety movement began in the 1920's. Prior to that time, some safety had been taught in the early schools and was integrated into books like the *McGuffey Readers* (Seaton, Stack and Loft 1969). The increase in child fatalities resulting from the revolutionary change in transportation first alerted educators to the need for a school safety program, and as early as 1913 the Safety Scouts were organized in Tacoma, Washington, to protect pupil pedestrians at school crossings (Stack, Siebrecht and Elkow 1949).

Financial support for school safety activities was first obtained through the efforts of Albert W. Whitney, a recognized leader in the safety education movement. In 1922, the Education Division of the National Safety Council was organized. Under the leadership of E. George Payne and a committee of prominent educators (including Harold Rugg, Zenos O. Scott, Ellwood P. Cubberley) the elementary school safety program expanded rapidly (Stack *et al.* 1949).

Secondary school safety programs did not develop until the introduction of driver education and training. In 1935 the National Safety Council issued the first driving instruction manual. Stack *et al.* (1949) write:

> Experimental work indicated that the high school student's interest in accident prevention was to a great extent the interest of an adult, and that the subject might best be introduced through such courses as civics, sociology, chemistry, and home economics. Physical education and organized games and sports offered an excellent approach, particularly when studies began to reveal the high incidence of injuries in these activities. (p. 10)

Safety training courses for teachers were first established at Teachers College, Columbia University, and at George Peabody Teachers College in Nashville in the summer of 1928 (Stack *et al.* 1949). In most institutions today, it has become traditional for safety education, including driver education and first aid, to be offered through the Department of Health and Physical Education. Unfortunately, most safety education courses and related textbooks are comprehensive, and do not include information for teachers in specialized subject areas such as vocational or science education.

Typically, education departments leave the safety training of science teachers to the disciplines concerned, and for this reason make little mention of laboratory safety in subject area methods courses. Unfortunately, instructors in college science laboratories are typically not concerned with the problem of educating teachers in safety, and do little to prepare them for the rigors of the school science laboratory (Macomber 1961 and Young 1970).

According to Halsey (1961) the school has two legal and moral responsibilities with regard to accident prevention:

> . . . to keep the child safe in school and on the way to and from school within the limits of the school's primary purpose, . . . and, secondly, to guide the pupil in the development of attitudes, habits, knowledge, and skills necessary for him to live safely and protect others throughout his lifetime. (p. 199)

Furthermore, in the *Twenty-fifth Yearbook of the National Society for the Study of Education* (1926) the point was made that while safety involves an attitude of mind "it has also been shown to be partly knowledge and partly technique" (p. 352). Based on this precept, safety concepts must be integrated into school curricula and students trained in the safety practices applicable to the subject area concerned. Nowhere is this more vital than in the "hands on" and "practical" laboratory experiences of the science classroom.

The concept of safety inevitably touches many facets of human life. Not only can school and personal teacher liability litigation result from inadequate student supervision, but there are ethical and moral considerations bound within the broad concept of safety consciousness. An educator makes use of philosophy to develop his goals, his objectives, and the basic underlying principles that guide his work. Worick (1975) presents this view most succinctly in relation to safety when he observes:

> Through philosophy man searches for truth, for the reasons for things . . . . His philosophy of life cannot be separated from his philosophy of safety, since both have to do with his values. Man must understand and believe that he has a responsibility to himself and to others to preserve human life and resources. It is simply the right thing to do. (p. 1)

Safety in Relation to the School Science Program

Safety in the school science laboratory has long been a neglected issue. The reasons for this omission are difficult to comprehend in view of the technological age in which we live. Moreover, the advent of Sputnik in 1957 provided the impetus for the curriculum reform of the sixties with the resulting inquiry/discovery emphasis propounded by Bruner (Parker 1981). Along with the "Structure of the Disciplines" movement in education, the school science program underwent a rapid and far-reaching change with student hands-on laboratory activity becoming the major emphasis. Secondary science curriculum improvement projects in biology, physics and chemistry were developed with support from professional associations of scientists and funding by the National Science Foundation. Traditional science textbooks were restructured to bring them more in line with the "new thinking"; materials were developed to actively involve secondary school students in science investigation; and new programs emphasizing a "hands on" approach to learning were introduced into the elementary science classroom.

These new curricula materials were used in the United States and adapted for use overseas, with workshops in the new methodology often accompanying their adoptions by school districts. Teacher training in laboratory safety, however, was often lacking or incidental. The continued emphasis on a predominantly laboratory-based approach to science teaching began to alert science educators to the need for a safety program that would parallel the new modus operandi.

The only research which deals specifically with safety in the secondary school science laboratory is a study conducted by Brennan in 1971. Brennan (1971) cited as the need for his study the additional time spent in the laboratory, increased enrollments in biology, chemistry and physics between 1957 and 1965, and thus increased potential for laboratory accidents.

A manual and full-text computer search in 1976 by this investigator of publications indexed by The Educational Resources Information Center (ERIC), revealed that safety material was extremely limited. Approximately half of the forty publications referred primarily to secondary school science safety. The remainder typically referenced articles in the *Journal of Chemical Education,* a major source of material and information relating to chemical laboratories in industry and tertiery institutions. A small number of articles were specific to the secondary school.

The Occupational Safety and Health Act (OSHA) was adopted by Congress in December 1970 and signed into law early in 1971 (*The Science Teacher,* 1974). This Act was largely responsible for the present concern in all areas of safety. The National Institute for Occupational Safety and Health (NIOSH) was established within the Department of Health, Education and Welfare for the purpose of carrying out the research and educational functions provided under the Act. In 1977 NIOSH, in conjunction with the Council of State Science Supervisors (CS^3), published an *Instructor's Resource Guide* (IRG) dealing with *Safety in the School Science Laboratory.* This manual, which was distributed to the Departments of Education in each state of the United States, included the following safety training goals:

Year	Total Percentage of Secondary School Teachers to have Received Training
1977	1%
1978	5%
1979	25%
1980	75%
1981	90%
1982	100%

Although these goals have yet to be attained, the IRG engendered an increased interest in laboratory safety. As of 1980 safety manuals were prepared independently by several states (Virginia, Iowa, Vermont, North Carolina) to provide science teachers with safety information specific to the State Safety Regulations. In response to a general demand, a comprehensive safety manual was also developed and published by the National Science Teachers Association (Virkus ed. 1978).

Since 1976, articles dealing with science laboratory safety have been published more frequently in professional journals. It appears that the recommendations of science educators that teachers be provided more information regarding laboratory hazards and safe practices (Brennan 1971 and Mann 1978) are slowly being realized. One of the leaders in the safety movement in science education was Franklin D. Kizer, presently the Executive Secretary of the Council of State Science Supervisors. As the science specialist for Virginia from 1956 to 1979, he was instrumental in alerting science teachers to the safety hazards in school laboratories.[1]

Has safety awareness come too late? At the present time there appears to be a gradual return to a textbook-oriented approach to science instruction (Beisenhertz 1981). The need for safety in the science classroom-laboratory, however, remains unquestioned. The OSHA Act of 1970, in providing for the establish-

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[1] An article by Franklin D. Kizer entitled "Design for Safety" was published in September 1979 in the *Science Teacher*.

ment and enforcement of occupational safety and health standards in the nation's workplaces, covers the safety of teachers within school laboratories (*Science Teacher*, 1974). In many areas, State Acts reinforce the OSHA requirements[2] and in addition extend the coverage of the Act to include the safety of students within the schools (Oregon Department of Education, 1980).

Irrespective, therefore, of the decreased emphasis on laboratory science instruction at the present time, the concept of safety must continue to be an integral part of science education. In this respect, Brennan (1971) concludes his dissertation with the following caution:

> A teacher's responsibility is to the pupil in the classroom. In the case of the science teacher it is a moral obligation and a legal and professional responsibility to provide the pupil with a meaningful and safe education. The obligations and responsibilities of the science teacher are achieved through his academic, professional, and classroom training and practices. (p. 146)

The Need for this Study

In response to federal and state safety acts and an increasing awareness of the teacher's responsibility to provide a safe workspace for pupils, the Council of State Science Supervisors (CS^3) focused on laboratory safety. In 1977 CS^3 suggested an in-service training program on *Safety in the School Science Laboratory* which was developed by representatives of the Council in cooperation with the National Institute for Occupational Safety and Health (NIOSH). An *Instructor's Resource Guide* (U.S. Department of Health, Education and Welfare, 1977) outlining the proposed training program was subsequently prepared and made available to State Departments of Education throughout the country. At this time (1981) workshops

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[2] ORS 654.001 through 654.295 and 654.991 establish authority for the Oregon Safe Employment Act (OSEAct) to provide safe and healthful working conditions for every working man and woman in Oregon.

have already commenced in several states and plans are underway for their start in Oregon.

Prior to implementing any safety training program, an assessment of the science safety knowledge base of the prospective trainees is essential. The assessment might begin with the question "What do science teachers already know about safety practices that are recommended for the school laboratory?"

Coupled with teacher knowledge is the teacher's classroom-laboratory practices that pertain to safety. Students learn by example as well as by precept and upon leaving school take with them (for good or bad) the "safety consciousness" endowed them by their teachers. For this reason, student perceptions of classroom-laboratory practices of their instructors are of utmost importance.

A need for in-service safety training programs for science teachers assumes a relationship between safety knowledge and laboratory safety practices. Do teachers put into practice their knowledge regarding laboratory safety?

The Problem

The purpose of this study is to investigate the relationship, if any, between the laboratory safety knowledge and student perceptions of safety practices of secondary school (grade 7-12) science teachers. It is further concerned with relationships that may exist between selected demographic factors and both (*a*) teacher safety knowledge, and (*b*) student perceptions of classroom-laboratory safety practices.

Enabling Problems

No satisfactory data collecting instruments were available prior to the study. Therefore, this investigator faced the problem of developing data-collecting instruments to measure--

1. the science safety knowledge of secondary school

science teachers;

2. the science safety practices of secondary school science teachers as perceived by students.

Hypotheses to be Tested

The investigator's educational hypothesis is that the safety knowledge of science teachers is related to classroom-laboratory safety practices which, in turn, relate to pupil safety. It is also hypothesized that the safety knowledge and practices of science teachers are related to personal and demographic factors including amount and recency of safety instruction.

In order to test these educational hypotheses, the following research hypotheses are proposed:

$H_0 1$: There is no relationship between teacher safety knowledge and student perception of classroom-laboratory safety practices of Oregon secondary school science teachers.

$H_0 2$: There is no difference between the safety knowledge of Oregon secondary school science teachers based on--

1. amount of safety instruction;
2. recency of safety instruction;
3. the number of classroom-laboratory accidents;
4. years of teaching experience;
5. present science teaching specialty;
6. instructional level (Grades 7-9 or 9-12);
7. size of school system;
8. percentage of class time devoted to student *hands on* science activities.

$H_0 3$: There is no difference between the student perception of classroom-laboratory safety practices of Oregon secondary school science teachers based on--

1. amount of safety instruction;
2. recency of safety instruction;

3. the number of classroom-laboratory accidents;
4. years of teaching experience;
5. present science teaching specialty;
6. instructional level (Grades 7-9 or 9-12)
7. size of school system;
8. percentage of class time devoted to student *hands on* science activities.

Definition of Terms

In most cases the terminology used in this study is either self-explanatory, or has widespread use and understanding. However, certain terms and acronyms have been adopted for compactness and/or to avoid laborious repetition. Although included here for convenience, each is identified where first used within the text proper and periodically thereafter.

Teacher Knowledge of Laboratory Safety (T-KOLS)

An instrument developed by the Delphi method to obtain a measure of teacher safety knowledge for the purpose of this study.

Safety knowledge

Data obtained by administration of T-KOLS to teachers who participated in this study.

Student Perception of Laboratory Safety (S-POLS)

An instrument developed by the Delphi method to obtain a measure of classroom-laboratory safety practices of the teachers who participated in this study.

Safety practices

Data obtained by the administration of S-POLS to students in classes taught by teachers who participated in this study.

Student perception of laboratory safety

Teacher safety practice behaviors as perceived by students in their science classes.

Teacher Background Information form (T-info)

The instrument administered to obtain selected personal and demographic data about the teachers who participated in this study, and the school system in which they taught.

Student Background Information form (S-info)

A brief questionnaire to obtain information about classes taught by the participating teachers.

Safety Professionals (SaP)

Individuals other than education personnel who have recognized expertise in the area of safety.

Council of State Science Supervisors (CS^3)

A group comprising the Science Specialist(s) or Science Supervisor(s) from each State Department of Education in the Union.

Science Educators (SEd)

Teachers and higher education personnel engaged in (or previously engaged in) instruction in science education.

Delphi

"Delphi may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem" (Linstone and Turoff 1975). In this instance, the technique was used as a means of obtaining concensus regarding the structure of the two instruments developed for this study.

Delphi Panel

The panel was composed of three groups selected from members of CS^3, safety professionals and science educators.

Classroom-laboratory

A place where science students are engaged in *hands on* activities such as observations and experiments (Tamir 1977).

Instructor's Resource Guide (IRG)

This manual entitled *Safety in the School Science Laboratory* was cooperatively developed by representatives from the Council of State Science Supervisors (CS^3) and the National Institute for Occupational Safety and Health (NIOSH). Published by the U.S. Department of Health, Education and Welfare in August 1977, it comprises a suggested in-service training program for science teachers.

Assumptions

The following assumptions underlie this investigation:

1. Teacher knowledge of science safety practices recommended for the classroom-laboratory can be measured adequately by means of a paper and pencil instrument

2. Student perceptions of teacher safety practices in the classroom-laboratory are, when averaged, sufficiently valid for the purpose of this study

3. Student perceptions of teacher safety practices in the science laboratory-classroom can be measured adequately with a paper and pencil instrument

4. The Delphi method is a valid means to identify safety categories that are important for secondary school science teaching and to assess the appropriateness of specific items to measure teacher safety knowledge and student perceptions of teacher safety practices

Limitations

The study is limited by--

1. teacher-administrator selection of participating class groups;
2. cooperation of the teachers in (*a*) responding honestly to items on the knowledge instrument, (*b*) administering the student instrument, and (*c*) packaging of the instruments for return to the investigator;
3. the extent to which student perceptions of teacher safety practices constitute a valid measure of those practices;
4. time allocation for student groups to respond to items on the student instruments.

Delimitations

This study does not intend to--

1. make observations or draw conclusions about teacher safety knowledge or classroom-laboratory safety practices other than those revealed by the instruments prepared for this study;
2. evaluate the effectiveness of teachers as instructors of science;
3. evaluate science safety programs presently in use in individual classrooms, schools or school districts.

Importance of the Study

The importance of this study rests on the assumption that increased safety knowledge of teachers results in safer classroom-laboratories for the students they teach. If safety training is to be provided for teachers, it is important to assess the teachers' safety knowledge prior to and following training. Valid and reliable achievement tests are required for this purpose.

To know if increased safety knowledge does, in fact, result in more acceptable classroom-laboratory safety practices, the latter must be assessed. Thus, valid and reliable instruments are needed to assess teacher safety practices.

A test of teacher knowledge of laboratory safety and a student questionnaire to obtain a measure of safety practices of teachers are to be developed and field tested in the state of Oregon. Valid data pertaining to the safety knowledge and practice of science teachers would be important in making decisions regarding the need for and effectiveness of safety workshops for science teachers.

CHAPTER II

REVIEW OF THE LITERATURE

This review deals with theoretical considerations involved in the assessment of safety knowledge and classroom-laboratory safety practices of teachers. To this end, organization of the chapter centers on the following:

1. An identification of literature relating directly to safety in the school science laboratory

2. An overview of theoretical concepts relative to the design of instruments to assess teacher knowledge and practice

3. An examination of the Delphi Method and its applicability to educational research

4. An analysis of studies dealing with student perceptions of teacher behavior

Safety in the School Science Laboratory

The urgent need for continued research results from the fact that few studies have dealt with the subject of science safety in the school laboratory. A 1971 study by Brennan represents the most comprehensive investigation in this field. Macomber (1961) and Young (1970, 1972) surveyed accidents specific to chemistry teaching, while Mann (1969) and Stoddard (1973) researched safety at the elementary school level. An exhaustive search of the literature failed to identify other studies specifically concerned with the subject of safety in the school science laboratory.

Despite the dearth of research, a limited but excellent variety of informative publications dealing with laboratory safety are contained in the literature. As mentioned earlier, (p. 5), journal articles and other resources specific to science education were relatively sparse prior to the advent of the National Institute of Occupational Safety and Health and the preparation of the Instructor's Resource Guide on safety in 1977. Nevertheless, safety materials that were then available covered topics of importance to the science teacher and were both specific and comprehensive in nature.

A publication by the National Science Teachers' Association (NSTA) which enjoyed wide circulation was a bulletin by Irving (1966). Similarly, a comprehensive handbook relating to safe laboratory practices was prepared by Frederickson (1966) for the San Diego schools. The American Chemical Society has consistently published material relating to laboratory safety. Under the editorship of Norman V. Steere, papers originally appearing in the Journal of Chemical Education (1964-73) have been republished in three paperback volumes entitled *Safety in the Chemical Laboratory*. The contents of these and other publications referenced as Appendix D, were tapped as resource information in the preparation of instruments for the present study.

Brennan (1971) conducted a "normative descriptive survey" utilizing a two-part questionnaire to survey a sample of 450 practicing science teachers within the 50 states of the United States. Participant data identified (*a*) the types of accidents and the laboratory areas in which they occurred, (*b*) factors contributing to accidents in the laboratory, and (*c*) safety measures that the teachers rated as successful in reducing accidents. Data were also obtained on the relationship of laboratory accidents to various indirect factors such as subject area, safety programs, teaching experience, school enrollment and laboratory space.

Based on these data, Brennan concluded that safety programs and specific safety procedures were significant in reducing accidents in the laboratory. Accidents were found to be more prevalent in chemistry (0.16/pupil), than in biology (0.05/pupil) or physics (0.02/pupil). The highest frequency of occurrences was reported for activities using chemicals, followed in order by those involving dissection, animals, electricity, mechanical devices, bacteria, sterilization and radiation.

Brennan identified teachers with 10 years and 26-plus years of teacher experience as having the most accidents; the first year and 21-25 year group recorded the fewest. By comparison, Young (1972) in a survey restricted to chemistry teachers, found the highest frequency of accidents to occur within the first four years of teaching. He recorded a decline for teachers with 4-7 years of experience, followed by a rise between 8-19 years. A declining accident rate was shown for teachers with 20-plus years of experience. Young (1971) suggested a lack of experience by recent graduates as the reason for the high incidence of accidents during the first four years of teaching. Brennan's findings, which were not restricted to chemistry teachers alone, showed a gradual increase in accident occurrences for teachers with 1-10 years of experience; a decline between 11-25 years was followed by a substantial increase for teachers with more than 25 years of experience.

Brennan found that the relationship between the number of accidents and years of teaching experience, while not statistically significant, was an important factor in the case of chemistry teachers. No such relationship was found for biology and physics teachers. A significant relationship was established, however, between the number of years of teaching experience and the number of laboratory accidents reported by teachers who had not participated in safety programs. This was not true of the teachers who had participated in safety programs.

It was also shown by Brennan that teachers in schools with lower class enrollments, greater laboratory space, individual laboratory stations, and safety programs, reported fewer accidents than did their counterparts. Although not statistically significant, schools with enrollments of 1000-2000 students had the highest yearly average of accidents (9.32/school), while those with over 3000 students had the lowest (5.79/school).

Two surveys dealing with safety in high school chemistry laboratories were conducted by Young (1972) in the state of Illinois. The initial study, involving 203 members of the Illinois Chemistry Teachers Association, identified the most common laboratory accidents encountered by teachers during the 1968/69 school year. Data revealed that the following six common accidents or improper techniques accounted for the greatest number of injuries:

1. Burns from hot glass tubing or metal
2. Burns from acids and bases
3. Cuts from the improper handling of glass tubing
4. Improper heating of test tubes often resulting in flying objects
5. Returning of chemicals to the wrong reagent bottles, or the improper selection of chemicals
6. The improper testing of vapors
(Young 1970, p. A.836)

Young (1970) conducted a second more comprehensive survey in 1970 in order to correlate accident encounters with various demographic factors. In addition to the relationship between accident rate and teacher experience described earlier (p. 17), the data obtained from 90 chemistry teachers revealed: more than half the respondents to be unaware of facts concerning teacher liability; a lower accident rate in classrooms using CHEM study materials as compared to the traditional curriculum; a substantial rise in accidents with an increase in class size; a decrease in accidents with an increase in laboratory space; one major accident per 40/ students per year.

Data also showed that 65.3% of respondents reported at least one accident/class/week. This rate appeared to be substantially higher than the yearly average (3.80 accidents/class) reported by Brennan (1971) for chemistry teachers. However, differences in compilation and reporting of the data could account for some variation in these results.

Young (1973) found that although the frequency of accidents reported was not high, the injuries that resulted were sufficiently severe to warrant greater precaution. He emphasized that:

> The major reason for most of the senseless and sometimes serious high school laboratory accidents undoubtedly rests with the inadequate anticipation of the accidents by students and/or instructors alike. . . . The inadequacy of accident anticipation by instructors is the greatest problem as well as the most ridiculous one. (p. 33)

A survey of high school chemistry accidents in the state of California during 1955-1958 was reported by Macomber (1961). Although conducted prior to the implementation of the new science curricula of the sixties, this study is of interest for comparative purposes. Data derived from questionnaires returned from 81 public high school respondents revealed the following:

1. A recorded average of one major accident (serious/ moderately serious) per 182.46 students

2. A total of 168 laboratory accidents reported as 62% minor; 33% moderately serious; 5% serious

3. Nearly two-thirds of all accidents reported as "minor" in classes using standard laboratory manuals

4. "moderately serious"/"serious" injury resulted in the majority of accidents arising from student-prepared experiments

5. "moderately serious" injury resulted in over 50% of accidents arising from teacher-prepared experiments

6. "horse-play" accounted for 10% of 109 recorded accidents,

with "serious"/"moderately serious" injury resulting in the majority of cases

The major accident ratio reported by Macomber (one/182.46 students), was substantially lower than the one/40 student ratio recorded by Young (1970). Macomber also showed that accidents were more likely to occur with the capable but inquisitive student. All three secondary studies found the ratio of laboratory space to class size (or number of students) to be an important factor in accident prevention.

Macomber contended that poor laboratory techniques rather than hazards in manual direction were responsible for minor injuries. This factor of safety was not shown to operate and more severe injuries were recorded where experiments were prepared by teacher or student in lieu of the laboratory manual. The importance of written instructions with appropriate safety information is supported by a study referenced by Brennan (1971) relating to an investigation carried out by the National Education Association Commission on Safety Education. This study revealed that

> In four Virginia school districts studied, the one system using science texts with twice as much safety information in the books as the other three systems also had the lowest accident rate. (p. 42)

The need to provide the classroom teacher with adequate safety information is inherent in a study by Stoddard (1973) directed specifically toward selected elementary science programs. This researcher investigated the Codes, Laws and Safe Practices relative to teaching science in Washington State. The findings have since been published by the Office of the State Superintendent for Public Instruction.

The provision of adequate safety information is also embodied in a study by Mann (1969) who investigated the potential danger in twenty-two elementary science activities selected from textbooks used by classroom teachers and in teacher training classes.

Findings indicated that: (*a*) authors, classroom teachers and safety specialists applied essentially the same standards in ranking the selected activities on the basis of danger potential, (*b*) flammable and explosive activities were judged to be the most hazardous; in four cases special teacher understanding and precaution was advised, and (*c*) the selected potentially dangerous activities were found to be used more frequently and in greater variety as grade level increased (fourth through sixth).

Mann (1969) contended that evidence of interest in the study was apparent from both the high response rate and the amount of correspondence received from participants.

The common theme in all studies cited, both elementary and secondary, is the need for the science teacher to be both adequately informed and knowledgeable regarding the hazards involved in teaching laboratory science. Macomber (1961) in discussing the most significant item in a follow-up letter from teachers polled in his study, noted that "several said they finished their college chemistry courses with only vague ideas about the dangers involved in certain experiments or in the use of certain chemicals" (p. 368). This same point was reiterated by Young (1970)

> The instructor should have an adequate teaching background gained through 4 years of rigorous college training. . . . many universities offer programs of science teacher preparation that are far from sufficient. . . . When an instructor is graduated with a BS in Chemical Education he may have the "legal" requirements to teach chemistry at the high school level, but he may not be well versed in the practical aspects needed for his profession. (p. A.838)

Irrespective of the curricula offering, the instruction of science by its nature will always involve a certain percentage of practical activity. Theoretical knowledge in and of itself is not sufficient safety preparation for the science teacher--the literature makes this point very well.

Concepts of Instrument Design

A passage by Lord Kelvin introduces a volume on assessment and testing--

> When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind (Schofield 1972, p. 1).

This observation appears particularly relevant in the case of paper and pencil instruments so often used in educational research, which are measuring devices of a special kind. If these instruments are to possess both validity and reliability, their construction becomes synonymous with their intended use. The complexity of building measuring instruments is stressed by Travers (1978), who discourages the educational researcher from building his own testing devices. He argues that "the instrument that has already been used has numerous advantages over the new device just developed by the research worker" (p. 313). Travers considers only those instruments that "have survived the years of trial and use" to have adequate reliability. He stresses, ". . . the new instrument often has to be worked and reworked in order to obtain a level of reliability that is acceptable for any purpose" (1978, p. 313).

The importance placed on the reliability of a measuring device may well be moot, however, since according to Wesman (1952) " . . . there is no such thing as *the* reliability coefficient for a test. Like validity, reliability is specific to the group on which it is estimated." He further argues that " . . . the reliability coefficient will vary with the range of talent in the group, even though the accuracy of measurement is unchanged" (Wesman 1952, p. 3). And the type of consistency (of pupils over time, over forms of the instrument, within the instrument) is determined by the method used to calculate the reliability coefficient.

Nevertheless, the twin concepts of instrument validity and reliability represent a real concern to all bona fide researchers; achieving acceptable levels within the constraints of research logistics is often a difficult task. Unlike a study by Rubba and Anderson (1978) which dealt specifically with the development of an instrument, the majority of researchers attempt instrument construction in response to the needs of a specific study only. This practice is indicated by Renner, Abraham and Stafford (1976) who observed, in relation to a review of research in science education, that the studies under consideration "involved the development of instrumentation in order to collect pertinent data necessary for the proposed research" (p. 67). They summed up the section dealing with instrument development by concluding,

> Science education needs well standardized systems for all phases of evaluation in science education. These 'tools' are necessary for the progress of research in this field. The continued proliferation of instruments is a necessary evil until a battery of well developed, reliable, and valid instruments can be developed. A system for categorizing and storing these instruments for retrieval by researchers in the field is needed. (p. 69)

Unfortunately, in constructing appropriate instruments for use in many research studies, the investigator is hampered by a lack of valid and reliable measuring instruments in the interest area. Much has been written relative to general survey methods and the development of various types of information-gathering procedures, including oral and written questioning techniques. Also, the literature abounds with studies of "attitudes" and the development of likert-type instruments. Although instruments developed and used by previous researchers are a viable resource, they often do not provide valid data for the subjects and purpose of a given study.

If a valid data collecting device is not available, the researcher has little choice but to prepare, validate, and establish the reliability of one of his own. The most promising guidelines to follow in the development of "professional quality" educational tests, attitude measures, and rating scales are probably modern books on educational tests and measures. Evaluation specialists (Gronlund 1981; Ebel 1972; Bloom 1971) recommend the use of tests, self-reporting techniques and observational techniques as methods for obtaining data for evaluation. The achievement test is typically recommended for use in measuring knowledge and was selected as the means to measure teacher safety knowledge. A broad survey-type achievement test measures the extent of difference in general achievement, the goal of the safety knowledge test developed for this study. An objective test form is recommended to assure high scorer reliability and for ease in calculating other reliability estimates.

Although the personal interview provides an almost ideal method of obtaining self-report information from pupils, it is extremely time consuming and the information provided is not standardized from one person to another. "In the interests of both feasibility and greater comparability of results, the self-report inventory or questionnaire is commonly used . . . " (Gronlund, p. 468). The use of such an instrument assumes that the student is willing and able to report the requested information accurately.

Test item writing guidelines are commonly found in the literature and vary little in content. Dillman (1978) poses three questions that researchers must ask regarding test items:

> Will it obtain the desired kind of information?
> Is the question structured in an appropriate way?
> Is the precise wording satisfactory? (p. 117)

Impediments to good item writing offered by Popham (1978) include:

> Unclear directions
> Ambiguous statements
> Unintended clues
> Complicated syntax
> Difficult vocabulary (p. 46)

Gronlund (1981) and other evaluation specialists, are in good agreement on the characteristics of good objective test items, self-reporting inventory items and checklists. These include: (*a*) clear statements of specific actions, (*b*) statements of actions that represent common errors, and (*c*) statements as to whether a characteristic is present or absent.

Dillman (1978), writing mainly in relation to mail and telephone surveys, offers excellent guidelines of general application. In regard to the preparation of test items he cautions: use simple words; do not be vague; keep it short; be specific; do not talk down to respondents; avoid bias; avoid objectionable questions; do not be too specific; and avoid hypothetical questions. According to Dillman, questions the researcher should ask in regard to each test item include--

1. is the question too demanding?
2. is it a double question?
3. are the answer choices mutually exclusive?
4. have you assumed too much knowledge?
5. has too much been assumed about respondent behavior?
6. is the question technically accurate?
7. is an appropriate time referent provided?
8. can the responses be compared with existing information?
9. are the questions too cryptic?

An important phase in assessing the quality of an instrument being developed is the trial run. Travers (1978) emphasizes that the major function of the trial run is to "determine what is and what is not measurable in terms of available instruments or new instruments that it is feasible to develop" (p. 262). He adds that attempts to execute part of a planned investigation commonly demonstrate that the suggested procedure could not possibly yield results because of the crudeness of the measuring device, and states:

> The need for such preliminary trial runs to establish the meaningfulness of results as well as the feasibility of obtaining measurements of adequate accuracy has not been properly recognized by educational researchers (p. 262).

Dillman suggested that the preliminary trial instruments be submitted to the scrutiny of colleagues, potential "users" of the data, and people drawn from the sample population. He offers the following as guidelines in the evaluation of preliminary trial items:

> Is each of the questions measuring what it is intended to measure?
>
> Are all the words understood?
>
> Are questions interpreted similarly by all respondents?
>
> Does each close-ended question have an answer that applies to each respondent?
>
> Does the questionnaire create a positive impression, one that motivates people to answer it?
>
> Are questions answered correctly? (Are some missed, and do some elicit uninterpretable answers?)
>
> Does any aspect of the questionnaire suggest bias on the part of the researcher? (Dillman 1978, p. 156)

An important phase of the trial run, whether or not the instrument has been developed specifically for the research study in question, relates to an evaluation of the "package" to be used in data collection. Dillman contends that the preliminary test is designed to "test" the instrument as well as the items (p. 156) and stresses that every effort should be made to develop a product that looks "final." This may involve the correct ordering of items, and pages, administration guidelines, instrument description, appropriate answer sheets, sample packaging . . . and so forth.

Where data collection is dependent upon a test or questionnaire, that instrument becomes an important part of the study.

Whether it is a standardized test, a revised form, or a new creation, it still must--as emphasized by Travers (1978)--prove both "itself" and its "applicability" during the trial run. The phases involved in instrument construction have only been tapped in the foregoing section. The entire process is lengthy, with each successive draft eventually leading to the "final" form.

The Delphi Method

The Delphi technique was pioneered by the Rand Corporation in the early 1950's. In brief, it is (*a*) a method for structuring group communication in order to find a solution to a complex problem, and (*b*) a means of reaching concensus through the use of expert opinion (Linstone and Turoff 1975).

Cyphert and Grant (1971) summarize the advantages of the method:

> Traditionally, the method for achieving concensus is a round-table discussion among individuals who arrive at a group position. There are a number of objections to this procedure. The final position, usually a compromise, is often derived under the undue influence of certain psychological factors, such as specious persuasion by the group member with the greatest supposed authority or even merely the loudest voice, an unwillingness to abandon publicly expressed opinions, and the bandwagon effect of majority opinion. In contrast, with the Delphi Technique an attempt is made to overcome these factors by not bringing the participants together in one place and by not reporting individual opinions. This eliminates committee activity and replaces it with a carefully designed program of sequential interrogations (with questionnaires) interspersed with information and opinion feedback. (p. 272)

Application of Delphi can, therefore, be viewed as a form of "structured communication" in which there is provided some feedback of individual contributions of information and knowledge. The group view is later assessed and opportunity given for individuals to revise their initial input. Ideally, there is some degree of anonymity for the individuals concerned, a situation which is not possible where participants are interacting in group meetings on a face-to-face basis.

Linstone and Turoff (1975) stress that it is not the explicit nature of the application that determines the appropriatness of utilizing Delphi, but "the particular circumstances surrounding the necessarily associated group communication process." They provide examples of various properties of the application which may lead to the need for employing Delphi, including:

> The problem does not lend itself to precise analytical techniques but can benefit from subjective judgments on a collective basis
>
> The individuals needed to contribute to the examination of a broad or complex problem have no history of adequate communication and may represent diverse backgrounds with respect to experience or expertise
>
> More individuals are needed than can effectively interact in a face-to-face exchange
>
> Time and cost make frequent group meetings infeasible
>
> The heterogeneity of the participants must be preserved to assure validity of the results (p. 4)

In discussing pitfalls of Delphi, Linstone (1975) contends that "sloppy execution" may lie with either analyst or participant (p. 582). In the case of the former this may include:

1. Poor interaction between participant and analyst

2. Superficial analysis of responses

3. Excessive specificity or vagueness in formulating Delphi statements

4. Lack of imagination by the designer

Linstone (1975), in emphasizing the importance of the last item, stresses that a good designer must be able to (*a*) conceptualize different structures for examining the problem, (*b*) perceive how different individuals may view the same problem differently, and

(c) develop corresponding designs which allow these types of individuals the opportunity to make their inputs.

Sloppy execution on the part of respondents include an impatience to get the job over with; answers hastily given without much thought; obvious contradictions in responses. However, Linstone (1975) argues that ". . . here, too, the fault may lie with the designer" who may have ". . . created a seemingly endless questionnaire weighted down with trivial, superficially unrelated, or repetitious statements" (p. 583).

In the majority of Delphi studies, consensus is assumed to have been achieved when a certain percentage of the votes fall within a prescribed range. However, Scheibe, Skutsch and Schofer (1977) consider that a bimodal distribution, or a distribution which may flatten out and show no peak shape at all, is no less important. They state that considering that there is a strong natural tendency in the Delphi for opinion to centralize, resistance in the form of *unconsensual* distributions should be viewed with special interest. They continue:

> A measure which takes into account such variations from the norm is one that measures not consensus as such, but *stability* of the respondents' vote distribution curve over successive rounds of the Delphi. Because the interest lies in the opinion of the group rather than in that of individuals, this method is preferable to one that would measure the amount of change in each individual's vote between rounds. (p. 277).

The most common form of the Delphi process is the paper and pencil version commonly referred to as a "Delphi Exercise" or conventional Delphi. Briefly, this consists of a small monitor team which designs a questionnaire which is sent to a larger respondent group. The results are then returned and summarized by the monitor team and a new questionnaire compiled based on the initial responses. The respondent group is then given at least one opportunity to re-evaluate its original answers based on examination of the group responses (Linstone and Turoff 1975, p. 5).

A Delphi usually undergoes four distinct phases, which are summarized as follows:

Phase 1: Exploration of subject under discussion; each individual contributes additional information he feels pertinent to the issue.

Phase 2: Reaching an understanding of how the group views the issue-- whether members agree or disagree and so forth.

Phase 3: Exploring significant disagreement in an attempt to determine the underlying reasons for the differences.

Phase 4: Final evaluation when all previously gathered information has been initially analyzed and the evaluations fed back for consideration (Linstone and Turoff, pp. 5-6).

An educational study described by Cyphert and Gant (1971) closely parallels the above four phases. They provide the following generalizations based on their analysis:

> 1. Prospective participants must be made to feel that their response is valid so that they will take part.
> 2. The variation in agreement with the consensus rating on all goals by individuals ranged from less than 20% to agreement with 100% of the consensus ratings.
> 3. A bogus item . . . was initially rated below average. However, when the feedback was distorted to reflect a high ranking, the participants then rated the item considerably above average, although it was not among the 10 highest-ranked targets. The hypothesis that the technique can be used to mold opinion as well as to collect it was supported.
> 4. When respondents disagreed with the consensus rating of a goal, they tended to attribute the consensus to a group of which they were not a member.
> 5. Virtually all (99%) of the respondents' changes in opinion occurred on Questionnaire III which informed them of the first "consensus" reached by the group. With hindsight, one can seriously question the need for going beyond Questionnaire 3. . . .(p. 273).

Weaver (1971) cites one of the earliest uses of Delphi in educational thinking as being that of Helmer's study, which was incorporated as part of the 1965 Kettering project to elicit preference judgments from a panel of education experts and knowledgeable individuals in various fields related to education. In this study, the respondents were required to compile a list of preferred goals for possible federal funding. Weaver (1971) also references studies made by Cyphert and Gant (1970) and Anderson (1970), in which Delphi was used as an opinion questionnaire to obtain preference statements relating to education. These three studies differed from the original use of Delphi in that the respondents were required to focus on what they would like to see happen rather than forecasting what was likely to happen.

More recently, Marsh (1978) utilized the Delphi questionnaire technique to determine behavioral objectives that were consistent with the stated goals and aims of an exploratory program in career education for the junior high in electricity/electronics. A series of three questionnaires were sent to panelists to provide a sequentrial consensus of opinion. Two objectives on safety were identified and determined critical by the sixty-five participants representing twenty-nine states. Eighteen additional objectives were identified and judged to be important.

Simpson and Brown (1977) attempted to validate twenty-three basic competencies for teaching secondary school science which had been prepared under the sponsorship of the National Science Teachers Association. Thirty-person state panels representing secondary science teachers, science coordinators/supervisors and principals/superintendents were established in Colorado and Georgia. All panel members were recognized as leaders in their profession. Using a modification of the Delphi method, two Rounds were conducted. Panelists were initially invited to rank the original list of competencies and to add those they considered conspicuously absent from the list. Group item means and newly generated items were supplied in Round 2. Respondents were then required to re-examine the list and again rank the items, but were permitted to change their responses on the basis of the Round 1 feedback.

Delphi's versatility makes it an appealing tool to use when expert feedback is essential. Maximal success, however, depends to a large extent on the skill, ingenuity and creativity of the monitor team. Where this falls to the single individual the task would become insurmountable were it not for the wealth of information now available on a variety of Delphi studies. This includes investigations designed specifically to examine its methodology (Barnette, Danielson and Algozzine 1978).

The philosophical and methodological foundations of Delphi provide the validity for its use in the immediate study, basic to which are the

> . . . variety of ways and mechanisms in which men have chosen to locate the criteria which would supposedly "guarantee" our true and accurate understanding of the "content" of a communication act or acts (Mitroff and Turoff 1975, p. 18).

Although space does not allow further examination of this concept, it is fully explored by Mitroff and Turoff (1975) and reference is made to their comprehensive article.

Student Perceptions of Teacher Behavior

Student feedback in measurement and evaluation of school and university teaching is not new. Research concerning student rating of instruction in colleges and universities has become commonplace. Studies dealing with pupil assessment of student teacher competence are numerous. Investigations relating to student reactions to educational programs and perceptions of teacher behavior are referenced frequently in the literature.

Several researchers have examined student perceptions in the science classroom. Boger (1973) investigated student perception of chemistry. Others (Pogorski 1971 and McNeil 1971) examined student perceptions in relation to aspects of the Biological Sciences Curriculum Study (BSCS) program, while Jones and Blankenship (1972), Sagness (1970) and Ackerson (1970) used student checklists to provide data on science classroom activities.

For decades researchers have used student feedback as a valid source of information on teacher classroom behavior. O'Hanlon and Mortesen (1977) contend that "student evaluation of teachers," "self-evaluation" and "supervisor observations" are the most frequently used methods of teacher evaluation.

Early studies dealing largely with student feedback in relation to various teacher characteristics, showed relatively few conflicting results. Ratings of teachers/student-teachers by elementary/secondary school pupils were generally found to be reliable (Bryan 1937, Bowman 1934, Cook and Leeds 1947), un-affected by grades (Bowman 1934) and to show some relationship with teacher ratings made by other school personnel (Cook and Leeds 1947). Bryan (1937) reported a slight tendency for students receiving high grades to rate their teachers somewhat higher than students drawing lower grades, but indicated that there were exceptions to this. Tiedeman (1942) found pupils to be " . . . fairly consistent and reliable in their judgements of teacher characteristics" in identifying the kind of teacher students most preferred.

Boardman (1930) contended that while pupil and supervisor ratings did not correlate to a high degree, there was no evidence to suggest that a·low correlation was a valid criterion for judging the pupils' rankings. He theorized " . . . it may be that pupils possess knowledge of their teachers' efficiency which would be valuable to supervisors" (p. 446). Reed (1953) also reported a positive but insignificant relationship between teachers, administrators, and participating teachers, although consistency in rank order of schools was maintained in each case. Tenth grade students showed a trend toward higher ratings and eleventh grade students to lower ratings. The students generally rated the teachers higher, and the administrators rated the teachers lower, than the teachers rated themselves.

The halo effect was studied by Remmers (1934) who generalized that (*a*) "Reliable judgements of classroom traits of instructors can be obtained from both high school pupils and college students" and, (*b*) "It is probable that high school pupils will invest the practice teachers with less halo than college students will their instructors" (p. 630).

The subject of pupil ratings of teachers was also addressed by Evans (1951) in a survey of methods of assessing teaching ability. She writes:

> . . . one of the difficulties in rating teachers is the fact that there are not usually many people who are sufficiently familiar with their work to rate them accurately. . . . There is, however, one group of people who see most of a teacher's work. Pupils who are taught by any teacher regularly over a period of time will know more about what goes on during lessons than any one else can do. (p. 92)

Reviewing related studies, she reported that the age and sex of a teacher "does not seem to have much influence on ratings" and noted also that ratings of teachers "made by other teachers, by superior officers and by pupils correlate well" (Evans 1951, p. 93).

The last decade showed a substantial rise in research dealing specifically with student rating of college instruction. Although secondary school studies appear minimal by comparison, most findings largely support earlier work. One case in point is a study by Wright and Saunders (1976) who sought the opinion of 1200 junior high students regarding the characteristics of a competent teacher. These researchers concluded, ". . . they describe as their ideal a rather excellent teacher by just about anyone's standards. They do not appear to be confused or biased." This view in large part supports the findings of Tiedeman (1942) referenced above.

Studies of student ratings of high school teachers were examined by Masters (1979) who found them to be stable over time and in several studies to have some agreement with ratings given these teachers by their supervisors. Lawrenz (1977) also reported stability of student perceptions over time. Weinstein and Middlestadt (1979) found not only that students perceived differences in the treatment accorded male high and low achievers (females were not included in the study) by the teacher, but that student perceptions were uninfluenced by the grade level, sex, or self-concept of academic attainment. In this case, results revealed both similarities and differences in the view of student and classroom observer or researcher.

Shaw (1973) reported ratings of high school teachers to be uninfluenced by years of teaching experience, teacher's sex, academic degrees or by students' grade point average. No significant relationships between ratings of high school teachers and their students' sex, grade level, grade-point average, expected course grade, or degree of absenteeism was found by Thompson (1974), Denton, Carlarco and Johnson (1977) reported a notable correlation between the supervisor rating scale and the student scale in instrument field testing studies, while Argulewicz and O'Keeffe (1978) found evidence to support the commonly held belief that ratings that are signed tend to be higher than ratings that are completed anonymously.

As with the early studies, some weaknesses in student evaluation are evident. O'Hanlon and Mortesen (1977) report that students may tend to be generous in their ratings and that factors other than the teacher may contribute to student satisfaction. This was confirmed by Smith and Brown (1976) who found that students' general attitudes toward teachers, the grade they expected to receive and their enjoyment of the subject matter, all influenced teacher ratings.

Masters (1979) also found that ratings of teachers seemed to be influenced by factors such as students' general feelings about school and teachers and, on the negative side, reported other studies which showed student ratings to vary as a function of the subject area taught. Jackson and Fuller (1966) reported that the socioeconomic status of students and teachers had some influence on teacher ratings and that girls perceived their teachers as more confident or poised than did boys. In selection of the least effective teacher, Tolor (1973) found no correlation in student ratings with those of parents, administrators or faculty members. He maintained, however, that although students may be quite inaccurate in their perceptions of poor teachers, it is possible that "students are more sensitive to crucial aspects in the teacher-student relationship than are those outside the classroom." This statement was not unlike that made by Boardman (1930).

Although the strengths of student feedback far outweigh their limitations, data collecting instruments must be carefully prepared to obtain valid data. Evans (1976) cautions that:

> It is possible . . . for the items on a checklist to be valid in the sense that they are or are not in agreement with practices recommended . . . yet, the use of the instrument may not provide a valid description of practices that actually occurred. (p. 50)

In referring to studies by Kockendorfer (1966), Ost (1971) and Hovsepian (1970), Evans (1973) commented that these researchers who obtained similar results used instruments that were deductively developed. In a similar investigation by Balzer (1973) which failed to show the same results the instrument had been inductively developed from teacher-learning situations within the classroom.

Evans argued that the lack of agreement using different instruments suggested the need to apply more than one observational instrument to the same classroom situations. He emphasized that "classroom behavior is so complex, a single instrument cannot be expected to completely describe the teaching-learning situation" (p. 87).

Ideally, instrument validation would include data on the relationship between student perceptions and the behavior observed by trained observers. In this regard, however, the literature appears relatively barren. McKeachie and Linn (1978) point out that the "cost of training observers and obtaining an adequate number of teachers and classes per teacher" make data of this nature particularly difficult and expensive to obtain (p. 45). Rosenshine (1970) attests to this when he argues that the cost of observers is a major disadvantage of category (observer) systems:

> Rating systems can also be less expensive if the students in the classroom are used as observers. For example, by using unpaid students as observers, the investigators . . . were able to obtain information on the classroom climate of more than 150 classrooms without any payment to observers. (p. 282)

One may also question which method--classroom observation by trained observers, or student feedback--provides the most valid and reliable data. McKeachie and Linn (1978) correlated student ratings of teacher rapport with observer categorization of teacher acts using a sample drawn from three introductory university psychology classes. Some significance was found, and it was concluded that the study lent some empirical support to the thesis that "student ratings of teaching are based on teacher behavior" (p. 47). Perfect agreement between student perceptions and observed behavior, however, was not obtained.

These findings could well illustrate the complexities of classroom behavior--a point made by Evans in emphasizing the need for more than one instrument in evaluations of this nature. Rosenshine (1970) also alluded to these complexities in reference to observational studies comparing behavior in traditional classrooms with that in classrooms using special instructional materials. Observing that few researchers reported significant differences, he concluded that such results "occurred because there was greater variation in student or teacher behavior within these curricula than among the curricula" (p. 289). This point is summed up well by Veldman and Peck (1969):

> Unlike ratings of observed behavior by adult judges, pupil evaluations have the advantage of averaging a large number of individual biases. They are also the product of observing the teacher on many occasions under normal conditions, and hence avoid many of the obvious problems encountered in typical "one-shot" classroom observations. . . . Pupil evaluations should not be considered apart from other indexes, any more than self-reports should be used as the sole basis for estimating a teacher's characteristics and potential. They do provide important information, however--from a unique viewpoint. (p. 107)

This review of the literature reveals the large number of studies that have used student feedback, making it an attractive alternative to direct observation, which is both expensive, difficult to obtain, and not without problems. The positive factors of student evaluation far outweigh the limitations. However, analysis has shown that care must be exercised in the preparation of instruments in order to maximize the validity of the results. Although the need for further study exists, recent research has lent some empirical support to the assumption that student ratings of teaching are based on actual teaching behavior, and that student perceptions are stable over time and uninfluenced by a large variety of factors.

Summary

The literature and research reviewed in this chapter lead to the following generalizations:

1. The need for additional research in science safety and

the safety training of teachers at both the elementary and secondary levels is of utmost importance and urgency.

2. Only if relevant instruments are unavailable should their construction be entertained. The importance of validation and instrument reliability is a major concern and in this respect, the value of the trial run should not be underestimated.

3. The Delphi exercise is a flexible and methodologically sound means of obtaining expert feedback in the solution of a variety of problem situations. Its value to education is seen in the versatility of the approaches that have been used in employing this technique.

4. The use of student feedback has empirical and logical support dating back nearly fifty years. Although continued research is needed in all aspects of classroom behavior, the use of student perceptions offers unique advantages not found in other methods.

CHAPTER III

METHODOLOGY

This investigation was concerned with the development and field testing of instruments to determine the relationship, if any, between the science safety knowledge and student perceptions of classroom-laboratory safety practices of Oregon secondary school science teachers. Teacher and class demographic data were also obtained and analyzed with respect to (*a*) science safety knowledge of teachers, and (*b*) student perceptions of safety practices of their teachers. A questionnaire was prepared to obtain the demographic data.

This chapter is organized as follows:

1. The instruments
2. Development of the Instruments
3. Pilot Studies using the Instruments
4. The Field Study
    - (*a*) Rationale
    - (*b*) Target Population and Method of Sampling
    - (*c*) Data Collection Procedures
        - *i*) Preparation of Materials
        - *ii*) Distribution and Collection of Materials
        - *iii*) Coding of Information and Preliminary Frequency Tabulations
    - (*d*) The Research Instruments
    - (*e*) Analysis of the Data
5. Revision of the Instruments

The Instruments

A comprehensive review of research pertaining to safety in the secondary school science laboratory revealed relatively few published articles. An urgent need for science teachers to be knowledgeable of recommended safety practices applicable to the secondary school classroom-laboratory was evident. In response to this need, an up-to-date Instructor's Resource Guide (IRG) dealing with the training of secondary school science teachers in laboratory safety methods was prepared in 1977 by the Council of State Science Supervisors (CS^3) in conjunction with the National Institute for Occupational Safety and Health (NIOSH). The IRG was made available to Departments of Education of each state for use in organizing and planning safety workshops.

Mr. Ray Thiess, Science Specialist for the Oregon State Department of Education, provided this investigator with a copy of the IRG which he contemplated using as a "blue-print" in setting up safety-training sessions throughout the state. In making decisions on the need for safety-training programs, and in identifying participants for workshops, information relative to the status of the safety knowledge and practices of science teachers is essential. The ability to measure safety knowledge and practices of the participants is also vital in assessing the effectiveness of training. A search of the literature revealed no instruments that would be appropriate for use in obtaining this information. Moreover, the need for such information-gathering devices was recognized at the time the IRG was prepared; in fact, space in the manual was reserved for this purpose.[3]

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[3] Appendix F of the IRG carries a notation reading in part ". . . reserved for supplemental instruments, test items and the like to be added later by CS^3, NIOSH and training personnel." (U.S. Department of Health, Education and Welfare, 1977)

Content Validity and Internal Consistency

The content validity of evaluative data require tests that are highly consistent with course content and the goals of instruction. In the case of the proposed safety-training workshops, the goal was safer science classroom-laboratories through more extensive and/or more recent safety instruction for teachers. The course content was to be broadly defined by the IRG. The use of this manual to identify both the science safety knowledge and the practices recommended for secondary school science teachers seemed logical. Also, it provided support for the content validity of the instruments to be developed.

Content validity of the instruments is also supported by the use of a Delphi Exercise in which CS^3 members were invited to participate as the major panel group. Concensus was sought in (*a*) the selection of high priority items consistent with the information provided in the IRG, and (*b*) the appropriate sequence of item response alternatives. The inclusion of the latter extends the concept of item validity to the scoring scheme for each instrument.

Following data collection, the reliability of each instrument was determined by the use of the Spearman-Brown formula.

Development of the Instruments

The IRG served as the primary source of information on recommended science safety knowledge and practice in the preparation of the instruments that were developed for this study. Also, the content categories of the IRG served as criteria in the selection of literature used in item preparation and in dividing the instruments into manageable sections.

Section titles representing ten safety areas were identified. After some modification, these lent themselves readily to the acronym SAFETY TEST which was adopted as the logo for both instruments. This grouping facilitated the organization and selection of test items in the course of the Delphi exercise.

Section Numbers and Titles

I Storage and disposal of chemicals/supplies
II Apparatus, glassware, equipment and related procedures
III First aid in the science classroom-laboratory
IV Eye, face and personal protection
V Toxic and chemical substances
VI Your responsibility and liability
VII Techniques, activities and chemical reactions
VIII Electrical, radiation and other physical hazards
IX Specific biological and animal safety
X Temperature, explosives and fire control

Two aspects of safety relevant to the secondary school science classroom-laboratory were assessed by the instruments prepared for this study. The first dealt with the safety knowledge of science teachers. The second focused on safety practices employed in their teaching. An objective test entitled Teacher Knowledge of Laboratory Safety (T-KOLS) was prepared to assess teacher safety knowledge. A multiple-choice student inventory with the title Student Perceptions of Laboratory Safety (S-POLS) was prepared as an indirect measure of classroom-laboratory safety practices of teachers based on student perceptions of teacher behaviors.

The ten safety areas outlined above, formed the framework for item categorization in both T-KOLS and S-POLS and were used to assure content parallelism between the two instruments. The procedures followed in research instrument preparation, validation and field testing are shown in Figure 3.1.

Preparation of T-KOLS and S-POLS

Teacher Knowledge of Laboratory Safety

Structure of T-KOLS

The format of this instrument was dictated by the following requirements:

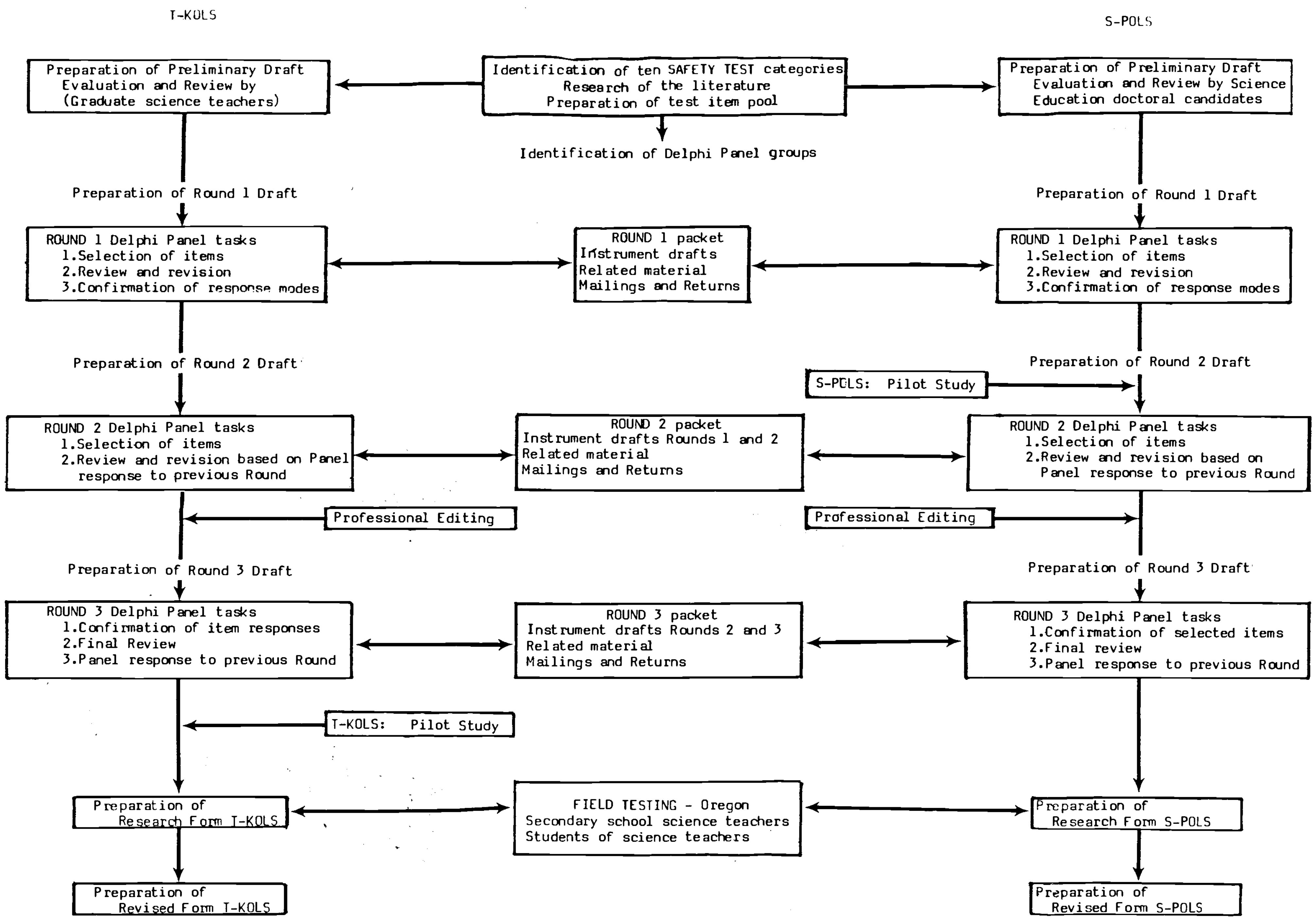


FIGURE 3.1 Flow Chart of Methodology used in Preparation of Instruments

1. Reasonably short number of pages and completion time

2. Readability (concise items to which teachers could respond readily)

3. Capability for inclusion of a relatively large number of safety topics

4. Possibilities for identifying both hazardous and safe practices

5. Objective scoring

A "topic statement" item structure was devised for T-KOLS. Although somewhat innovative, it proved to be a viable alternative to the standard objective-type test item. This format appeared to satisfactorily meet the requirements outlined above. The brevity of the topic statements (test items), as opposed to complete sentences, conserved space and reduced reading time. Responses were categorized into color-coded alternatives on the basis of the safety/hazard potential of the item.

Item selection and preliminary draft

The only exception to the use of the IRG categories in the preparation of instrument items was the inclusion of first aid. Following publication of the IRG, first aid training for teachers had become a requirement in several states. This topic was included in the Round 1 drafts and subjected to Delphi Panel critique.

Both a preliminary manual search of published materials using periodical indices, and an ERIC manual and full-text computer search was conducted in 1976 in an endeavor to locate all studies and information relevant to safety in the school science laboratory. A supplementary search was made in 1978/79 prior to item preparation in order to bring the resource material up to date. In certain instances similar information was contained in several publications. For this reason, and since topics were discarded and/or combined in the process of instrument development, a compilation of these resource references are included as Appendix D.

As each tentative test item was prepared, it was typed on a tagboard strip and arranged under acetate on photographic mounting boards classified according to one of the ten safety areas. This method permitted items to be revised and/or moved to more appropriate sections of the instrument as necessary. An item bank of 502 items was assembled with at least fifty in each of the ten sections. "Best" answer check-marks were placed in the appropriate response columns based on the IRG and the literature on science safety. Where ambiguities were found, a mark of interrogation (?) was used. These acetate-covered "pages" of items could be conveniently photocopied. They formed the preliminary draft of the instrument.

The ten sections of the preliminary draft were randomly distributed to science teachers and graduate students attending summer session science education classes at Oregon State University. Approximately thirty individuals from two classes were involved in the initial review. Volunteers were asked to read each item (topic statement) and to indicate those that were poorly worded, too obvious, too technical, or failed to communicate the intent of the statement. Individuals were verbally asked to offer suggestions for improvement of clarity or readability.

This initial review was essential to learn of possible objections of teachers to the use of the "topic statement" form of test item. The general reaction was positive toward the structure of the instrument, and no major problems were identified by the science teachers and graduate students.

Round 1 draft

Following the preliminary draft review, the test items were re-written to correct ambiguities and to accommodate appropriate suggestions or recommendations. The Round 1 draft was then prepared for submission to the Delphi panel.

Student Perceptions of Laboratory Safety (S-POLS)

Structure of S-POLS

The format of this instrument was dictated mainly by the following:

1. Ten sections to conform to the T-KOLS pattern

2. Capability for division into student sub-tests to keep the completion time reasonably short

3. Appropriate reading level for target grades (7-12)

4. Provisions for written responses where students found the three response alternatives to be inappropriate

5. Objective scoring capability

It was essential that both T-KOLS and S-POLS be constructed in such a way that the relationship between teacher safety knowledge and the student perceptions of teacher safety practices could be determined by appropriate statistical procedures. For this reason both instruments were developed around the following five common characteristics:

1. Identical source material

2. Total test length of 100 items

3. Division of test items into ten similar sections

4. Three response alternatives

5. Similar item-scoring scheme

In order to reduce the time needed for test administration and to avoid problems of student fatigue, the 100-item instrument, was to be divided into ten-item student sets. Each set to contain one item drawn at random from each of the ten sections. This format would provide each student with a cross-section of ten items to which he or she could respond within a reasonable time.

Since the instrument was required for use over a 7-12 grade span, the concepts of readability and comprehension were of major concern. A partial solution was effected by the adoption of a semi-objective test format. This provided students the option of checking one of three response alternatives, or writing a response which they believed to be more appropriate to their classroom-laboratory situation. It also permitted the test-taker an alternative method of responding in the event of reading or comprehension difficulties.

Parallelism was maintained in the writing of all items to enhance both the readability of the instrument and to provide uniformity in each of the ten items selected for the student sets.

Item selection and preliminary draft

The source material used in the preparation of the 500 T-KOLS items was methodically reviewed in writing items for the student instrument. A parallel between each of the T-KOLS and S-POLS items was not appropriate because some safety knowledge items did not lead to teacher behaviors observable by students. For this reason, a limit of one hundred items, representing the same number of safety topics, were initially prepared. Written in single-sentence "likert-scale" format, these items constituted the preliminary draft of S-POLS. This draft was shared with graduate students attending a doctoral seminar at Oregon State University, and their comments were invited regarding the appropriateness of the items for the target group. Following this review, relevant suggestions and revisions that improved the items were incorporated into the Round 1 draft.

Round 1 draft

Each item was tentatively placed in the relevant section and re-written in the three-alternative multiple choice format to be used for the instrument. These responses were initially placed in consecutive order with the most acceptable alternative first.
They were later re-arranged by random selection for use in the pilot study, the Round 3 Delphi review, and field tests. The revised

draft was then prepared for submission to the Delphi Panel.

Delphi Exercise

A Delphi Exercise was conducted as a means of establishing instrument validity. Concensus was sought in the selection and refinement of items and item responses, clarification of terminology, applicability of items for the target audience, and other minor issues. Three groups of knowledgeable individuals concerned with safety in secondary school classrooms and laboratories comprised the Delphi Panel. Since the members of the Council of State Science Supervisors (CS^3) had been instrumental in the development of the IRG they were invited to participate as the major Panel group. To provide additional expertise and focus, two smaller groups were also invited to serve on the Panel.

A group described as Science Educators (SEd) was comprised of individuals both from within Oregon and out of state who were active in science education at national, state or local levels. This group included key Oregon science teachers and other individuals in addition to university personnel. The second group of panelists was classified as Safety Professionals (SaP) for the purposes of the study. These individuals possessed qualifications in industrial chemistry, toxicology, first aid, industrial safety, and other specialized areas.

Mr. Ray Thiess, Science Specialist with the Oregon Department of Education, assisted in the identification of potential Delphi panelists and was instrumental in seeking their co-operation. A mailing list of Delphi Panel members was compiled in preparation for Round 1 and was revised as necessary for subsequent rounds.

Since the Council of State Science Supervisors had a major role in the preparation of the Instructor's Resource Guide, three Delphi Panel rounds were considered to be sufficient. The third round consisted of a final review of the research instruments and required only a minimal participation by panelists.

A similar procedure was followed in each of the three Delphi rounds. A listing of materials typically contained in the packet mailed to each panelist, is summarized as follows:

1. Current round packet mailed according to prepared mailing list

2. Contents of current round packet:
   - (a) Letter from Ray Thiess requesting the co-operation of panelists and including the target date for packet return
   - (b) Letter from this researcher thanking panelists for their cooperation and briefly explaining the project or bringing panelists up to date in the case of Rounds 2 and 3
   - (c) Draft copies of T-KOLS and S-POLS
   - (d) Summary of major objectives and findings of previous round (Rounds 2 and 3)
   - (e) Listing of consecutive "steps" to follow in review and evaluation of each item and the instrument of which it was a part
   - (f) Photocopy reduction of items included in the T-KOLS and S-POLS drafts from preceding rounds (Rounds 2 and 3)

3. Documentation of the contents of packets returned by panelists

4. Letter of thanks mailed to each panelist immediately upon return of the packet

5. Letters of request mailed to panelists not returning packet by target date. Follow-up letter and/or telephone request as necessary

6. Analysis of panel responses to current round

7. Preparation of T-KOLS and S-POLS drafts and accompanying materials for subsequent round

The number of mailings and returns for each of the three rounds are shown in Table 3.1.

TABLE 3.1 Delphi Exercise: Mailings and Returns

		Mailings	Returns
Round 1:	CS^3	77*	29
	Science Educators	14	8
	Safety Professionals	9	5
	Totals	100	42
	Percentage Returns		42%
	Disregarding duplicates		51%
Round 2:	CS^3	73*	32
	Science Educators	13	11
	Safety Professionals	8	4
	Totals	94	47
	Percentage Returns		50%
	Disregarding duplicates		61%
Round 3:	CS^3	40	34
	Science Educators	13	10
	Safety Professionals	6	4
	Totals	59	48
	Percentage Returns		81%

*Duplicates sent to seven State Departments of Education

Disregarding duplicates sent to Departments of Education (several states having more than one state science supervisor), a 51% return was shown for Round 1 and a 61% return for Round 2. While it had been anticipated that only one CS^3 member from each Department would wish to serve on the panel, a round packet was sent to each CS^3 member in order to acquaint that individual with the project. It was anticipated that this action might prompt a more immediate decision as to the person most qualified to serve on the panel.

The initial invitation to panel members requesting their participation in Round 1 was accompanied by the Round 1 packet. This had the effect of both expediting the return of the Round 1 materials and also permitting the selected individuals to peruse the T-KOLS and S-POLS drafts and other materials before electing to serve on the Panel. Several individuals declined participation in Round 1 on the basis of workload but, upon review of the materials, expressed a willingness to contribute to Round 2 and were retained on the mailing list. The Round 3 mailings, however, were limited to respondents who had contributed to at least one of the previous rounds. The number of rounds served on the panel by members of each of the three groups is shown in Table 3.2.

TABLE 3.2 Delphi Exercise: Number of Rounds Served by Panelists

	3 Rounds	2 Rounds only	1 Round only
CS^3	27	7	2
Science educators	8	2	1
Safety professionals	1	4	2
Totals	37	13	5

To facilitate the return of the Round 2 and 3 packets by the target date, two sections in each instrument were randomly selected and marked with a large "signal dot" prior to mailing. Although panelists were requested to give these sections priority, they were also offered the option of reacting to another section or completing additional sections as time or interest permitted.

While a majority of Delphi Panel members responded to both T-KOLS and S-POLS, some chose to respond to one instrument only.

As a facet of the Delphi process, a photo-copy reduction of all items included in the drafts for a given round were mailed with the revised drafts for the following round. This permitted panelists to make a comparative examination of the items and respond accordingly. Although returned together, each of the instruments was independently analyzed and revised following review by the Panel.

T-KOLS Delphi

The number of Delphi panelists involved in T-KOLS item selection and review for each round is shown by section in Table 3.3.

TABLE 3.3 T-KOLS: Delphi Panel Involvement in Item Selection and Review

T-KOLS section	Round 1: n=42				*Round 2: n=47				Round 3: n=48			
	CS^3	SEd	SaP	Total	CS^3	SEd	SaP	Total	CS^3	SEd	SaP	Total
I	17	5	2	24	6	4	2	12	16	4	4	24
II	18	4	2	24	6	4	1	11	16	4	4	24
III	18	4	2	24	8	2	1	11	14	3	3	20
IV	18	4	2	24	6	3	1	10	17	4	4	25
V	16	4	1	21	7	5	1	13	13	2	4	19
VI	17	4	2	23	5	4	1	10	9	4	2	15
VII	16	3	2	21	7	4	1	12	14	3	3	20
VIII	18	5	3	26	4	4	1	9	13	3	3	19
IX	14	4	1	19	6	3	0	9	16	6	3	25
X	17	5	1	23	5	2	1	8	14	3	3	20

[*] To expedite return of Rounds 2 and 3 panelists were asked to specifically review only two pre-selected Sections. While completion of additional sections was encouraged as time permitted, the count for Round 2 was substantially below that of the other rounds.

The major tasks of each panel member were to:

1. Discard items not considered relevant to safety in the secondary school science program

2. Select the 100 (ten items per section) "best" items from an item bank of 502 items in Round 1

3. Confirm the three alternative response modes ("best answer," "less preferred" and "not acceptable")

4. React to (*a*) the structure of T-KOLS, (*b*) the clarity of test items, (*c*) inclusion of the section dealing with first aid, and (*d*) relevant recommendations made by other panelists

Delphi panel feedback relative to each of the above tasks is summarized briefly below:

Discard of items. There was no indication by panelists that any of the 502 items were not relevant to the secondary school science safety program, and none were discarded solely on this basis. Items were, however, discarded as a result of the selection process described below.

Selection of items. The selection of items was a major facet of the Delphi process as used in this study. For this reason, the selection procedure is discussed in some detail.

The items in each section (approximately fifty) were reduced by about one-half as a result of Round 1 and half again by Round 2, with the number reduced to ten by Round 3. The item selection procedure was based on the number of panelists recommending that an item be retained in the instrument compared to the total number of panelists reacting to that item. Not all panelists reviewed and selected items for each T-KOLS section (Table 3.3). The participation of panelists depended (*a*) on their expertise in the safety area concerned, (*b*) their interest in the safety area and the time at their disposal, and (*c*) the pre-selected sections they were asked to review.

The sequence of steps used in the selection process for T-KOLS follows:

1. Each section item was listed in numerical order, and a record made of the number of panelists selecting the item for retention in the subsequent round

2. This tally was converted to a "Panel Percent" by dividing the count for retention by the total number of panelists reacting to that item, and multiplying this number by one hundred

3. The panel percent for each item was analyzed by section and the lowest percent that would eliminate approximately half of the section items was chosen as the "Cut-off Percent"

4. All items with a panel percent less than the cut-off percent were eliminated from the section. The next T-KOLS draft included only those section items with a panel percent greater than, or equal to the cut-off percent

Although CS^3 panelists were included in the foregoing selection procedure, an independent "CS^3 Percent" was also calculated. Since the CS^3 group was involved in the preparation of the IRG and were most knowledgeable of its contents, any wide disparity in the Round 1 Council of State Science Supervisors and total panel selections would have been cause for concern. While this factor was of less importance to the Round 2 selections since no great differences had been shown for Round 1, a CS^3 percent was nevertheless computed for Round 2. This provided both an additional check on possible group bias and maintained procedural consistency between the two rounds.

The information associated with the item selection procedure for Rounds 1 and 2 is given in *Appendices Tables 1 and 2* and is summarized by section in Table 3.4. The selection mean for CS^3 and for the total panel was obtained by averaging the "CS^3 Percent" and the panel percent respectively over all section items. Although

TABLE 3.4 T-KOLS: Item Selection by Delphi Panel

	ROUND 1					ROUND 2				
Section	Number of items in section	* Cut-off Percent	Mean percent of items voted to be retained by CS3 and the entire Delphi Panel (EDP)		Items Retained for Round 2	Number of items in section	* Cut-off Percent	Mean percent of items voted to be retained by CS3 and the entire Delphi Panel (EDP)		Items Retained for Round 3
			CS[3]	EDP				CS[3]	EDP	
			%	%				%	%	
I	50	59%	57.04	57.86	27	27	58%	61.63	61.93	17
II	50	63%	58.32	60.78	27	27	64%	53.63	62.44	16
III	50	67%	65.08	64.10	26	26	55%	59.92	60.15	16
IV	50	58%	60.84	50.80	27	27	60%	58.52	62.59	17
V	50	62%	60.08	59.16	24	24	69%	65.46	68.00	14
VI	50	65%	59.86	60.88	27	27	70%	67.41	70.00	17
VII	50	62%	57.66	59.40	27	27	67%	62.41	59.96	13
VIII	50	58%	61.08	60.56	29	29	67%	50.00	55.14	15
IX	51	50%	61.00	57.88	30	30	67%	56.70	59.30	15
X	51	65%	63.22	63.08	28	28	63%	46.43	54.79	18
Total	502				272	272				158

* Cut-off is the minimum percentage of Delphi Panel respondents voting to retain any item in the section yet reducing the number of items by approximately one-half.

the panel percent was heavily weighted by the CS^3 group, and similar means could be expected for this reason, the influence of the other two groups is nevertheless apparent.

The Round 1 cut-off percent was higher than the panel mean for all sections except IV and VIII, and higher than the CS^3 mean for all sections except IV, VIII and IX. In Round 2 the cut-off percent was higher than the panel mean for all sections except I, III, IV and VI and higher than the CS^3 mean for all sections except I and III. The lack of a consistent pattern between cut-off and group percentages from round to round combined with relatively small percentage differences suggests that the differences are probably not important.

In Round 1, proportionally more items were selected for inclusion in the following round by CS^3 than the overall panel for Sections III, IV, V, VIII and IX (CS^3 mean higher than the panel mean). Only Section VII showed this pattern for Round 2. With fewer items in Round 2, the selections were not as variable. However, the mean percentage differences between CS^3 and the entire panel were not substantial for either round.

Although thirty-three items selected by the panel as a result of Round 1 and included in Round 2 showed a CS^3 percent less than the cut-off percent, only eleven of these items were carried through to Round 3 and five to the Research form of T-KOLS. That is, twenty-two items were selected out (eliminated) as a result of Round 3 (Table 3.5).

Eighteen Round 2 and ten Round 3 items showed a CS^3 percent greater than the panel percent. In these cases, the selection procedure based on the panel percent eliminated these items at the time of selection, and they were not included or carried through to subsequent rounds. These items, however, represented a relatively small fraction of the total (502).

This investigator was satisfied that the selection process

TABLE 3.5 T-KOLS: Fate of Items with CS^3 Selection Percent Less than Cut-off Percent

	Round 2 Draft	Round 3 Draft	Research T-KOLS
	Item Number		
I	22	out	-
	23	out	-
II	3	out	-
	10	out	-
	12	out	-
	17	included	included
	25	out	-
	32	included	included
III	22	included	included
	36	out	-
IV	4	out	-
	36	included	included
	46	out	-
V	17	included	out
	34	included	included
VI	5	out	-
	44	included	out
VII	1	out	-
	4	out	-
	12	out	-
	17	out	-
	39	out	-
	50	out	-
VIII	7	out	-
	27	out	-
	39	included	out
	41	out	-
IX	9	out	-
	21	included	out
	42	out	-
	48	out	-
X	5	included	out
	27	included	out
Totals	33 items	11 items included	5 items included

used in Rounds 1 and 2 was satisfactory and provided the best means of identifying those items that were to be carried through to the Round 3 T-KOLS draft. While some differences in the CS^3 and panel selections were apparent, these were not unduly large and moreover, did represent the influence of the other two panel groups (Safety Professionals and Science Educators). Since the aim of including these two groups was to reinforce the expertise of the CS^3 it appeared that this purpose was fulfilled.

Confirmation of Response modes. Concensus regarding the classification of responses to T-KOLS items was more difficult to achieve than any other component of the Delphi exercise. Response to each topic statement required the respondent to categorize the item according to its safety or hazard potential in relation to the secondary school science program. Three alternatives were provided: (*a*) "permissible and recommended" (color-coded *green*), (*b*) "permissible with qualifications" (color-coded *yellow*), and (*c*) not permissible under any circumstances" (color-coded *red*).

During item preparation by this investigator, an "X" was placed in the appropriate response column on the basis of the literature. A mark of interrogation (?) was used where the correct response was not clearly defined or where the intent of the literature was questioned. Round 1 panelists were asked to review the placement of these markings and, where agreement was lacking, to indicate the correct response column on the basis of their own expertise. Where Round 1 concensus was not obtained, essentially the same procedure was followed for Round 2. This method of reaching concensus was considered appropriate for the first two rounds since a large number of items were involved including somewhat similar items. Where items on the Round 3 draft continued to show a lack of unanimous agreement, a percentage concensus figure was calculated and placed in the appropriate column.

Panel Reaction. Both oral and written responses to the Round 1 packet revealed no adverse reaction to the general structure of T-KOLS. Slight modifications were made in the section titles and in the headings of the color-coded response columns. Minor revisions in the topic statement items included the suggestion that chemical symbols be used in addition to words. Concensus regarding the inclusion of first aid as a separate section was unanimous.

S-POLS Delphi

The number of Delphi panelists involved in the review of S-POLS items for each round is shown in Table 3.6. As indicated previously in the case of T-KOLS (p. 53), not all panelists examined the items in each section, and for this reason the panel group numbers vary for each round.

TABLE 3.6 S-POLS: Delphi Panel Involvement in Item Selection and Review

Round 1 n=42				Round 2 n=47				Round 3 n=48			
CS^3	SEd	SaP	Total	CS^3	SEd	SaP	Total	CS^3	SEd	SaP	Total
21	6	3	30	21	7	2	30	32	10	4	46

The major tasks of the Delphi Panel over the three rounds were to:

1. Suggest section changes where items appeared to have been misplaced

2. Discard and/or substitute items not considered appropriate

3. Evaluate the readability/comprehension level with respect to the target grade level (7-12)

4. Evaluate item content in relation to secondary school science subject areas and grade levels to ensure a fair distribution

5. Review the consecutive order of the three (*best answer, less preferred, nonacceptable*) multi-choice response alternatives

Discard of items. The full complement of 100 items divided into ten sections of ten items each, were included in the Round 1 draft. Although items were to be discarded when inappropriate, and alternative topics could be suggested, unlike T-KOLS, there was no specific process required to reduce the number of items. The count of 100 items was to be maintained throughout instrument development. Two respondents appeared not to understand this, and between them suggested the discard of thirty-six of the 100 Round 1 items. These data are not shown in Table 3.7 which shows the distribution of items suggested for discard by Round 1 panelists. Follow-up revealed, however, that any difficulties these panelists may have had in regard to the appropriateness of the discarded items were apparently resolved in subsequent rounds.

A breakdown of the number of items proposed for discard by panelists in each of the three groups is shown in Table 3.8 for Rounds 1 and 2. Nineteen individuals did not discard any items in the Round 1 review, and there was little concensus in the rejection of others. The few suggestions to discard most of the specific items appeared weak when considered against those panelists who responded favorably. For this reason, only one item (VIII.3 in Table 3.7) was dropped in the Round 2 draft. However, upon the suggestions of panelists, two items (VI.9 and VIII.1 in Table 3.7) were completely rewritten and assigned new item numbers. The following rationale was used as the basis for retention of the remaining Round 1 items:

1. There was little concensus by respondents on the items to be discarded

2. In most instances replacement items or topics were not suggested

TABLE 3.7 S-POLS: Round 1 Items Checked for Discard

Item Number	Section									
	I	II	III	IV	V	VI	VII	VIII	IX	X
1										
2					✪			✪		
3								✪✪✪		
4	☆ ✪									
5		☆								
6	✪									
7								✪		
8				✪						
9				★				✪		
10				★				✪✪		

Legend:
✪ CS^3
☆ Science Educator
★ Safety Professional

TABLE 3.8 S-POLS: Number of Round 1 and 2 Items Checked for Discard

Delphi Panel Group	Round 1		Round 2	
	Number of items to be discarded	Number of respondents recommending	Number of items to be discarded	Number of respondents recommending
CS^3 members	20	1	8	3
	5	1	6	3
	2	2	4	1
	1	3	3	2
	0	14	2	3
			1	5
			0	4
Science Educators	16	1	12	1
	2	1	8	1
	0	4	4	1
			3	2
			1	2
			0	0
Safety Professionals	1	2	1	1
	0	1	0	1

3. A majority of the panelists approved those items that others had rejected

4. Excellent suggestions were frequently offered by panelists for the revision of many of the items included in the reject list of others

5. New topics were suggested and incorporated into the Round 2 draft as additional items

6. When panelists were not in agreement with the revised or new additions, Rounds 2 and 3 were available to obtain concensus

Rearrangement of Items. Table 3.9 shows the re-arrangement of Round 1 items. Additional topics suggested by panelists were written in appropriate form and incorporated into the Round 2 draft. As described above, although shown as discards in Table 3.9, these included both item VIII.1 and item VI.9. Transfers to other sections retain the original item numbers in Table 3.9 in order to simplify the identification of items in following rounds. A total of 108 items were prepared and included in the Round 2 draft. In this round panelists were asked to identify the ten items in each section that should be included in the final instrument (100 items).

Preparation of student sets A-J. Prior to the Round 2 returns from Delphi panelists, and in preparation for the Pilot study, the S-POLS items in Sections I-X were randomly divided into ten individual student sets A-J each containing one item from each section. In order to maintain the integrity of the sections, the first item in each set was a Section I item; the second a Section II item, and so on. Table 3.10 shows both the resulting set items and the randomization of the response alternatives. The eight items in excess of the required ten in each section (see Table 3.9) were placed temporarily in an extra set "K". In order that the K Set would contain the same number of items as Sets A-J, two additional items were constructed (IV.14 and X.12 in Table 3.10). Unlike Sets A-J the ten items in the K Set did not represent each of the ten sections and the item

TABLE 3.9 S-POLS: Re-arrangement and Additional Items Incorporated into the Round 2 Draft

Item Number		Section									
		I	II	III	IV	V	VI	VII	VIII	IX	X
	1	x	IX*	x	x	x	x	x	out	x	x
Round 1 item numbers	2	x	x	x	x	x	x	x	x	x	x
	3	x	VI*	x	x	x	x	x	out	x	x
	4	x	x	x	II*	x	x	x	x	x	x
	5	x	x	x	x	x	x	x	x	x	x
	6	x	x	x	x	x	x	x	x	x	x
	7	x	x	x	x	x	x	x	x	x	x
	8	x	VII*	x	V*	x	x	x	x	x	x
	9	x	x	x	x	x	out	x	x	x	x
	10	x	x	x	x	x	x	x	x	x	x
"New" Round 2 additions	11		o		o		o		o		o
	12		o		o		o		o		
	13				o				o		
Transfers from other sections			IV.4$^+$			IV.8$^+$	II.3$^+$	II.8$^+$		II.1$^+$	
Total items		10	10	10	11	11	12	11	11	11	11

Legend:

x	original Round 1 item retained for Round 2
o	new item included in Round 2
out	item that has been discarded (VIII.3) or re-written (VIII.1 and VII.9)
*	item transferred to the section shown
+	item transferred from the section shown

Total number of items incorporated into the Round 2 draft = 108

TABLE 3.10 S-POLS: Randomization of Inventory Items and Multi-choice Alternatives for Sets A-K

	Set item numbers[*]									
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Set	Sections									
Set	I	II	III	IV	V	VI	VII	VIII	IX	X
A	B C 10 A	C A 5 B	C A 9 B	A B 7 C	B A 3 C	B A 7 C	A C 10 B	B C 8 A	C A 7 B	A B 9 C
B	B A 5 C	B C 7 A	C A 2 B	A C 6 B	A C 2 B	A C 12 B	A C 9 B	C A 10 B	A B 10 C	C B 4 A
C	A C 2 B	B C IV.4 A	C A 6 B	A C 13 B	C B 10 A	A C 2 B	B C 4 A	B C 7 A	A B 8 C	B A 10 C
D	B A .7 C	A C 11 B	C B 1 A	B A 1 C	C A 4 B	A C 11 B	B A 6 C	A C 13 B	A C 4 B	A C 5 B
E	B A 8 C	A C 4 B	C A 10 B	B A 5 C	C A 5 B	B C 5 A	C A II.8 B	A B 9 C	C AII.1 B	C B 2 A
F	B C 1 A	B A 12 C	C A 5 B	A B 12 C	C A 1 B	B A 6 C	A C 5 B	C B 6 A	A B 2 C	C A 3 B
G	C A 3 B	A C 10 B	A C 4 B	B C 2 A	C A 8 B	C A 3 B	B A 7 C	B A 11 C	A B 3 C	A B 11 C
H	B A 5 C	A B 9 C	B C 8 A	A B 9 C	B C 6 A	C B 1 A	A C 8 B	C A 2 B	A B 1 C	C B 6 A
I	A C 9 B	C B 2 A	A B 7 C	C A 11 B	C B 9 A	A B 8 C	C B 1 A	A C 4 B	C A 5 B	A C 8 B
J	C A 4 B	B A 6 C	C A 3 B	A B 10 C	C A 7 B	C A 10 B	A C 3 B	C A 5 B	B A 6 C	A C 7 B
K				*1* A C IV.3 B	*2* C A IV.8 B	*3* A C II.3 B	*5* C VII. A 2. B	*6* C VIII. A 12 B	*7* C A IX.9 B	*8* C B X.1 A
				C + A IV. B 14 *9*		A B VI.4 C *4*				A + B X.12 C *10*

[*] The item numbers of the SETS correspond to the Section--except in the K SET which is independently numbered.

[+] Additional items constructed to bring the K SET count to ten items.

numbering scheme used in this case was purely arbitrary.

K Set. The distribution of S-POLS items suggested for discard (items not selected as the best ten) by Round 2 panelists is given in Table 3.11. Analysis of these returns were studied in conjunction with the Pilot study data. The eight original Temporary K Set items which were satisfactory on the basis of both the Round 2 and the Pilot study data, were used to replace the items included in Sets A-J which were found unsuitable. The two additional items (IV.14 and X.12) constructed to bring the Temporary K set item count to ten, were not used as replacement items since these had not been included in the original Round 1 and Round 2 S-POLS drafts and subjected to Delphi panel review. They were retained, however, in the Revised K set as items K1 and K9. Some re-shuffling of items was necessary in order to ensure that the replacement items were appropriate for the set items they replaced. *Appendices Tables 3 and 4* show the replacement process items used in the formation of the Revised K Set and the reorganized Sets A-J following preparation of the Round 3 draft.

Seven of the original Round 2 items replaced by the Temporary K Set items were incorporated into the Revised K Set (items K2 to K8). Only one item IV.13 was completely discarded, and in this case a substitute item (K10) was constructed in its place. Together with K1 and K9 these ten items formed the Revised K set which was retained throughout the field study. This provided a bank of ten items that could be used to substitute for any of the 100 items contained in Sets A-J if these were found to be deficient.

Since the use of the K set was an important phase of item development, the following summary is provided in order to further clarify the process used:

1. One hundred and eight items resulted from Round 1

2. Following division of S-POLS into ten-item Sets A-J by random selection (100 items) the excess items (8) were placed

TABLE 3.11 S-POLS: Round 2 Items Checked for Discard

	Item Number	Section									
		I	II	III	IV	V	VI	VII	VIII	IX	X
Original Round 1 items (100)	1		▦						▦	⧅ ✪✪✪	
	2		✪✪	✪	☆☆☆ ✪						
	3		▦				✪✪	☆	▦		
	4		☆		▦	⧅ ☆☆★✪ ✪✪✪✪	☆			✪	
	5		☆	✪	☆ ✪	✪	✪	⧅ ☆ ✪✪✪	✪✪	✪✪	☆
	6		✪			✪	☆ ✪✪✪		☆		✪
	7				☆		☆ ✪	✪			☆
	8		▦		▦		⧅ ☆ ✪✪✪		☆		
	9		✪		☆ ✪✪		▦			✪	
	10		✪✪✪✪				⧅ ☆☆ ✪✪		☆ ✪		⧅ ✪✪✪
"New" Round 2 additions	11	░	☆ ✪✪	░	☆	░	☆☆	░	☆	░	✪
	12	░	✪✪	░		░	☆ ✪✪	░		░	░
	13	░	░	░	☒ ☆ ✪✪✪	░	░	░	⧅ ★	░	░
Transfers from other sections	II.1	░	░	░	░	░	░	░	░	☆ ✪	░
	II.3	░	░	░	░	░		░	░	░	░
	II.8	░	░	░	░	░	░	✪	░	░	░
	IV.4	░		░	░	░	░	░	░	░	░
	IV.8	░	░	░	░		░	░	░	░	░
Total items		10	10	10	11	11	12	11	11	11	11

Legend:
- ✪ CS^3
- ☆ Science Educator
- ★ Safety Professional
- ▦ Item eliminated or transferred from Section by Round 1
- □ Round 2 addition or transfer from another section as a result of Round 1
- ☒ Item discarded completely on the basis of Round 2 analysis
- ⧅ Item placed in revised K Set as substitute item (not included in field study data) on the basis of Round 2 analysis

temporarily into Set K

3. Two additional items were constructed for the Temporary K Set in order to form a ten-item set consistant with Sets A-J for the Pilot study

4. Following examination of the Round 2 returns and analysis of the Pilot study data, the eight original temporary K set items were used to replace the deficient items in Sets A-J

5. Apart from one item that was completely discarded, the eight items in Sets A-J that were displaced by K Set items were retained and formed the Revised K Set (7 items)

6. A new item was constructed to replace the discarded item IV.13 and together with the two items previously constructed for the Temporary K set, completed the complement of ten items.

7. The Revised K Set was retained through the field study as a replacement bank for the A-J Set items in the event that any of these were found to be deficient

8. The item numbers in the K Set (unlike Sets A-J) do not coincide with the Section numbers I-X but were in most cases arbitrarily assigned

Response alternatives. The order of the A, B and C response alternatives for each item was maintained through Rounds 1 and 2 in order to simplify Panel review. Although a few changes were suggested to make the wording of some of the alternatives more precise, they were acceptable to all Panel members. This was an important phase of the Delphi exercise, since it was essential that the 2-1-0 scoring scheme reflect an exact sequence of response alternatives for each item in order to preserve instrument validity. For this reason Panel review and concensus was vital. The item response alternatives were randomized prior to division into the student sets to prevent the order of choices serving as a clue to the keyed responses.

Readability. The readability/comprehension level of the instrument was an expressed concern of several panelists in view of the seventh to twelfth grade range of the students. One panelist expressed the fear that the instrument could be both incomprehensible to the lower grade student, and insufficiently challenging to the top level physics student. Suggestions for dividing the instrument into two parts, each at different reading/comprehension levels, were explored through the Delphi process. In many cases, recommended item revisions and topic changes were useful in refining the instrument for the target groups.

The pilot study findings were available during the preparation of the Round 3 materials. These results were invaluable in successfully resolving many of the difficulties expressed by panelists in relation to the reading/comprehension level of S-POLS. Both analysis of results and feedback from teachers regarding student reaction to the S-POLS items alleviated many of the concerns of the first two rounds. By the completion of Round 3 a concensus of the panelists had been obtained.

Incidental issues. Incidental issues resolved through the Delphi process included the following:

1. Clarification of terms used in the instrument such as "classroom-laboratory," "laboratory tables" and so on

2. Specification that all items dealing with the immediate first aid treatment given by the teacher include a notation to the effect that this was provided "before the student was sent to the school nurse . . ."

3. Panel agreement that field trips be considered a major part of laboratory safety and that items dealing with this subject should be included in the instrument

4. Confirmation of items which appeared on the basis of pilot study data to be common (or applicable) to all grades seven through twelve and to all science subject areas

Item four above was an important phase of Round 3 which had not been anticipated at the outset. This topic is further elaborated upon in relation to the preparation of the Research instrument p. 105).

Round 3

The Panel tasks of the third and final Delphi round consisted mainly of a review of the edited instruments and related materials. The latter included (*a*) a description of T-KOLS and the related response scheme, (*b*) instructions for administering S-POLS, and (*c*) student instruction sheets. In the case of T-KOLS, Delphi panelists were asked to identify items remaining in the instrument that they recommended not be included in the Research instrument. In addition, panel concensus was still sought where the "best answer" had not been determined for several items. Concensus and identification of items common to all grade levels and science subject areas was necessary in the case of S-POLS.

Round 3 returns were received for both instruments following data collection for the field study. For this reason, and to maintain a sequential account of the Methodology of the study, Round 3 analysis is deferred and shown in conjunction with the preparation of the Research instruments (p. 105).

Professional Editing

Following the preparation of the Round 3 draft, both instruments were submitted to a team of three individuals for professional editing. Since their advice was conveyed to the Delphi Panel as a part of Round 3, the details of their review are presented for each instrument in turn.

T-KOLS

Professional advice regarding the use of a "topic statement" form of test item had been obtained by this investigator prior to instrument preparation. Assurance had been given by language instructors that the use of the "topic statement" form of items was grammatically correct. This style of writing was adopted because a large number of items could be completed relatively rapidly by the test-taker and a large number of safety topics could be surveyed. In addition, by eliminating extraneous words, each item focused on a "general" rather than a "specific" safety situation. In the assessment of teacher knowledge, general information was more important to the immediate study than specific safety facts.

One of the three editors, however, advised that the items could be transformed into sentence-structure without unduly increasing their length, and with added improvement in clarity. This possibility was explored and writing specialists were consulted in converting the items into complete sentence form. It was found, however, that several topic statements could not be revised to sentence form without loss of original meaning or intent. In addition, the parallel form of item structure used in the instrument could not, in several instances, be adapted to sentence form.

The decision to retain the topic statement form of the T-KOLS test items was based on the following:

1. All items could not easily be converted to sentence form

2. Satisfaction with the topic statement form of the test items had been reported by (*a*) science teachers reviewing the preliminary draft, (*b*) pilot study participants, and (*c*) the Delphi panelists

3. Two of the three editors were satisfied with the original "topic statement" structure of the items

Professional editing of the original T-KOLS items was completed prior to the pilot study and preparation of the Round 3 packet.

S-POLS

Editing of the student instrument revealed a lack of "preciseness" since items focused on "practices in the classroom-laboratory" and not specifically on safety "practices of the teacher." This focus was deliberate in order to avoid placing the teacher in a "threatened" position which might jeopardize cooperation in administering the student instrument.

Although it could be inferred that these two concepts were the same, it was decided to revise the items to avoid any misconceptions in this regard. S-POLS items were re-written by this investigator in order to ensure that (*a*) all revisions made as a result of the first two Delphi rounds were incorporated into the revised items, and (*b*) the original intent of the items was maintained throughout. Following re-writing, the instrument was again submitted for professional editing prior to final preparation of the Round 3 packet.

Scoring

A similar scoring scheme was used for each instrument. Both T-KOLS and S-POLS contained 100 items which were divided into ten 10-item sections. Each instrument contained three response alternatives ("best answer," "less preferred" and "not acceptable") that were scored on a 2-1-0 basis. The procedure followed in scoring each instrument is as follows:

T-KOLS

Each section was scored and a total T-KOLS score was calculated for each teacher. Where five or more items were completed in a section, the score was tallied with missing items scored as zero. A section was not scored when less than five items were marked. Total T-KOLS scores were calculated only when scores were obtained for all ten sections. In cases where less than ten sections were scored, independent section scores (partials) were recorded and these were included in statistical analyses that did not require a total score.

S-POLS

In addition to the three response alternatives described for T-KOLS, two other response options were available to the students. They could indicate that the situation described in the item was not applicable to their own class or they could supply a written response if the safety practice in their classroom-laboratory was not accurately described by any of the three response alternatives. On coding the S-POLS responses it was found that in those instances where students supplied a written response, a majority of the written responses were consistent with one of the three alternative modes. When this occurred, the written response was scored according to the relevant response.

As described earlier, the structure of S-POLS was such that all items numbered one in sets A-J were Section I items; those numbered two in Sets A-J were Section II items, and so on. To obtain a section score which was necessary to test for a possible relationship between knowledge and practice, student responses to items of the same number across all Sets A-J were summed. The Set scores were unimportant for the purpose of this study. The scheme used to obtain a science safety practice score for each participating teacher is depicted in Figure 3.2.

A cell average (shown in parenthesis in Figure 3.2) was first obtained by averaging the item scores. This procedure was followed on the advice of Nancy Carter, Department of Statistics, Oregon State University. "Nonapplicable" items, scored as -1, were not included in calculating the cell average unless the item was one of the thirty-five "common items" which were to be answered by all students. In that case it was scored as zero. Where each cell of the same number (A-J) was filled, the cell averages were summed to give the section total. In those cases where certain cells of the same item number remained unfilled, the cell averages were first summed, a mean was then calculated and multiplied by ten to give the section total. An example from Figure 3.2 follows:

Legend:
0 1 2 Individual student response scores for the item
-1 Individual student response symbol for item that "does not apply"
☐ Item to be completed by all students (common item)

Section	Item #	Class 1 Set										Class Score
		A	B	C	D	E	F	G	H	I	J	
I	1	1 2 2 (1.67)	1 0 1 (0.67)	2 2 (2)	1 1 (1)	1 1 (1)	2 2 (2)	2 2 (2)	2 2 (2)	2 2 (2)	1 (1)	15.34
II	2	1 2 1 (1.33)	2 1 -1 (1.5)	1 1 (1)	1 -1 (1)	2 2 (2)	-1 -1	-1 -1	-1 -1	1 0 (0.5)	2 1 (1.5)	12.61
III	3	-1 -1 (0)	2 2 2 (2)	1 2 2 (1.67)	0 1 1 (0.67)	2 2 (2)	1 1 2 (1.33)	-1 -1	-1 -1	1 1 (1)	-1 -1 (0)	10.84
IV	4	etc.	etc.									16.19
V	5											14.44
VI	6											11.86
VII	7											14.98
VIII	8											12.45
IX	9											13.33
X	10											12.67

ADDITION +

Class 2 Set						Class Score
A	B	C	D	....	J	
						16.34
						14.45
						12.00
						12.67
						10.55
						14.32
						15.78
						16.55
						14.44
						12.78

ADDITION +

Class 3 Set						Class Score
A	B	C	D	....	J	
						14.55
						15.69
						13.78
						14.32
						9.67
						12.14
						14.12
						15.12
						13.98
						10.67

Teacher Practice Score by Section	
= 15.41	I
= 14.25	II
= 12.21	III
= 14.39	IV
= 11.55	V
= 12.77	VI
= 14.96	VII
= 14.71	VIII
= 13.92	IX
= 12.04	X

Teacher's S-POLS Score: 136.21

FIGURE 3.2 S-POLS: Example of the Scoring Scheme used in Computing a Teacher Practice Score

Class 1, Section III
(In this case *nonapplicable* items (*-1*) were scored as zero)

Aggregation of averages for each filled cell = 8.67
Number of filled cells (counting A.10 and J.10 as zero) = 8

Calculated section total (8.67/8) x 10 = 10.84

The total scores for each section (I-X) were then averaged to give the teacher practice score for that section. The teacher's S-POLS score was then obtained by summing the scores for all sections (I-X).

Readability

The readability of S-POLS was of concern in view of the range of grade levels (7-12) of the students. Although there are various readability formulae available, the majority are designed for use with continuous prose and do not lend themselves well for use with multi-choice test items. Moreover, it is recognized that science terminology tends to raise the reading level of most textual material, making the readability difficult to determine accurately.

Prior to the pilot study, the *Flesch* formula (Flesch 1951) was adapted and used to obtain a readability index for S-POLS. Counting the stem and each of the three response alternatives as a total of four sentences, nine random 100 word samples were taken. *Flesch* formula calculations placed the reading level at low 8th grade. Using the same sample, the interpreted score from the *Fry's Readability Graph* (Fry 1968) gave an identical value.

Eyers (1975) utilized a *SMOG* readability formula (McLaughlin 1969) that had been adapted for multiple choice items by using every test item and treating the item stem and its longest alternative response as a complete sentence. In this scheme, each student Set (A-J) of ten items, provided the ten consecutive sentences required by the adapted method. An average 9.17 reading level was obtained by this formula for the re-organized S-POLS items prior to field testing. A range of 9.00 to 9.86 was calculated for each of nine sets and an 8.20 level obtained for Set H. However, the readability level dropped by two grades when the stem and each item alternative were counted as four independent sentences (as in the case of the Flesch and Fry methods described above). This "sentence" count would not appear to be inappropriate for S-POLS since the stem of all items ends with the words "Most Often." In this instance, the stem in many respects represents a "complete thought" which is the criterion used for defining a sentence count by the SMOG method.

As previously discussed, a concern had been expressed by Delphi panelists regarding the development of an instrument that would be suitable both for 7th and 12th grade science students. With this in mind, many Round 1 Delphi panel recommendations were incorporated into the individual items and the instrument itself. Based on data from the readability tests, the reading level of S-POLS was considered acceptable in view of the intended target audience. This view was supported by the pilot study data, where no apparent difficulties were reported with respect to readability of the instrument.

Pilot Studies using the Instruments

Since Oregon was to be the site of field testing, arrangements were made for pilot studies on both instruments to be conducted in Washington State. Although science teachers in both states were most receptive to the need for safety workshops, state-organized safety training sessions had been conducted in neither state prior to the pilot study. For these reasons, the level of safety knowledge of science teachers was assumed to be similar in Oregon and Washington.

In addition to T-KOLS and S-POLS, related materials were prepared and tested in the pilot studies. The additional materials included:

1. Instructions for completion of T-KOLS

A description of the instrument including a listing of each of the ten sections was contained on one side of a page; the opposite side provided the teacher with the scheme to be used in responding to the T-KOLS items

2. Teacher Background Information Form (T-info)

A teacher questionnaire prepared by this investigator to obtain personal and school demographic information. This information was to be analyzed in conjunction with the knowledge and practice scores to be obtained by administration of the two instruments.

3. Instructions for completing S-POLS

The instructions included an example of responses to a typical S-POLS item together with information to aid in the administration of the student instrument and aid the student in understanding S-POLS task

The pilot studies were not conducted simultaneously because of differences in the stage of development of the two instruments. Since the Round 2 S-POLS draft was amenable to student use, and it was desirable that pilot study data be made available to the Round 3 panel, this instrument was pre-trialed before T-KOLS. Following the editing and re-writing of the items subsequent to the pilot study, S-POLS was again reviewed by science teachers participating in the safety workshop for chemistry teachers held in Tacoma, Washington, (the site of the T-KOLS pilot study). At this time, S-POLS was in the form to be used for field-testing, and a final review and proofreading of individual sets (A-J) was essential. This examination not only provided some assurance that S-POLS would be acceptable to the participating field study teachers, but also ensured that errors, omissions, or lack of clarity would not detract from the quality of the instrument and thereby impair student response.

The T-KOLS pilot study was conducted after preparation of the Round 3 draft by which time the number of items in the instrument had been reduced to 158 for the field testing program. Although the stage of T-KOLS development did not permit the pilot study data to be reviewed by the Delphi panel, this was considered not to be critical in preparation of the field study version of T-KOLS.

The pilot study procedures, organization, and findings relative to S-POLS and T-KOLS are described below in the order in which the pilot studies were conducted.

Pre-trial of S-POLS

S-POLS was administered to 133 students in five classes within two schools in Centralia, Washington. The grade levels and subject areas selected by school personnel were as follows:

Grade 12	Physics	27 students
11	Chemistry	23
10	Biology	30
8	Physical science	27
7	Biology	26
		133 students

Each teacher of the five participating classes was mailed (*a*) a sufficient number of S-POLS sets (A-K) for the class in question, (*b*) instructions for administering S-POLS, and (*c*) a brief teacher questionnaire dealing with factors pertaining to the administration and use of the instrument.

Results obtained from the S-POLS pilot study, together with feedback from the teacher questionnaire were evaluated in relation to the following:

1. The general reaction of teachers to the intent and wording of S-POLS items referring to safety practices in the classroom-laboratory

2. The use of two additional response alternatives (*a*) "Explain" with space for a written response, and (*b*) "Nonapplicable," a mode to be used when the item did not pertain to the science subject matter of the class in question

3. The feasibility of dividing S-POLS into the ten-item student sets used in the pilot study

4. The comprehension and reading level of the instrument in relation to the target audience

5. The time required for the administration of S-POLS over the various grade levels and subject areas

6. The relevancy of the items over all grade levels and related subject areas

7. The applicability of the proposed 2-1-0 scoring scheme

Teacher responses to the questionnaire indicated that an instrument dealing with student perceptions of safety practices in the classroom-laboratory was not objectionable to the teachers. Moreover, the phrasing and intent of the items in reference to teacher practices did not appear to cause discomfort on the part of either teachers or students.

Although it was noted that 7th graders experienced some difficulty in concisely expressing their thoughts when providing a written response, feedback from teachers favored the use of this "fill-in" option in addition to the "nonapplicable" response alternative. The inclusion of items that were not applicable to the class in question appeared to present no real problem although one teacher stated that students felt they were contributing little to the project when they were unable to respond to items of this nature. On the other hand, a second teacher reported that students were more likely to check the "nonapplicable" response alternative in preference to the appropriate response since this required less effort.

It was generally agreed that in those cases where students experienced difficulty with item terminology, the item itself was most often inappropriate, and for this reason, did not apply to the class in question. In only one case was difficulty in terminology reported for an applicable item, and this was in reference to the term "deluge shower." In this instance, a chemistry teacher reported that although the term was not inappropriate, he had neglected to use it in reference to the emergency shower unit in the laboratory; the term was easily explained in response to the student query.

The instructions provided for the administration of S-POLS were considered clear and readable. The amount of time spent in completing the ten-item student sets was judged to be appropriate with the following ranges recorded for each participating class:

	Minimum	Maximum
Grade 12 Physics	7 min	15 min
11 Chemistry	8	-
10 Biology	8	-
8 Physical science	10	20
7 Biology	10	20

Since S-POLS was subject specific (the one hundred items were not applicable to all grade levels and related subject areas), the adequacy of the proposed scoring scheme was a major concern of the pilot study. It was found that when the 2-1-0 scheme was applied in calculating the teacher safety practice score for each class, those teachers who devoted relatively little time to practical or "hands-on" type laboratory experiences, received a definite score advantage over teachers who spent substantial class-time on student activities with science materials and apparatus. This can be seen from Table 3.12 where the physical science class with the lowest percentage response showed a total teacher practice score proportionally greater than the other subject classes where students had responded to a greater number of items.

Since the function of S-POLS was the measurement of student perceptions of laboratory safety, it was necessary to adjust the scoring scheme to fairly assess teacher practices. To reward teachers with a high practice score where student activity was infrequent, was to defeat the purpose of the study. Although the field study sample was to include predominantly laboratory-based classes, the degree of student activity in each class was not a factor that could be easily controlled in the selection of participating class groups.

From analysis of the data, thirty-five S-POLS items appeared to be common over most grade levels and subject areas. The percentage response to these items by each of the five participating classes is shown in Table 3.12.

TABLE 3.12 S-POLS: Pilot Study Response Percentages by Subject

Subject	Grade	Total Response %	Response to Common Items %	Total Score	*Revised Total Score
Physics	12	56	91	111.08	107.41
Chemistry	11	78	91	149.75	142.81
Biology	10	84	94	124.22	121.34
Physical Science	8	45	69	127.49	102.43
Biology	7	67	89	115.08	109.02
Physics Chemistry	12) 11)	82	83	130.42	125.11

*Revised Total score calculated by assigning a zero score to the thirty-five common items.

Moreover, it was found that the variation in student response to the "common items" was proportional to the overall class response. For example, in physical science only 45% of the total items showed a student response, but 66% of these were "common items." By comparison, students responded to 84% of the total items in tenth grade biology, and 94% were identified as "common items."

In order to achieve a more realistic scoring pattern, the thirty-five "common items" were considered applicable to all science subject areas and grade levels. Unlike S-POLS items marked as "nonapplicable" which were scored as missing data, all "common items" were scored as zero where an appropriate response was not provided. The revised scores, based on this scoring scheme are also shown in Table 3.12. These scores were found to be in much better agreement with the specific aims and intent of the study than the entire set of scores and more realistic in terms of the total student response.

The low percentage response to the S-POLS items by the physical science class was explained by the participating teacher in completing the teacher questionnaire. It was indicated that many of the items checked as "not applicable" would have received an appropriate response later in the school year when additional practical activities would have been completed by the students. This factor was taken into account by scheduling the field study as close as practical to the end of the school year. This permitted students to have the maximum number of "hands-on" type activities provided by their science curriculum, and provided the greatest amount of time for teacher-student interaction in the classroom-laboratory prior to the administration of S-POLS.

A second purpose was served by identifying the thirty-five common items. Apart from physical science, students in other classes had responded to more than fifty percent of the S-POLS items. Item analysis revealed that in addition to the thirty-five common items, at least fifteen other items were applicable to each of the classes. In other words, a 50-item student instrument, applicable to any secondary school science class, was built into S-POLS.

These findings were of importance since the advisability of dividing S-POLS into two discrete 50-item instruments, each appropriate for upper or lower secondary level science students had been recommended by members of the Delphi panel and was a topic awaiting resolution in Round 3. The pilot study data, coupled with teacher feedback, confirmed both the adequacy and the versatility of the single instrument. It appeared, therefore, that little advantage would be gained by the preparation of two separate 50-item instruments and many advantages of the single instrument would be lost. For example, the range of safety topics provided by the single instrument better accommodated lower secondary level classes involved in extensive and/or esoteric laboratory experiences and also satisfactorily met the needs of those introductory upper secondary level courses providing basic student laboratory activities. In addition, since a score representing student perceptions of safety practices in all science classes taught by the participating teacher was to be derived, data from two different student instruments would be difficult to interpret. Where a teaching load included both different subject areas and students from more than one secondary level, there were obvious advantages in the use of a single measuring device. These included the simplified preparation and distribution of instruments and related materials, simpler teacher administration of the instruments, facility in the collection and coding of information, and subsequent data analysis. These were all important factors in the decision to maintain S-POLS in its original 100-item form.

Pre-trial of T-KOLS

T-KOLS was pre-trialed in Tacoma, Washington, following mailing of the Round 3 draft to the Delphi panel, but prior to the final preparation of the materials for field testing. Forty-three science teachers from a total of approximately seventy-five attending the first state-wide workshop for chemistry teachers in Washington state were selected to participate in the pilot study.

T-KOLS was administered in two parts. Half of the participating teachers were asked to complete and return Part 1 (Sections I-V) at the start of the two-day workshop. At the termination of the workshop, Part 2 (Sections VI-X) was to be completed and mailed to this investigator in a pre-stamped and self-addressed envelope. This procedure was reversed for the other half of the participants who were asked to complete Part 2 initially and return Part 1 of the instrument by mail.

It was anticipated that the effectiveness of the workshop could be appraised by this method of data collection. Unfortunately, failure of participants to promptly complete and return T-KOLS at the commencement of the workshop, coupled with the small number of mailed returns, did not make such an analysis feasible. Early workshop returns were received from forty-three participants with nineteen teachers returning Part 1 and twenty-four teachers returning Part 2. Only sixteen of these participants, however, returned the second set of T-KOLS sections by mail at the conclusion of the workshop.

Participant response to individual items was carefully evaluated in order that any extremes in the selection of response alternatives could be identified. Although scores were not obtained for each section, total scores and group means were calculated for both parts of the instrument. This procedure permitted an assessment of the adequacy of the 2-1-0 scoring scheme for the three response alternatives.

During two small-group sessions arranged as a part of the workshop, this investigator discussed the instrument with workshop participants. Reaction to the design of T-KOLS was quite positive. The 68% photo-copy reduction of the instrument did not appear to present reading or comprehension difficulties, and the majority of teachers favored both the overall appearance and the brevity of T-KOLS. A favorable reaction to the color coding of the response alternatives was voluntarily expressed by many teachers. Participants further indicated that the instructions for the instrument and its administration were clearly worded and adequate. No problems were encountered in comprehending the intent of the topic statement form of item, although one or two participants experienced some initial uneasiness in responding to a "different" form of objective test item. However, this was quickly dispelled as the teachers worked their way through the items.

The Teacher Background Information form (T-info) was completed by twenty-eight of the teachers. Two respondents failed to provide information relative to personal laboratory accidents, and one neglected to indicate the teaching specialty. Apart from these exceptions, all questionnaires were completed in their entirety. Based on these returns and on teacher feedback during the small group sessions, both the number and scope of items contained in T-info were considered reasonable.

Summary of Instrument Development

Two instruments which formed the basic tools for the study were constructed within a common framework. T-KOLS (Teacher Knowledge of Laboratory Safety) was designed to measure the safety knowledge of teachers, and S-POLS (Student Perceptions of Laboratory Safety) to assess the student perception of teacher safety practices within the classroom-laboratory. The one hundred item instruments were divided into ten sections, each representing a distinct but related aspect of secondary school science safety. The acronym SAFETY TEST (which also formed the test logo) was coined to coordinate the instruments and the section topics. The student inventory was subdivided into ten-item sets for ease of administration within reasonably short time periods.

The Delphi Method was used in the development of both T-KOLS and S-POLS. A panel of approximately fifty individuals was composed of three groups; members of the Council of State Science Supervisors (CS^3), Science Educators and Safety Professionals. The tasks of the Delphi panel dealt primarily with the review, evaluation and selection of instrument items. During the course of the three Delphi rounds, within-group and between-group concensus was sought regarding various aspects of the items and the test format.

Prior to the Delphi exercise, the proposed format and sample T-KOLS and S-POLS items were evaluated by graduate students and in-service teachers attending classes in science education at Oregon State University. Pilot studies were conducted on both instruments in Washington, a state other than Oregon which provided the subjects for field testing.

T-KOLS was pre-trialed in Tacoma, Washington during a safety workshop organized for chemistry teachers. A total of forty-three science teachers from all areas of the state were involved. The pilot study was conducted following mailing of the Round 3 draft, but prior to the final preparation of material for field testing.

One hundred and thirty-three students from five science classes in Centralia, Washington, took part in the S-POLS pilot study. Results obtained from this pre-trial were made available to the Round 3 Delphi panelists and resulted in the identification of thirty-five items common to all grade levels and subject areas. The resulting adjustment in the scoring scheme for this instrument appeared to contribute substantially to the validity of the S-POLS data.

The Field Study

It was essential that S-POLS be administered as near to the end of the school year as feasible in order to maximize student-teacher interaction and the number of laboratory activities provided by the science curriculum. Since two Delphi rounds and the pilot studies had been completed and all feedback was positive, it was decided to conduct field studies in May 1980 prior to return of Delphi Round 3. The tasks for this last round were largely confirmatory in nature and while more time might have been used to perfect the instruments, this was not essential to the collection of valid data. The analysis of the Round 3 feedback and the field study data were examined jointly in preparation of the revised instruments.

Target Population and Method of Sampling

The target population was defined as all Oregon public secondary school science teachers except approximately forty (4% of the state total) employed by Portland district 1J. Exclusion of these teachers was based on past experience in which district 1J preferred not to give administrative permission for Portland teachers or schools to participate in doctoral research. In order to avoid the possibility of jeopardizing the study by a delay in the collection of field study data, the 1J science teachers were excluded from the prepared sampling frame used in the sample draw.

Source of Population Data

The state of Oregon was divided into forty-five demographic-geographic areas for the purpose of organizing safety training workshops to be conducted by the State Department of Education. These proposed training areas provided logical units from which to select teachers to participate in field testing of T-KOLS and S-POLS. The following procedures were followed in defining the training areas:

1. A listing of all science teachers employed during the 1977-78 school year by Oregon public schools except Portland district 1J was obtained from the Oregon Department of Education

2. The number of science teachers and the name and address of each school was transferred onto cards

3. Mapping pins of various colors were used to indicate on an Oregon map the location of each school employing a science teacher and the number of science teachers in that school

With the aid of Mr. Ray Thiess, Science Specialist with the Oregon Department of Education, training areas were then defined on the map according to the following criteria:

1. Proximity of schools to one another

2. Highway or freeway accessibility between schools

3. Formation of compatible groups of schools that traditionally worked together

4. Location of "key" schools within the area that contained facilities appropriate for workshops

5. Total number of science teachers within the area

The specific aim in delineating the training areas was to identify workshop groups of between ten and twenty science teachers. Where several larger schools were located in the same area, group sizes were considerably larger than in the more remote parts of the state. These larger groups were deliberately planned in order that more than one workshop could be offered in the area, thereby providing teachers a selection of time and place. Each designated training area was randomly listed and identified by letter code in preparation for the sampling technique to be used in the present study. The training area scheme outlined on the map of Oregon is shown in Figure 3.3.

The Sample

Although the sample could have been drawn by simple random selection, this procedure lacked many of the attributes of cluster sampling. This study was concerned specifically with safety at the secondary school level, and the forty-five areas identified for workshop training seemed appropriate for population grouping. Since the training areas were identified solely on geographical/demographical considerations, there was no stratification by school or district size. The investigator judged those science teachers employed within a given area to be representative of the target population.

Size of the Sample

Teacher Sample

The adequacy of a ten-percent sample in the present study was confirmed by Dr. Roger Petersen, Statistics Department, Oregon State

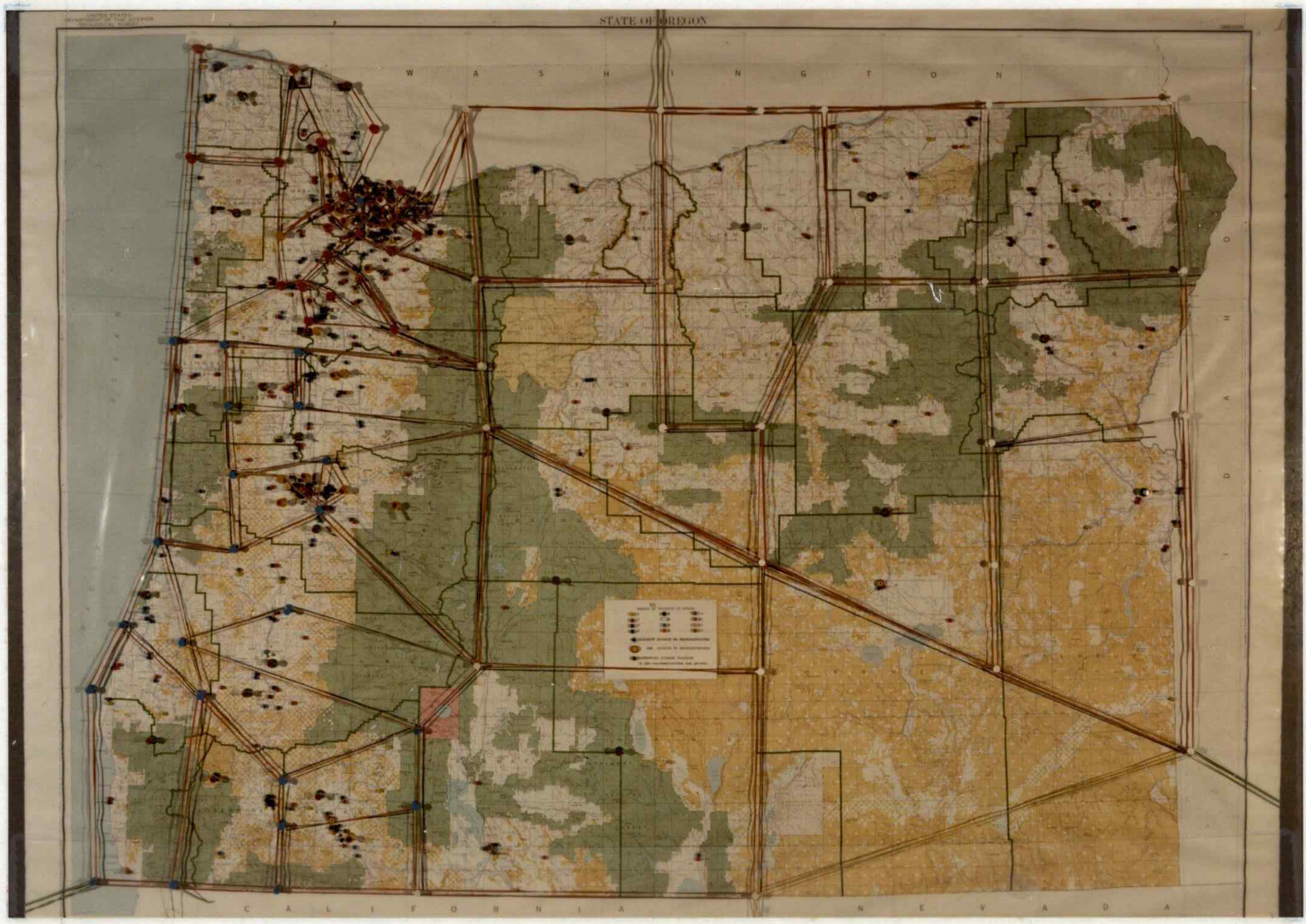


FIGURE 3.3 Map of Oregon showing Training Areas and Schools

University, who indicated that fifty teachers (or approximately five-percent of the population) would be minimal. Employment data obtained from the Oregon Department of Education revealed that excluding Portland district 1J, 907 science teachers were employed in the state public schools during the 1979/80 school year. Thus 45 teachers were required to provide a minimal five percent and 91 teachers for the ten-percent sample for this study.

In order for students to acquire the best perception of the classroom-laboratory safety practices of their teachers, it was essential that S-POLS be administered near the end of the school year. An end-of-the-year field testing provided a maximum period of time for teacher-student interaction in the same classroom-laboratory and allowed completion of most of the "hands-on" laboraory activities scheduled for the year.

For the above reasons, field testing was scheduled for May, 1980. Since this was the busiest month of the school year and a high attrition was anticipated, it was decided to double the sample draw to twenty percent. On this basis a target figure of approximately 200 science teachers was projected. This was considered to be logistically the maximum sample that could be accommodated. A sample of this size also had the advantage of including teachers from a larger number of training areas.

Student Sample

Statistical requirements of the study called for a minimum of one student response per test item for each teacher (1%). For this reason, the student sample was dependent both on the total number of items on the instrument and the number of teachers in the sample. Although the student inventory contained a total of one hundred items, an additional ten items were included for field testing. This instrument was designed to be administered to students in ten-item sets. Doing so required a 1:11 teacher/student ratio to provide the minimum sample for the 110 items.

Ideally, the response to individual inventory items would be approximately the same for every student in the one class. Pilot study data, however, revealed a large variability in item responses. Coupled with this, was the fact that not all items were applicable to each subject area and grade level. To assure an adequate number of student responses to each item, the teacher/student ratio was increased to 1:55.

Selection of the Sample

Teacher Sample

Simple random selection procedures were not useful in the present study since the number of science teachers varied within training areas. For this reason, it was necessary to use the probability proportional to size (PPS) sampling technique, which is a method of selecting units of unequal sizes. Developed by Hansen and Hurwitz (1943), the PPS technique is most conveniently used when the number of units is only moderate, which was the case in the present investigation. This sampling method allows each teacher the same chance of being selected irrespective of the number of teachers within the training area.

A sampling frame (Appendix F) had been prepared on the basis of the 1977/78 training area data. Oregon State Department of Education data revealed that there was only a slight decrease in the number of science teachers employed within the public schools for the 1979/80 year over 1977/78. The teacher/student ratio had remained essentially the same. Six training areas supplying 194 science teachers were randomly selected by the PPS sampling method. Schools within each training area were re-checked against information provided by the Oregon Department of Education in order to confirm that all 1979/80 secondary school science teachers were included in the sample. Although there were some slight variations in the teacher count within the selected areas, in only one case was a new secondary school operating. No schools were lost during the intervening two year period.

Student Sample

The actual selection, or arrangements for selection, of the student sample was made by school administrators. It was felt that maximum cooperation with the study could be anticipated by limiting the demands placed on school personnel.

Guidelines to be followed in selection of the student sample were provided both orally by this investigator, and in written form. Although a sample of fifty-five students for each teacher had been the goal, student numbers were largely dependent on the number of students enrolled in each participating science class. When the number of students was as low as twenty to twenty-five, two classes were combined to obtain the fifty-five student minimum. In small schools with few students, several classes were typically required to provide the 1:55 teacher/student ratio. Where a teacher did not have a total of fifty-five students in all of his or her science classes, students received more than one of the ten-item sets to complete. The problem of small numbers of students per teacher seldom occurred except in the case of part-time staff.

School personnel were advised that the student inventory should be administered to those classes involved in laboratory or practical hands-on instruction. A cross-section of various grade levels and/or science subject areas was recommended where an individual teacher was responsible for a varied class load. In most schools, the classes were identified by the administrator in the presence of this investigator. In some cases, the teachers were free to select the science classes in which the instrument was administered.

Data Collection Procedures

Preparation of Materials

Following the Tacoma pilot study, both instruments and all related materials were prepared and packaged for distribution to the schools. In order to produce a high quality product, Xerox photocopy procedures were used throughout. All copy was reproduced on standard 8½" x 11" American quarto.

The contents of the total packet delivered to the schools for use by participating teachers included:

1. T-KOLS Packet
    - (a) The test of Teacher Knowledge of Laboratory Safety
    - (b) Instructions for completion of T-KOLS including:
        - i) Description of the instrument
        - ii) Scheme to be used in responding to items
    - (c) Teacher Background Information Form (T-info)
2. S-POLS Packet
    - (a) Sufficient copies of the inventory Student Perception of Laboratory Safety (in consecutive sets, A-K) for the participating classes
    - (b) Student Background Information Form (S-Info)
    - (c) Instructions for administering S-POLS
3. Student instruction forms

T-KOLS packet

The format and appearance of the materials prepared for the Tacoma pilot study was considered satisfactory, and no major changes were necessary for the purposes of field testing. In order to reduce reproduction costs and postal charges, T-KOLS had been prepared as a 68% photo-copy reduction. This allowed each part of the instrument to be completely contained on a single 8½" x 11" page. Although this investigator had reservations about using this form of the instrument for the field study, feedback provided by the Tacoma pilot study indicated that the copy was clear and readable. For this reason the format used in the pilot study was retained.

The description of the instrument, and the scheme to be used in responding to test items, were contained on both sides of a single sheet of paper (Instructions for completion of T-KOLS). This was left in the form prepared for the Tacoma group, since it had proved to be acceptable to teachers. Comments had indicated that it was both easy to follow yet concise and to the point. Unlike T-KOLS, the instructions were left in standard typescript, not photocopy reduced.

The Teacher Background Information Form (T-Info) was also left in the form used for the Tacoma pilot study. It was initially typed in such a way that a 68% photocopy reduction produced a standard page of copy. This had presented no problems in the Pilot study.

In lieu of color print which was prohibitive in terms of both time and expense, colored "signal dots" were affixed to all copies of the instrument and accompanying information sheets. These not only clearly identified the three response alternatives but also improved the appearance of the material.

T-KOLS and related materials were packaged in a large manilla envelope with two small labels affixed to the front. One listed the contents of the packet:

TEACHER INSTRUMENT
INSTRUCTION SHEET
BACKGROUND INFORMATION FORM

while the second label read, "This is a survey-type instrument. Please complete without reference to printed materials or discussion with others."

S-POLS packet

The Round 3 draft of the instrument and the student instruction sheet prepared for the Centralia pilot study had initially been prepared on legal size paper. It was subsequently found that this size, while providing good copy, was both expensive to photocopy and difficult to package. For this reason, the complete test was retyped onto standard size American quarto. Readability became a major factor in reducing the paper size, since printed copy that is too closely typed onto the page has the effect of reducing text readability.

It was advised by reading specialists that a 10% photocopy reduction both improved the readability of the items by providing more space and at the same time produced typescript that was not too small for the target group. Unfortunately, this particular photocopy reduction was not available locally, and time did not permit the delay that would have ensued for this work to be carried out elsewhere. For this reason, it was decided to adopt a 5% photocopy reduction. In order to gain additional "space" however, it was necessary to combine the "nonapplicable" with the "fill-in" response mode, and to substitute a single response alternative--

D. Other ______________________________________

____

This still permitted students the option of indicating that the item was "nonapplicable" while maintaining space for a written response.

The instructions for completing S-POLS drawn up for the Centralia pilot study were revised. Two separate instruction sheets were prepared. The first was directed to the administrator(s) of S-POLS, while the second provided information for the students. The instructions for administering S-POLS were typed in such a manner that a 68% photocopy reduction was attached with rubber-base cement to the face of a 9" x 12" manilla envelope. Space was provided on this instruction sheet for information (S-info) including the class subject area, grade level, number and sex of students.

A sufficient number of student instruction sheets were provided in standard typescript for approximately thirty students, and test administrators were advised that these should be re-used for each class taught by the participating teacher. Where classes were exceptionally large, or upon the request of school administrators or other personnel, additional sheets were included.

The required number of S-POLS student sets were placed in the appropriate envelope in consecutive A to K order in preparation for distribution.

Response Sheets

Although printed response sheets that could be conveniently computer scored would have been the most practical course to follow, these were not used for the following reasons:

T-KOLS. It was judged that a checkmark placed in the appropriate response column of the instrument would be both more efficient in terms of "teacher-time" and possibly more accurate than use of a separate answer sheet. Since T-KOLS was prepared as a photocopy reduction, the repeated transition from the test item to the answer score-sheet might be a more difficult task for the test-taker than would marking responses on the instrument itself. Since teacher cooperation was an important factor in completion and return of the instruments, it was decided that the additional time needed for scoring the test was warranted both for this reason, and for the added assurance of response accuracy.

S-POLS. Since a large number of students were to be involved in the study, the use of printed response sheets suitable for computer scoring was particularly attractive. In addition, the use of answer sheets would have permitted the S-POLS sheets to be reused over several classes which would have greatly reduced printing costs. After much deliberation, the decision was made to not use separate answer sheets for the following reasons:

1. It was a quicker and more accurate process for students to circle the correct response on the S-POLS item sheet than to use a separate answer sheet

2. Additional time would be needed to distribute, collect and package separate answer sheets

3. S-POLS item sheets would have to be collected and redistributed to other classes following each administration

4. There was a greater chance for loss of answer sheets than would be the case in distribution and immediate collection and packaging of the S-POLS item sheets

5. The use of computer scoring was precluded in the case of the "fill-in" response although this could have been accommodated on the answer sheets

Teacher packet

An envelope containing S-POLS student sets and another envelope containing T-KOLS and related materials were both packaged in a larger envelope together with the student instruction forms. A card attached to the outside of the teacher packet read in part:

> To the Science Teacher:
>
> All information necessary for the completion of T-KOLS and the administration of S-POLS is contained in this Package.
>
> PLEASE RETURN ALL INSTRUMENTS TO ENVELOPE when completed.
>
> Arrangements will be made to collect these before the end of the present month.

Three names, together with the respective telephone numbers, were provided on the outer envelope. These were to be used as necessary to obtain additional information in relation to the field study materials or the research project itself.

All packet envelopes carried a three-segment identification code. An upper-case letter identifying the training area was followed by a "school" number and a lower-case "teacher" letter, e.g., AA 12 (a). Although no attempt was made to identify the teacher, the code designation permitted a check on the number of packets delivered and returned from each school within each training area. The "teacher" letter also provided a means of packet identification for school personnel and, by avoiding the use of real names, protected the anonymity of the teachers.

All of the data collecting instruments for a given teacher and his or her students carried the same identification code. This was essential for matching teacher and student instruments when these were returned in other than the original envelopes. It was also useful in scoring the testing instruments and in coding the demographic responses.

Distribution and Collection of Materials

Delivery to the Schools

In order to obtain maximum cooperation from school personnel, this investigator personally delivered the teacher packets to all schools within the selected training areas. As far as possible, packets were delivered in the order of the training area sample "draw." Since the projected sample was considerably larger than that actually needed to meet the statistical requirements of the study, this procedure allowed the areas selected last to be dropped from the sample if time did not permit delivery and/or collection of all packets. However, no schools or teachers were dropped from the sample.

A letter from Ray Thiess of the Oregon Department of Education, introducing this researcher and seeking cooperation for the project, was mailed to school administrators immediately prior to delivery of the testing materials. In a majority of the schools it was possible for this investigator to speak directly with the principal. This permitted details of the study to be explained. The instruments and related materials were discussed and, in many cases, the participating classes were selected at that time.

Fifty-five student instruments were contained in the teacher packet and additional sets added as necessary following discussion with school personnel. In some schools the vice-principal and/or science chairman were asked by the school principal to discuss the project with this investigator and to handle the details of packet distribution. Typically a tentative date was arranged for administration of the instruments and a date scheduled for collection of the completed packets.

In a majority of the cases administrative personnel were gracious in their reception of this researcher, appeared interested in the project, and verbally expressed their willingness to cooperate. There were, unfortunately, a few schools where the atmosphere was less than cordial. Although in these instances the packets were accepted by school personnel, they were, in many cases, "lost," "unopened" or at best incomplete, at the time of collection.

Collection of the Materials

In most instances the method and route used in the delivery of safety materials was retraced in the collection of packets. In some schools, where an approximate date had been scheduled for retrieval of materials, it was agreed that no further communication would be necessary prior to collection. In others, a postal card was mailed to the principal confirming the date for collection of the instruments or a telephone call was made to the school to arrange an appropriate collection date.

In a majority of schools, the completed packets were obtained from teachers by administrative personnel and placed in the school office for collection. Where packets were not available on the scheduled collection date, they were generally returned immediately by mail.

Preliminary frequency tabulations

Following collection and return of packets from the schools responses to both instruments and the related demographic information were coded and subsequently transferred to computer punch cards. Preliminary frequency tabulations were then obtained using an SPSS standard computer package. These are provided in *Appendices Tables 5 and 6* for each of T-KOLS and S-POLS respectively.

The Research Instruments

One hundred and fifty-six T-KOLS items were submitted to the field study teachers and eleven ten-item sets of S-POLS items were administered to students taught by the participating teachers. During the time of the field study, Delphi panelists were asked to critically review all topic statements included in the field study instruments and to discard any items considered either inappropriate or ambiguous. In addition, Round 3 sought panel concensus as to the "best answer" responses to those items for which agreement was not reached in Rounds 1 and 2.

Preliminary frequency tabulations of the field study responses to T-KOLS and S-POLS items were "eye-balled" to spot what appeared to be faulty items. A major goal of these selection processes was to select ten ten-item sets to comprise the Research versions of both T-KOLS and S-POLS. The procedure followed in the final selection of items is described for each instrument in turn.

Teacher Knowledge of Laboratory Safety (T-KOLS)

Final selection of the one hundred items comprising the Research version of T-KOLS was made by--

1. eliminating items that Delphi panelists identified as inappropriate or ambiguous;
2. "weeding-out" those items for which "best answer" concensus was not reached in Round 3;
3. maintaining a reasonable ratio in each section and throughout the instrument of each of the three color-coded response categories;
4. "eye-balling" the preliminary frequency tabulations to spot faulty items and to ensure a reasonable balance in the three response alternatives to the items to be selected.

The Round 3 "best answer" selections made by the three panel groups are given in Table 3.13 for Sections I and II. Selections

TABLE 3.13 T-KOLS: Round 3 Color-coded Item Response Frequencies

Section and Statement number	CS_3 n=16				Science Educators n=4				Safety Specialists n=4				TOTAL n=24			
	G	Y	R	X	G	Y	R	X	G	Y	R	X	G	Y	R	X
Sect.I																
* 1	16				4				4				24			
* 3		2	14				4			1	3			3	21	
* 4	15			1	4				4				23			1
8			15	1			3	1			4				22	2
* 9		1	15				4				4			1	23	
* 10			16				4				4				24	
15	12	1		3	4				4					1	20	3
20		1	14	1		1	2	1			4			2	20	2
21	9	5		2	1	2		1	3	1			13	8		3
24	6	10			1	3			2	2			9	15		
* 26			16				4				4				24	
* 28		16				4			1	3			1	23		
* 34	16				4				4				24			
* 36	16				4				4				24			
* 38	13			3	2			2	3			1	18			6
50		1	14	1			3	1			4			1	21	2
51	12			4	3			1	4				19			5

Section and Statement number	CS_3 n=16				Science Educators n=4				Safety Specialists n=4				TOTAL n=24			
	G	Y	R	X	G	Y	R	X	G	Y	R	X	G	Y	R	X
Sect.II																
* 1			13				4				1	2			18	2
2		1	7	6			3	1		1	2	1		2	12	8
* 5			14				4				3				21	
7			15				4				2	1			21	1
* 9	9	2		1	1	3			2	1			12	6		1
16			14	1			4				2	1			20	2
* 17			14				4				3				21	
21		2	12				3	1		1	1	1		3	16	2
30	3	11				1	3			2	1		3	14	4	
* 32			14				3	1			2	1			19	2
* 33			14				4				4				22	
37			13	2			3	1			3				19	3
* 42			14			1	2	1			3			1	19	1
* 43	14				4				3				21			
* 46			14	1			4				2	1			20	2
* 49	12	2			3			1	3				18	2		1

Selection scheme:

GREEN	-	(G)	permissible and recommended
YELLOW	-	(Y)	permissible with qualifications
RED	-	(R)	not permissible under any circumstances
X	-		suggested discard
*	-		item included in research instrument

are categorized as *green, yellow* or *red* according to the safety/ hazard potential of the "best answer" responses for the Round 3 items. Although one hundred percent concensus was not reached on all items, the majority vote is clearly indicated. This information is provided for Sections III to X in *Appendix Table 7*. Some items were marked for discard by panelists because a similar item appeared in another section. For instance, two sections contained items dealing with the storage of glass tubing, and respondents were asked to indicate which should be discarded/retained. Suggested discards and items selected for the research instrument are also identified in Table 3.13; comments and recommendations made by panelists were reviewed in conjunction with this selection/discard process.

A tally of the color coding for the "best answer" response alternatives for both the Round 3 draft and the research instrument is given in Table 3.14. A total of seven items were discarded because concensus on the "best answer" was not obtained. Examination of Table 3.14 will show that twenty-eight of the forty Round 3 items with a "green" color code were selected. This was the maximum that could be retained in the research instrument if an equitable ratio (in terms of the three colors of the "best answer" alternatives) was to be maintained over individual sections. A majority of the "yellow" alternatives were considered appropriate for inclusion.

Where more than ten items remained in a section following (*a*) the discard of items, (*b*) selection on the basis of the color ratio, and (*c*) Delphi panel concensus, the excess items were eliminated by random selection. Following the selection of items as described, the preliminary frequency response tabulations were used to confirm that the majority of teachers had attempted each selected item, and that at least two of the three response modes had been selected by some of the respondents.

TABLE 3.14 T-KOLS: Color-coded Section Distribution of Items for Round 3 Draft and Research Instrument

Section	Round 3 Draft			Research Instrument		
	Green	Yellow	Red	Green	Yellow	Red
I	6	1	8	5	1	4
II	3	1	12	3	-	7
III	9	2	5	5	2	3
IV	9	2	5	5	2	3
V	-	3	11	-	3	7
VI	6	-	10	3	-	7
VII	2	-	11	2	-	8
VIII	1	3	11	1	3	6
IX	-	4	10	-	4	6
X	4	2	10	4	2	4
TOTALS	40	18	93	28	17	55

Color-coded distribution of items:

	Round 3 Draft	Research Instrument
Green	40	28
Yellow	18	17
Red	93	55
Green/Yellow/Red ("best answer" still uncertain)	7	___
Totals	158	100

Student Perceptions of Laboratory Safety (S-POLS)

The major purpose of Delphi Round 3 was to obtain Panel (*a*) concensus in the identification of items common to all grades (7-12) and all science subject areas, and (*b*) approval of the items and responses contained in S-POLS Sets A-J.

Fifty items that appeared both from specific examination and from pilot study data to be common to most science grade levels and subject areas were identified as such on the Round 3 S-POLS draft. These included the thirty-five common items identified on the basis of the scoring scheme used for the Centralia pilot study.

Although teachers participating in the pilot study concurred in the retention of the item response alternative "Does not Apply," it had been suggested that, in some cases, this option had the effect of encouraging students to preferentially check this response mode in lieu of a more appropriate alternative. In order to ensure student response to the largest percentage of items, those designated as common items would require a response from all students irrespective of class subject area or grade level. That is, they could not be checked by students as nonapplicable, and would be scored as zero when this occurred.

The final selection of the one hundred items comprising the research version of S-POLS was made by--

1. reviewing feedback provided by Delphi panelists regarding (a) the fifty items identified as common in the Round 3 draft, and (b) confirmation of the items and response alternatives included in Sets A-J;
2. "eye-balling" the preliminary frequency tabulations in order to ensure uniformity of response to the three item response alternatives;
3. examining the preliminary frequency tabulations to confirm that student response to the selected common items showed low "nonapplicable" response frequencies.

Confirmation of the S-POLS items was achieved as a result of Round 3 panel concensus. The preliminary frequency tabulations of the one hundred items included in Sets A-J and the ten alternative items in the K Set were examined in order to confirm that (*a*) an adequate number of respondents had attempted each item, and (*b*) there was some uniformity in the response alternatives selected for each individual item. Since there did not appear to be any items in Sets A-J that were inadequate with respect to these criteria there was no need to use items in the K Set.

The fifty items identified in Round 3 as having properties common to all classes and grade levels were also examined with respect to the preliminary frequency tabulations. Ideally, the most common items would show the lowest "nonapplicable" response pattern. The ordered frequency response for the one hundred items contained in S-POLS is shown in Table 3.15. The thirty-five common items identified from the Centralia pilot study and the fifty suggested common items submitted for Delphi panel review are indicated accordingly. Of the one hundred items, the fifteen showing the lowest nonapplicable response frequencies were all common items. Of the thirty items marked nonapplicable by the fewest students, 87% were common.

Although not all the thirty-five items identified by the Centralia pilot study showed the lowest "nonapplicable" response frequencies, they were retained for the following reasons:

1. Recommendations and concensus of the Round 3 panelists

2. Each ten-item set contained at least two, but no more than five of the thirty-five common items

3. Items that showed lower "nonapplicable" response frequencies were (a) not the most appropriate in terms of "balancing" the ratio of common items in each set, or (b) pertained to specific subject areas.

TABLE 3.15 S-POLS: Ordered Percentage of Field Study Students Marking Instrument Items as Nonapplicable

70.2

66.1
66.0
65.9
65.3
*65.1
61.2
61.2

59.7
59.6
*57.8
56.4
*53.9 (H.8)
53.9
52.9
52.5
*51.2 (D.9)
51.1

48.8
48.4
*47.3 (E.6)
47.1
46.5
44.5
44.5
44.3
44.2
42.5
41.5
*41.3

39.6
39.2
38.2
*38.1
*37.8 (D.6)
*37.6
*37.2
36.6
35.6
*34.0
*32.2
*31.2
30.9
30.8

29.6
*29.3
27.9
27.6
27.5
27.3
27.0
26.4
*26.1 (G.3)
26.0
25.7
*25.4 (B.3)
25.3
24.5
24.0
*23.6 (E.8)
23.1
22.9
*22.6 (B.10)
21.7
*21.5 (J.10)

*19.3
19.0
*18.7
18.6
*18.3
*17.7 (H.6)
*17.6
*17.2 (F.1)
*16.1 (J.9)
*14.9 (A.10)
*14.5 (B.1)
*13.9 (J.4)
*12.0 (E.2)
*11.8 (I.2)
*11.5 (C.1)
*11.4
*11.3 (A.7)
*10.1 (C.6)
*10.0
10.0

*8.8 (G.6)
*8.7 (F.6)
8.7 (E.7)
*8.2 (B.5)
*7.9 (C.2)
*7.2 (H.5)
*6.8 (I.6)
*6.4 (J.6)
*6.3 (E.4)
*4.9 (H.1)
*4.3 (A.5)
*4.1 (D.1)
*2.9 (H.7)
*2.4 (I.9)
*1.8 (A.6)

Legend: * Suggested common item submitted to Delphi Panel

( ) Common item identified by Centralia Pilot study

Topic of common items with frequency greater than 20%

H.8	Dangers of viewing an eclipse
D.9	Organization of field trip
E.6	Permission slip for field trip
D.6	Preparation of accident report
G.3	Student use of first aid kit
B.3	Treatment for cut finger
E.8	Procedure for removal of electrical plugs/extension cords
B.10	Grouping chemical bottles
J.10	Discussion of fire triangle

Topic of items with frequency less than 20% not identified by the Centralia Pilot study as common items:

E.10	(19.3%)	Wearing of loose flowing clothing
F.4	(19.0%)	Instructions regarding use of eye-wash eqpt.
H.3	(18.7%)	Covering open cut/would prior to class
A.4	(18.6%)	Wearing lab aprons (or coats)
F.10	(18.3%)	Correct handling of hot objects
G.1	(17.6%)	Chemicals placed ready for use
G.7	(11.4%)	Checking student apparatus set-up
J.1	(10.0%)	Equipment stored in high places
B.6	(10.0%)	Student record on learned procedure

Analysis of the Data

The SPSS Library of computer programs available at Oregon State University was used to obtain the majority of statistics used in analysis of the data.

Following examination of the preliminary frequency tabulations described above (p. 101), the S-POLS response frequencies were adjusted to exclude the nonapplicable mode prior to item and comparative analysis. This was necessary since the S-POLS items were subject specific and, therefore, not all items were relative to the specific classes and grade levels analyzed. The T-KOLS and S-POLS response/ no response frequencies were then re-tabulated and graphically examined on the basis of the three item response alternatives (best answer, less preferred and nonacceptable). Item and comparative analysis was conducted on both sets of responses.

Subsequent to analysis of the frequency tabulations, the instrument responses were computer scored using programs written specifically for the purpose. Section and total T-KOLS and S-POLS scores were obtained according to the scoring scheme described earlier (p. 73). The process of aggregating items of the same number across Sets for each class group and then combining these to obtain the teacher practice score, required a somewhat more detailed computer program for S-POLS than that needed for the more conventional T-KOLS scheme. Score frequencies including cross-tabulations were obtained and examined prior to data analysis of the knowledge and practice scores.

Reliability coefficients were computed for the scored instruments and the internal consistency of the T-KOLS and S-POLS items assessed by section and total. Various statistics were used to analyze the data prior to testing the study hypotheses. The mean and standard deviation of the knowledge and practice scores were comparatively examined for cases where a T-KOLS score was "matched" by an S-POLS score for the same teacher, and for "all" knowledge and practice scores obtained from the data. An analysis of variance was then applied to the "all" knowledge and practice scores and the results analyzed by training area.

Mean and standard deviation values were obtained for the S-POLS class scores which were independently analyzed. Correlation coefficients were used to assess the possible effect of student sex and the differences in scores where classes were taught by the same teacher. F- and t-statistics were applied in analysis of class scores by subject area.

The first study hypotheses dealing with the relationship between knowledge and practice was tested by means of the Pearson-r correlation coefficient. The t-statistic was also used to further assess the obtained knowledge and practice section and total mean values. An analysis of variance was applied to the T-KOLS and S-POLS scores in testing the remaining study hypothesis which dealt with various personal and demographic factors.

Internal consistency of T-KOLS and S-POLS

Split half procedures were used to obtain reliability estimates for both instruments.

T-KOLS

Since the scoring of T-KOLS was carried out using conventional computer methods, a program from the SPSS Library was used to calculate various measures of test reliability. Table 3.16 shows the results of the split half procedures using Spearman-Brown, Guttman and Alpha methods. Both first half/second half and even/odd splits were used in these calculations.

Both the Spearman-Brown and Guttman methods produced very similar results. The reliability of the total or full test was calculated at 0.65 by the Spearman-Brown formula based on the average of both splits. However, the single even/odd split showed a test reliability of 0.70 calculated by both Guttman and Spearman-Brown

TABLE 3.16 T-KOLS: Reliability coefficients

Method	Procedure			
	First-half/ Second-half Split	Even/odd Split	Mean of Split Half coefficients	Full Test
Spearman-Brown	.59	.70	.65	
Guttman	.58	.70	.64	
Alpha				.64

methods. The full test Alpha coefficient was 0.64.

S-POLS

It was not possible to obtain the final reliability coefficients for S-POLS by use of a packaged statistical program since the method of scoring prohibited this. However, the test was computer-scored and correlation coefficients were obtained using both the even/odd and first-half/second-half procedures.

Since Item 1 of each Set A-J on S-POLS represented Section I on T-KOLS, Item 2 of each set represented Section II, and so on, the split half procedure was applied to sets and not to individual items. For example the total score for Item 1 of Sets A, B, C, D and E was correlated with the total score for Item 1 of Sets F, G, H, I and J for the first-half/second-half test. For the odd/even test, the Item 1 total for Sets A, C, E, G and I was correlated with the Item 1 total for Sets B, C, F, H and J. The Spearman-Brown formula was then applied to the correlations obtained in this manner to provide a measure of reliability:

$$\text{Reliability on full test} = \frac{2 \times \text{reliability on } \tfrac{1}{2} \text{ test}}{1 + \text{reliability on } \tfrac{1}{2} \text{ test}}$$

The reliability coefficients are provided in Table 3.17 for both splits. The total or full S-POLS reliability coefficient was 0.77 for both splits compared to 0.64 and 0.65 for T-KOLS. Thus, it appears that the reliability of both instruments is sufficiently high to produce useful evaluative data.

TABLE 3.17 S-POLS: Reliability Coefficients

SET	Section (Item) Number										
	I(1)	II(2)	III(3)	IV(4)	V(5)	VI(6)	VII(7)	VIII(8)	IX(9)	X(10)	I - X
A,B,C,D,E vs F,G,H,I,J	.55	.26	.41	.55	.17	.50	.54	.10	.28	.60	.77
A,C,E,G,I vs B,D,F,H,J	.69	.15	.28	.57	.12	.45	.52	.21	.01	.59	.77
Average of Split Half coefficients	.62	.20	.34	.56	.14	.48	.53	.13	.14	.60	.77

Summary

The major purpose of this study was to determine the relationship, if any, between the safety knowledge of science teachers and the classroom-laboratory practices of these same teachers as perceived by their students. In order to study this relationship, two instruments were constructed:

1. One to measure the safety knowledge of secondary school science teachers (T-KOLS)

2. A second (S-POLS) to assess student perception of the classroom laboratory safety practices exhibited by these teachers

A sample of 145 Oregon secondary school science teachers and approximately 8000 of their students participated in the study. This group represented six regional training areas selected from a total of forty-five that had been set up within the state for workshop training sessions in laboratory safety for science teachers.

The student sample was selected by school personnel in the approximate teacher-student ratio of 1:55. Instructions specified that complete science classes participate in the study; that the selected classes should involve students having frequent laboratory or "hands-on" activities.

A Delphi exercise was used in the preparation of both instruments. All materials used in field testing were professionally edited prior to distribution of the instruments to the participating schools. Following data collection, preliminary frequency tabulations were used in conjunction with the Round 3 Delphi panel returns to define the 100-item research instruments. All participant responses to the instrument items and the related demographic information was coded and transferred onto computer punch cards for subsequent scoring and statistical analysis. Specific and standard programs were used to obtain frequency tabulations, scattergrams, analysis of variance tables, correlation coefficients and other test statistics.

Revised versions of T-KOLS and S-POLS

The final phase of this study dealt with the preparation of the revised instruments. Following field use, both T-KOLS and S-POLS were critically examined by this investigator in order that any revisions suggested by the field study data could be incorporated into the revised instruments.

T-KOLS

The frequency tabulations for the 156 items comprising the data collecting instrument (Round 3 draft) and the 100 items contained in the research T-KOLS were re-examined in order to confirm the inclusion of the latter set of items in the revised T-KOLS. Table 3.18 gives the mean, standard deviation and range of the response frequency values calculated for all section items included in the data-collecting instrument (n=13 to n=18) and the ten section items comprising the research T-KOLS.

Examination of the two sets of data showed relatively little variation in the frequency of response to the three item alternatives. Moreover, the number of teachers failing to respond to items was comparable in both cases. No major revisions appeared necessary, and the revised instrument was prepared using the same items included in the research form of T-KOLS. The items were re-numbered from one to one hundred and minor revisions and/or corrections made as necessary.

S-POLS

During the transfer of data onto computer cards, a record was made of all information provided by students in completing the written response. This "fill-in" mode was designed to describe the teacher practice where none of the other alternatives was adequate. Each of the three response alternatives for the 100 S-POLS items was critically re-evaluated on the basis of the student written response(s). Where necessary, revision was made by *(a)* construct-

TABLE 3.18 T-KOLS: Frequency (as %) Response Statistics for Round 3 Draft and Research Instrument

Section		Selection Categories							
		Preferred		Less Preferred		Not acceptable		No Response	
		ALL*	TEN	ALL*	TEN	ALL*	TEN	ALL*	TEN
I	HI	68.9	62.2	55.6	71.1	26.7	18.5	15.6	14.8
	$\bar{X}$	45.97	45.93	33.91[a]	35.86	9.90	7.24	11.02[b]	10.96[b]
	s	17.09	13.85	13.91	13.22	7.53	5.86	2.50	2.54
	LO	15.6	15.6	13.3	23.7	3.7	0.7	7.4	7.4
II	HI	78.5	55.6	57.8	46.7	37.8	37.8	22.2	22.2
	$\bar{X}$	43.99	37.64	30.74	33.55	13.80	15.93	11.98	12.90
	s	18.45	10.34	14.54	9.70	10.36	12.01	4.11	4.12
	LO	21.5	27.4	7.4	21.5	2.2	3.7	8.1	8.1
III	HI	75.6	75.6	34.1	34.1	50.4	50.4	18.5	18.5
	$\bar{X}$	50.74	43.33	20.84	22.97	14.04[a]	19.71[a]	14.43	14.04
	s	17.61	17.75	7.18	7.10	15.06	16.61	2.59	2.54
	LO	25.2	25.2	10.4	11.9	1.5	1.5	9.6	9.6
IV	HI	71.1	71.1	67.4	67.4	40.0	40.0	35.6	35.6
	$\bar{X}$	41.19	29.94[b]	29.32	36.51[a]	10.89	14.22	18.65	19.42
	s	20.59	16.57	16.47	17.91	12.52	14.44	5.73	6.92
	LO	14.8	14.8	13.3	15.6	0.7	0.7	12.6	12.6
V	HI	75.6	75.6	34.8	34.8	48.1	48.1	34.1	34.1
	$\bar{X}$	44.29	42.89	19.85	19.34	9.73	11.46	26.19[a]	26.37[a]
	s	17.22	18.08	11.46	11.92	12.52	14.19	3.75	2.45
	LO	23.0	23.0	3.7	3.7	0.7	0.7	20.7	21.5
VI	HI	81.5	74.8	77.8	35.6	6.7	6.7	15.6	15.6
	$\bar{X}$	61.36[a]	57.98[a]	21.54	24.76	2.87[b]	3.03[b]	14.24	14.21
	s	19.75	13.89	19.28	12.08	2.14	2.30	0.91	0.86
	LO	6.7	31.1	1.5	11.1	0.7	0.7	13.3	13.3
VII	HI	70.4	69.6	33.3	33.3	9.6	9.6	31.1	31.1
	$\bar{X}$	55.72	55.77	17.72[b]	18.15[b]	3.64	3.99	22.90	22.07
	s	12.22	12.70	7.98	8.01	3.24	4.44	4.19	3.83
	LO	26.7	26.7	5.9	6.7	0.7	0.7	18.5	18.5
VIII	HI	75.6	74.1	41.5	41.5	37.8	37.8	25.9	25.9
	$\bar{X}$	57.73	52.01	18.23	21.79	6.21	8.07	17.83	17.92
	s	13.61	12.89	10.60	11.15	9.28	11.02	3.14	3.52
	LO	31.1	31.1	3.7	6.7	0.7	2.2	13.3	13.3
IX	HI	56.3	54.1	65.9	50.4	40.7	40.7	23.7	22.2
	$\bar{X}$	37.24[b]	39.63	28.05	24.60	13.88	15.34	20.83	20.43
	s	16.05	12.97	16.06	13.43	13.09	13.55	1.25	1.05
	LO	10.4	23.7	8.9	8.9	2.2	3.0	18.5	18.5
X	HI	68.9	45.9	75.6	75.6	23.7	23.7	28.9	28.9
	$\bar{X}$	38.60	32.73	28.94	33.12	8.34	10.57	24.07	23.55
	s	18.44	14.04	18.28	16.40	6.74	7.25	3.08	3.16
	LO	3.7	3.7	5.2	14.8	0.7	0.7	19.3	20.0
I-X	HI	81.5	75.6	77.8	75.6	50.4	50.4	35.6	35.6
	LO	3.7	3.7	1.5	3.7	0.7	0.7	7.4	7.4
Average of highest and lowest $\bar{X}$s		47.68	43.79	24.91	27.07	9.33	10.96	18.21	18.19

[a] highest mean [b] lowest mean

* number (n) varies from n=13 to n=18 according to section

ing an alternative response to replace or to augment the original statement, or (*b*) broadening the scope of the original response alternative.

The revised version of S-POLS was completely objective and did not include space for a "fill-in" student response. This "fill-in" feature had been incorporated into the field study form of the instrument to (*a*) provide students an alternative means of response, and (*b*) ensure that all possible situations were accounted for in the item response modes provided.

Instrument Review

Both instruments were professionally re-edited following revision. They were then reviewed by a committee of science department chairmen of secondary high schools in Brisbane, Australia. The appraisal of these teachers who had not previously seen or been involved in the project was to ensure that no inaccuracies or gross errors had crept into the *Safety Test* materials as a result of the revisions, editing and final re-typing. The revised forms of *T-KOLS* and *S-POLS* and related materials are included as *Appendices A and B*.

Comparative Examination

As a final assessment in the relevancy of the T-KOLS items included in the revised version, the degree of Delphi panel concensus (from Table 3.13 and *Appendix Table 7*) was compared with the response frequencies obtained for Oregon teachers. This information is provided in *Appendix Table 8*. Although not necessarily related to the analysis of data and the hypotheses of the immediate study, it does appear that these findings have considerable value in assessing the safety status of Oregon secondary school science teachers.

CHAPTER IV

ANALYSIS OF FIELD STUDY DATA

Data reported and analyzed in this chapter were the products of the spring 1980 field study administrations of two instruments; Teacher Knowledge of Laboratory Safety (T-KOLS) and Student Perceptions of Laboratory Safety (S-POLS). A total of 145 teachers from 55 schools in six regional training areas in the state of Oregon responded to the T-KOLS items. Eight thousand and three students in 372 classes taught by these teachers responded to one or more sets of ten S-POLS items representing each of ten safety areas identified for this study. A minimum of 642 students responded to each S-POLS item.

Sampling Returns and Distribution

Instrument Returns

Safety knowledge (T-KOLS) and practice (S-POLS) returns by training area are shown in Table 4.1. A 75% teacher response rate was obtained with 145 of 194 science teachers participating. They were from fifty-five schools grouped into six training areas. Teachers from four schools did not respond. Eighty-nine teachers submitted "matched" instruments (complete T-KOLS accompanied by complete S-POLS). Data for each teacher from both instruments were required for correlation purposes. Fifty-six incomplete or single instruments were returned. These were used for independent analysis of knowledge and practice scores.

Demographic Returns

T-info: The number of Teacher Demographic (T-info) returns are shown by training area in Tables 4.2 and 4.3. Two respondents teach-

TABLE 4.1 T-KOLS and S-POLS: Sampling Returns by Training Area

					Type of Instrument Returns							
					Complete		Partial					
Training Area	Total Schools	Participating Schools	Total Teachers	Responding Teachers	Teachers returning both T-KOLS and S-POLS	Percent respondents completing both T-KOLS and S-POLS	Complete S-POLS + Incomplete T-KOLS	Partial T-KOLS only	Complete S-POLS only	Complete T-KOLS only	Total	Percent of Responding Teachers submitting Partial returns
	n	n	n	n	n	%	n	n	n	n	n	%
1	7	7	22	19	8	42	10	1			11	58
2	12	12	36	25	18*	72	5	1*	1		7	28
3	11	9	51	41	29	71	9	1	2		12	29
4	16	15	36	27	14*	52	7	2	3	1*	13	48
5	6	5	24	16	11	69	3		1	1	5	31
6	7	7	25	17	9	53	6		2		8	47
Tot	59	55	194	145	89		40	5	9	2	56	
				Average:		61					Average:	39

* Instrument coding error - teacher omitted

TABLE 4.2 T-KOLS: Demographic Returns by Training Area

Training Area	T-KOLS + S-POLS + T-info		T-KOLS + S-POLS without T-info		T-KOLS (Total)	S-POLS without T-info without T-KOLS	TOTAL Sample
	(9-12) n	(7-9) n	(9-12) n	(7-9) n	n	n	n
1	11	7	1		19		19
2	16	7	1		24	1	25
3	34	5			39	2	41
4	13	11			24	3	27
5	10	5			15	1	16
6	8	7			15	2	17
Total	92	42	2		136	9	145

TABLE 4.3 S-POLS: Demographic Returns by Training Area

Training Area	S-POLS + T-KOLS + T-info		S-POLS + T-KOLS without T-info		S-POLS (Total)	T-KOLS + T-info without S-POLS	TOTAL Sample
	(9-12) n	(7-9) n	(9-12) n	(7-9) n	n	n	n
1	10	7	1		18	1	19
2	15	7	2		24	1	25
3	33	5	2		40	1	41
4	11	10	2	1	24	3	27
5	9	5		1	15	1	16
6	8	7	2		17		17
Total	86	41	9	2	138	7	145

ing biology and general science respectively at the 9-12 level submitted both instruments but failed to return the T-info. Nine teachers (two 7-9 level) submitted S-POLS but returned neither T-KOLS nor T-info. Four of this group taught combined science classes. Three were biology teachers and the remaining two taught general science and chemistry respectively.

In order to assess possible grade-level bias of the returns, the 7-9 to 9-12 instructional level ratio was calculated for those teachers returning T-info with either T-KOLS or S-POLS or both instruments. The instructional level of teachers who failed to return T-info was obtained from the S-info. The following summary of instructional level ratios of the returns is based on data contained in Tables 4.2 and 4.3.

	Instructional Level	n	(7-9)/(9-12) ratio
Teachers who returned both T-info and T-KOLS	9 - 12	92	
	7 - 9	42	1 : 2.19
Total Sample	9 - 12 (92+2)	94	
	7 - 9	42	1 : 2.24
Teachers who returned both T-info and S-POLS	9 - 12	86	
	7 - 9	41	1 : 2.10
Total Sample	9 - 12 (86+9)	95	
	7 - 9 (41+2)	43	1 : 2.21

The (7-9)/(9-12) instructional level instrument return ratios for teachers who returned either T-KOLS or S-POLS and T-info are reasonably close to the instructional level ratios of the entire sample. Thus, the investigator considers statistical analyses based on the T-info data to be representative of the entire sample.

S-info: Class information (S-info) consisting of name of science subject, grade level of students and number of male and female students in the class was provided by teachers on the cover of

S-POLS return packets. The majority of teachers provided this information. Subject area and class level were obtained from the T-info when S-info data were not provided.

Distribution of the students by subject area is shown in Figure 4.1. The largest group was biology (31.2%) followed by general science (23.7%). The remaining three major subject areas of chemistry (11.6%) earth science (9.5%) and physics (4.5%) together accounted for fewer students than did biology.

A total of 8003 students in 372 science classes were involved in the study. The subject distribution of classes and students by instructional level is given in Table 4.4. Two-thirds of the students were identified as upper secondary (Grade 9-12). The teacher/student ratio for the study was approximately 1:55.

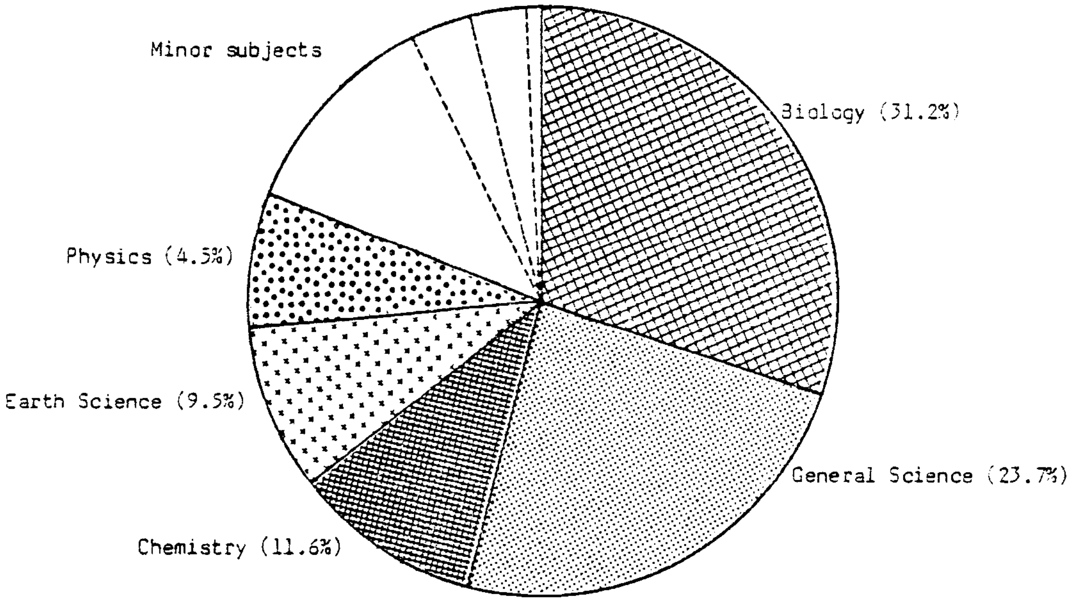


FIGURE 4.1 Distribution of Students by Subject Area

TABLE 4.4 Distribution of Students and Classes by Instructional Level, Training Area and Subject

TA	Grades 7 - 9							Grades 9 - 12							Grades 7 - 12							
	B $^{\Phi}$	C	P	GS	ES	Other	Total	B	C	P	GS	ES	Other	Total	B	C	P	GS	ES	Other	TOTAL
	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
1	64 (3)$^{\theta}$			86 (3)	144 (7)		294 (13)	320 (19)	160 (5)	70 (2)	198 (7)	18 (1)	GBS 10 (1)	776 (35)	384 (22)	160 (5)	70 (2)	284 (10)	162 (8)	GBS 10 (1)	1070 (48)
2	127 (7)			118 (8)	46 (1)	PS 69 (3) ISCS 61 (3) GBS 57 (3)	478 (25)	255 (13)	208 (10)	23 (2)	327 (18)	67 (5)	PS 82 (3)	962 (51)	382 (20)	208 (10)	23 (2)	445 (26)	113 (6)	PS 151 (6) ISCS 61 (3) GBS 57 (3)	1440 (76)
3	62 (3)			59 (2)	206 (6)		327 (11)	655 (31)	296 (9)	148 (7)	347 (13)		GBS 82 (4) PS 515 (24) PR 47 (2)	2090 (90)	717 (34)	296 (9)	148 (7)	406 (15)	206 (6)	GBS 82 (4) PS 515 (24) PR 47 (2)	2417 (101)
4	77 (3)	51 (3)	17 (1)	316 (14)	80 (4)	PS 150 (7) ISCS 56 (3) GBS 48 (3)	795 (38)	256 (15)	82 (4)	5 (1)	14 (1)	23 (2)	PS 100 (6)	480 (29)	333 (18)	133 (7)	22 (2)	330 (15)	103 (6)	PS 250 (13) ISCS 56 (3) GBS 48 (3)	1275 (67)
5		51 (3)		252 (10)		ISCS 106 (5)	409 (18)	175 (7)	121 (6)	56 (3)		22 (1)	PS 66 (3)	440 (20)	175 (7)	172 (9)	56 (3)	252 (10)	22 (1)	PS 66 (3) ISCS 106 (5)	849 (38)
6				188 (9)	141 (7)	PS 45 (2)	374 (18)	327 (15)	92 (3)	40 (1)	61 (3)	8 (1)	PS 50 (1)	578 (24)	327 (15)	92 (3)	40 (1)	249 (12)	149 (8)	PS 95 (3)	952 (42)
Total	330 (16)	102 (6)	17 (1)	1019 (46)	617 (25)	592 (29)	2677 (123)	1988 (100)	959 (37)	342 (16)	947 (42)	138 (10)	952 (44)	5326 (249)	2318 (116)	1061 (43)	359 (17)	1966 (88)	755 (35)	1544 (73)	8003 (372)

Φ (Major subject areas: B=Biology; C=Chemistry; P=Physics; GS=General Science; ES=Earth Science
(Other (minor subject areas): PS=Physical sciences; GBS=General biological sciences; PR=Practical sciences;
ISCS=Intermediate Science Curriculum Study

θ ( ) = number of classes

Summary

A total of 145 teachers took part in the study with 89 submitting matched (T-KOLS and S-POLS) returns. A 1:55 teacher-student ratio was obtained with 8003 students within 372 science classes participating. These returns fulfilled the statistical requirements of the study.

The majority of teachers provided the requested demographic information by completing both T-info and S-info. The instructional level ratio was calculated in order that inferences based on statistical analysis for either the (7-9) or the (9-12) group would be applicable to the entire sample.

The major subject areas represented by the class groups were biology, general science, chemistry, earth science and physics, with the distribution ranging from 31.2% (biology) to 4.5% (physics). Minor subject areas accounted for approximately 20% of the total.

Frequency Tabulations

Prior to scoring and statistical analysis, the following frequency tabulations were analyzed:

1. Instrument response patterns
    a) Pattern of response by teachers to items within each of the ten T-KOLS sections
    b) Pattern of response by students of six randomly selected teachers over the 100 S-POLS items

2. Item analysis of the three alternative and *no response* categories for each set of 100 T-KOLS and 100 S-POLS items

3. Comparative section analysis of the three alternative and *no response* categories for T-KOLS and S-POLS items

Instrument Response Patterns

Teacher Knowledge of Laboratory Safety (T-KOLS)

The percent of items checked by respondents over each section of T-KOLS is tabulated in Table 4.5. An average across all sections showed that 83% of the respondents checked five or more items. Since T-KOLS was scored only where a response was made to five or more section items, this information is of importance to the results of statistical analysis.

Section I (Storage and disposal ...) showed a 92.6% response to five or more items (the highest) compared to Section V (Toxic and chemical substances) on which only 72.8% of the teachers responded to five or more items.

The number of respondents failing to complete any of the T-KOLS items and the number responding to four or fewer items are both tabulated in Table 4.5 and shown graphically in Figure 4.2. The relatively small differences between these figures supports the 5-item minimum for the T-KOLS scoring scheme described in the methodology (p. 73). For comparative purposes, responses to ten out of ten, and nine out of ten items are also shown in Figure 4.2.

Student Perception of Laboratory Safety (S-POLS)

Typically, the student sample consisted of one to three class groups taught by each participating teacher. In some cases, the classes were studying the same subject, and in others, the subject areas differed. As described in the methodology (p. 82), the nature of S-POLS was such that only 35 items were "common" or applicable to all science subject areas and grade levels. The remaining items were subject specific, and for this reason, it was necessary to substantiate both the validity and statistical requirements of S-POLS by determining the number of cells (Sets A-J by items 1-10) which remained either unfilled or showed a "nonapplicable" response.

TABLE 4.5 T-KOLS: Response Frequencies for Section Items

Number of items checked	Section										Average
	I	II	III	IV	V	VI	VII	VIII	IX	X	
	%	%	%	%	%	%	%	%	%	%	%
10	34.6	8.1	.7	5.9	8.1	60.3	37.5	25.0	18.4	15.4	
9	29.4	24.3	20.6	24.3	33.1	16.9	25.7	29.4	15.4	24.3	
8	14.7	23.5	29.4	22.8	12.5	7.4	10.3	16.2	15.4	18.4	
7	5.1	18.4	20.6	16.2	8.8	.7	4.4	6.6	16.2	10.3	
6	4.4	11.8	8.1	8.8	7.4	-	1.5	4.4	10.3	6.6	
5	4.4	2.9	5.1	5.1	2.9	.7	-	2.2	2.2	3.7	
4	.7	1.5	2.2	.7	2.9	.7	.7	1.5	2.2	.7	
3	-	.7	1.5	2.9	-	-	2.2	.7	.7	-	
2	-	.7	2.2	-	2.2	.7	.7	.7	-	1.5	
1	-	.7	-	.7	1.5	-	.7	.7	-	2.2	
5-10	92.6	89.0	84.5	83.1	72.8	86.0	79.4	83.8	77.9	78.7	82.78
1-4	.7	3.6	5.9	4.3	9.5	1.4	4.3	3.6	.7	4.4	3.84
0	6.6	7.4	9.6	12.5	20.6	12.5	16.2	12.5	19.1	16.9	17.23

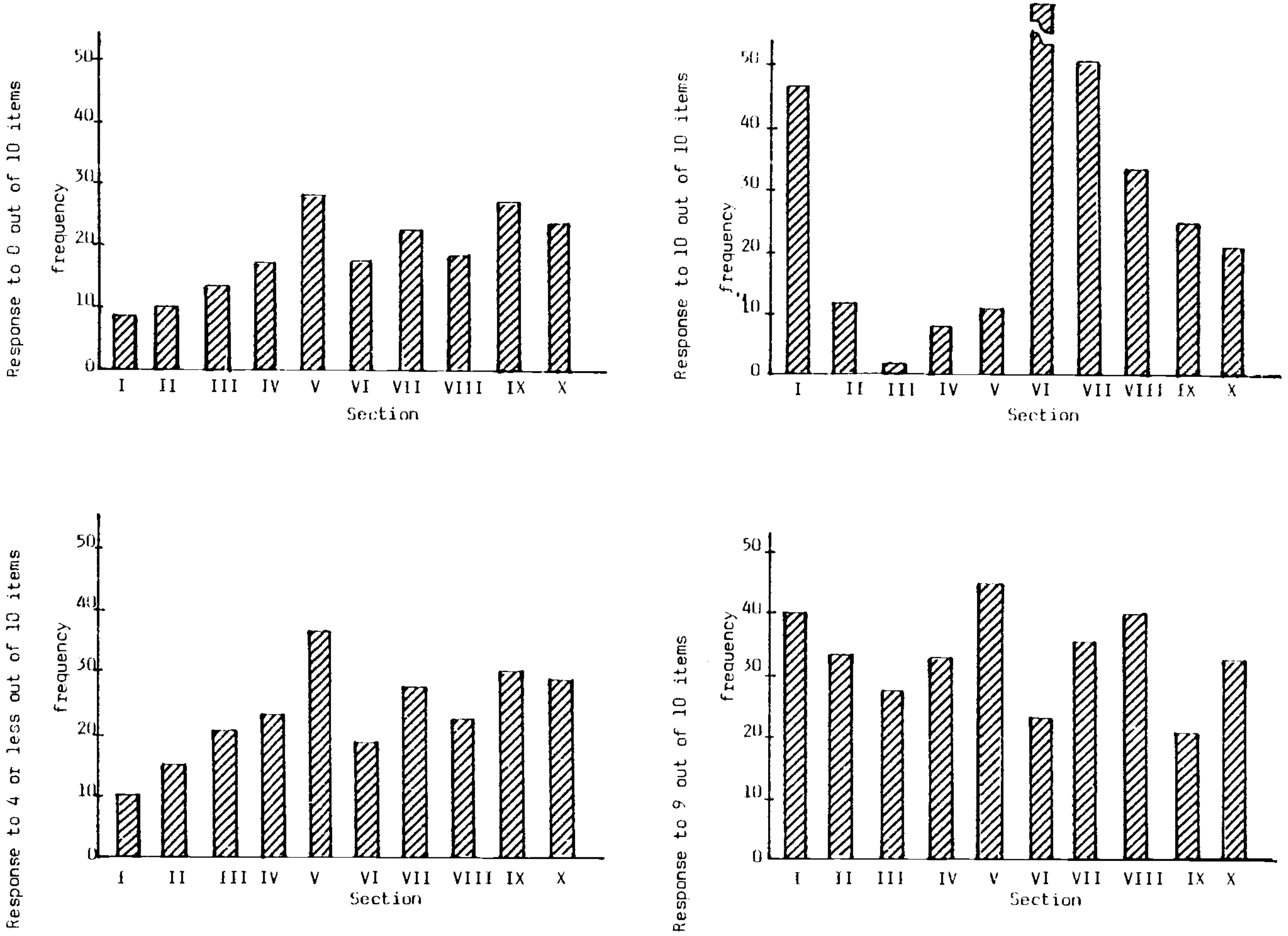


FIGURE 4.2 T-KOLS: Frequency of Response by Section

Since the sample numbers precluded examination of every case, one teacher was selected by computer randomization from each of the six training areas, and a student response grid prepared for each. A sample of the grid for Training Area 1 is shown in Table 4.6. Examination of these six grids permitted assessment to be made of the response pattern based on (*a*) the frequency of response (number of items answered/unanswered) over the 100 S-POLS items, and (*b*) the response variability (selection of same/different response alternatives) for each of the 100 S-POLS items.

The 2-1-0 instrument scoring scheme is used throughout for all items with the exception of those checked by students as *not applicable* which are identified as a "-1" score in Table 4.6. For each grid cell the score is contained in parenthesis and the response frequency provided adjacent to the score. The score written as "6 x (-1)" can be interpreted as six students providing a nonapplicable response. The number of students completing each Set A-J is given at the bottom of each column while the frequency of response to each item appears at the right of column J.

Table 4.7 summarizes the student response data contained in the six response grids, one of which is represented by Table 4.6. All common items (items to be answered by all students) were scored as zero when a nonapplicable response was made in lieu of one of the three item response alternatives. An assessment was made of the number of items which were scored in this manner. It turned out that twenty of the items showing both an identical response from all students and a corresponding zero response were in fact common items. In other words 9.5% of the common items (20 items out of a total of 210 representing the 35 common items over the six grids) appeared to be inappropriate as common items based on the response pattern shown by the six grids. Thus, more than 90% of the common items were in fact applicable to the subject area classes represented by the sample. Since these items were not identified on the S-POLS sets in order to avoid a forced and possibly inaccurate student

TABLE 4.6 S-POLS: Sample Scoring Pattern

Subject Areas: Earth science (9th) .... n=18
General science (9th) 47
Biology (9th/10th) .... 16 81 students completed sets A-K (n=74 in A-J sample)

*common item

Q #	A	B	C	D	E	F	G	H	I	J	freq.
1	6 x (-1) 1 x (0)	* 5 x (0) 2 x (2)	* 1 x (0) 3 x (1) 2 x (2)	* 8 x (2)	2 x (-1) 4 x (1) 2 x (2)	* 2 x (0) 3 x (1) 3 x (2)	1 x (-1) 1 x (0) 6 x (2)	* 1 x (0) 6 x (2)	1 x (-1) 1 x (0) 2 x (1) 3 x (2)	1 x (0) 6 x (2)	74
2	3 x (-1) 1 x (1) 3 x (2)	2 x (-1) 2 x (0) 3 x (2)	* 1 x (0) 2 x (1) 4 x (2)	7 x (-1) 1 x (2)	7 x (-1) * 1 x (2)	7 x (-1) 1 x (2)	6 x (-1) 2 x (2)	5 x (-1) 1 x (1) 1 x (2)	* 7 x (2)	2 x (-1) 1 x (0) 1 x (1) 3 x (2)	74
3	2 x (-1) 5 x (2)	* 4 x (0) 2 x (1) 1 x (2)	6 x (-1) 1 x (1)	3 x (-1) 5 x (2)	8 x (-1)	2 x (-1) 1 x (1) 5 x (2)	* 5 x (0) 1 x (1) 2 x (2)	3 x (0) 3 x (1) 1 x (2)	5 x (-1) 1 x (0) 1 x (2)	5 x (-1) 1 x (0) 1 x (1)	74
4	1 x (0) 6 x (1)	6 x (-1) 1 x (1)	4 x (-1) 3 x (1)	4 x (-1) 3 x (0) 1 x (2)	* 2 x (0) 3 x (1) 3 x (2)	2 x (-1) 3 x (0) 1 x (1) 2 x (2)	4 x (-1) 2 x (0) 2 x (1)	1 x (-1) 6 x (0)	3 x (-1) 4 x (0)	* 7 x (0)	74
5	* 1 x (0) 6 x (2)	* 2 x (0) 4 x (1) 1 x (2)	5 x (-1) 2 x (2)	2 x (-1) 1 x (0) 5 x (2)	2 x (-1) 1 x (0) 2 x (1) 3 x (2)	7 x (-1) 1 x (1)	3 x (-1) 5 x (2)	* 7 x (2)	2 x (-1) 2 x (1) 3 x (2)	2 x (-1) 1 x (1) 4 x (2)	74
6	* 1 x (0) 1 x (1) 5 x (2)	1 x (-1) 1 x (0) 5 x (1)	* 2 x (1) 5 x (2)	* 4 x (0) 4 x (1)	* 2 x (0) 5 x (1) 1 x (2)	* 8 x (2)	* 2 x (1) 6 x (2)	* 4 x (0) 1 x (1) 2 x (2)	* 3 x (0) 3 x (1) 1 x (2)	* 1 x (0) 3 x (1) 3 x (2)	74
7	* 3 x (1) 4 x (2)	1 x (-1) 5 x (1) 1 x (2)	2 x (-1) 1 x (1) 4 x (2)	2 x (-1) 2 x (1) 4 x (2)	* 4 x (0) 4 x (2)	4 x (-1) 1 x (0) 3 x (2)	1 x (-1) 2 x (0) 4 x (1) 1 x (2)	* 1 x (0) 1 x (1) 5 x (2)	5 x (-1) 2 x (2)	2 x (-1) 2 x (0) 3 x (2)	74
8	5 x (-1) 2 x (2)	5 x (-1) 1 x (0) 1 x (2)	3 x (-1) 1 x (1) 3 x (2)	2 x (-1) 1 x (0) 2 x (1) 3 x (2)	* 5 x (0) 1 x (1) 2 x (2)	6 x (-1) 2 x (2)	2 x (-1) 3 x (0) 2 x (1) 1 x (2)	* 6 x (0) 1 x (2)	2 x (-1) 3 x (0) 1 x (2)	3 x (-1) 1 x (1) 3 x (2)	74
9	5 x (-1) 2 x (2)	3 x (-1) 3 x (1) 1 x (2)	4 x (-1) 3 x (1)	* 1 x (1) 7 x (2)	4 x (-1) 3 x (1) 1 x (2)	4 x (-1) 2 x (0) 2 x (1)	5 x (-1) 2 x (0) 1 x (1)	5 x (-1) 2 x (1)	* 1 x (1) 6 x (2)	* 6 x (0) 1 x (1)	74
10	* 3 x (0) 1 x (1) 3 x (2)	* 4 x (0) 1 x (1) 2 x (2)	2 x (-1) 1 x (1) 4 x (2)	2 x (-1) 3 x (0) 1 x (1) 2 x (2)	3 x (-1) 2 x (0) 2 x (1) 1 x (2)	2 x (-1) 6 x (1)	4 x (-1) 3 x (0) 1 x (2)	2 x (-1) 2 x (1) 3 x (2)	3 x (-1) 1 x (0) 2 x (1) 1 x (2)	* 5 x (0) 2 x (2)	74
n	7	7	7	8	8	8	8	7	7	7	740 10

TABLE 4.7 S-POLS: Summary of Scoring Pattern Responses

Training Area	Subject Area	Grade Level	Number of Students	Response frequency/cell										
				Unfilled cells	All Responses		Identical Response from all Respondents							Variable responses over all items
							*Scores over all Items				*Scores over common Items			
					Min.	Max.	(-1)	(0)	(1 or 2)	Total	(0)	(1 or 2)	Total	
1	Earth science Gen. science Biology	8 9 9/10	18 47 16	0	7	8	1	1	4	6	1	4	5	94
2	Gen. science	8 8 8	19 20 16	0	4	6	16	3	2	21	3	2	5	79
3	Biology	10	22 19 24	0	5	6	2	7	0	9	7	0	7	91
4	Gen. science	8 8 7	24 25 25	0	6	7	0	0	0	0	-	-	-	100
5	Chemistry	11	21 27 18	0	5	6	5	3	2	10	3	1	4	90
6	Earth science Gen. science/ Phys. science Phys. science	8 7 7	21 23 20	0	6	7	15	6	0	21	6	0	6	79
			Overall Range =		4 (min)	8 (max)			TOTALS:	67	20			533

*Scoring Key:

Not applicable	= -1
Best answer	= 2
Less preferred	= 1
Not acceptable	= 0

response, and respondents were unaware of the scoring scheme to be used, this figure did not appear to be unreasonable.

The cell frequency over the six samples ranged from four to eight. The number of cells showing identical response patterns to nonapplicable (-1) items, ranged from zero (Training Area 4) to sixteen (Training Area 2) with both extremes recorded by general science classes. However, in the case of Training Area 2, an additional three items scored as zero were in fact nonapplicable items. This adjustment changed the range from zero to nineteen. In other words, no less than 81 (Training Area 2) and as many as 100 items (Training Area 4) were found to be relevant to the six classes sampled.

Since the aim was to prepare an instrument with at least fifty appropriate items, these findings support the relevancy of S-POLS for the use for which it was constructed.

Although an identical response from all students of each participating teacher would be the ideal, in practice, this seldom occurred. While only 11% of the items (67 items out of 600 representing the 100 items over the six samples) showed an identical response, examination of the sample scoring grid (Table 4.6) reveals that many cells showed surprisingly little response variability.

Responses over the sixty sets (Sets A-J over the six samples) are as follows:

Students responding	Number of sets in which students responded to each item
8	4
7	13
6	32
5	10
4	1

Although one response per item would have met minimal statistical requirements, an aim of five responses (50 students per teacher over Sets A-J) was sought in order to improve the statistical validity of the data and ensure that at least a single response was made for each item. For this reason, the per item response shown by the six samples was substantially better than had been anticipated.

The number of students shown in Table 4.7 by subject and grade level for each of the six teachers sampled also includes those students who completed the K set. The response pattern for the K Set was excluded from Table 4.6 since these replacement items were not needed and thus not included in the items scored as the research instrument. However, although the student count does not correspond exactly to the sample number shown in Table 4.6 it is useful for comparative purposes.

Item Analysis

The frequency response to each of the T-KOLS and S-POLS item alternatives was analyzed independently. Although the findings are not relative to the central purpose of this study, they are of importance to the laboratory safety training of secondary school science teachers. Based on the three selection categories used in the instrument (*permissible and reccommended, permissible with qualifications* and *not permissible under any circumstances*), teacher responses to selected T-KOLS items revealed the following:

1. Fifty percent of the teachers did not recognize that the storage of oxidizing agents with reducing agents or with organic materials was *not permitted under any circumstances*

2. Forty percent incorrectly assumed that the substitution of contact lenses for prescription lenses was a *permissible and reccommended* practice when these were worn under approved chemical goggles

3. Thirty-three percent correctly recognized that it is *not permissible under any circumstances* to apply a tourniquet immed-

iately where extensive injury results in severe arterial bleeding

4. Twenty-five percent correctly checked that the heating of small quantities of potassium chlorate with manganese dioxide in the preparation of oxygen was *not permissible under any circumstances;* 33.3% felt the practice was *permissible with qualifications*

5. Nearly seventy-five percent either failed to respond, or incorrectly considered that the practice of exposing agar plates to the school environment during the study of micro-organisms was a *permissible and recommended* practice

Student perceptions of laboratory safety practices of their teachers based on responses to selected S-POLS items revealed that:

1. Only twenty percent of the teachers required students to cover open wounds or cuts prior to working in the science classroom-laboratory

2. Over fifty percent permitted either contact or prescription lenses to be worn, and did not require students to wear safety goggles

3. Only 12.3% required students to wear laboratory aprons (or coats) at all times and did so themselves

4. Only forty percent required students to wash their hands following the use of chemicals, while thirty-three percent never required students to wash their hands after a science experiment

5. When called out of the science room for some reason, sixty percent of the teachers left students to work on science activities on their own without supervision

Comparative analysis

The frequency response to each of the T-KOLS and S-POLS items was averaged over each section of the instruments. These values are given in Table 4.8 together with the highest and lowest

TABLE 4.8 T-KOLS and S-POLS: Frequency (as %) Response to Item Alternatives

Section	n	Instrument T-KOLS S-POLS	Response Alternatives			
			Best Ans. $\bar{X}$	Less Pref. $\bar{X}$	Non-Accept. $\bar{X}$	No Resp. $\bar{X}$
I	136	Knowledge	45.9	35.9	7.2	11.0[b]
	597	Practice	52.9	27.6	15.6	3.9[b]
II	136	Knowledge	37.6	33.6	15.9	12.9
	463	Practice	57.5	22.9[b]	13.6	6.0
III	136	Knowledge	43.3	23.0	19.7[a]	14.0
	437	Practice	48.9	30.0	13.5[b]	7.6
IV	136	Knowledge	29.9[b]	36.5[a]	14.2	19.4
	525	Practice	30.0[b]	24.0	40.0[a]	6.0
V	136	Knowledge	42.2	19.3	12.2	26.3[a]
	505	Practice	58.3[a]	23.2	14.1	4.4
VI	136	Knowledge	58.0[a]	24.8	3.0[b]	14.2
	620	Practice	45.6	27.4	19.3	7.7
VII	136	Knowledge	55.8	18.2[b]	3.9	22.1
	620	Practice	49.9	27.9	16.0	6.2
VIII	136	Knowledge	52.0	21.8	8.1	18.1
	400	Practice	52.2	23.9	14.0	9.90[a]
IX	136	Knowledge	39.6	24.6	15.3	20.5
	439	Practice	38.5	36.1[a]	17.4	8.0
X	136	Knowledge	32.7	33.1	10.6	23.6
	558	Practice	35.7	30.5	26.8	7.0
Average over all Sections						
	136	Knowledge	43.70	27.08	11.01	18.21
	516	Practice	46.94	27.35	19.03	6.69

[a] highest, and [b] lowest frequency (as %) response for each alternative

selection frequencies for each response alternative. For easier comparison, a graphical representation of Table 4.8 is provided as Figure 4.3, which shows that:

1. The *best answer* was selected most often by teachers for items in Section VI (Your responsibility and liability), and by students in Section V (Toxic and chemical substances)

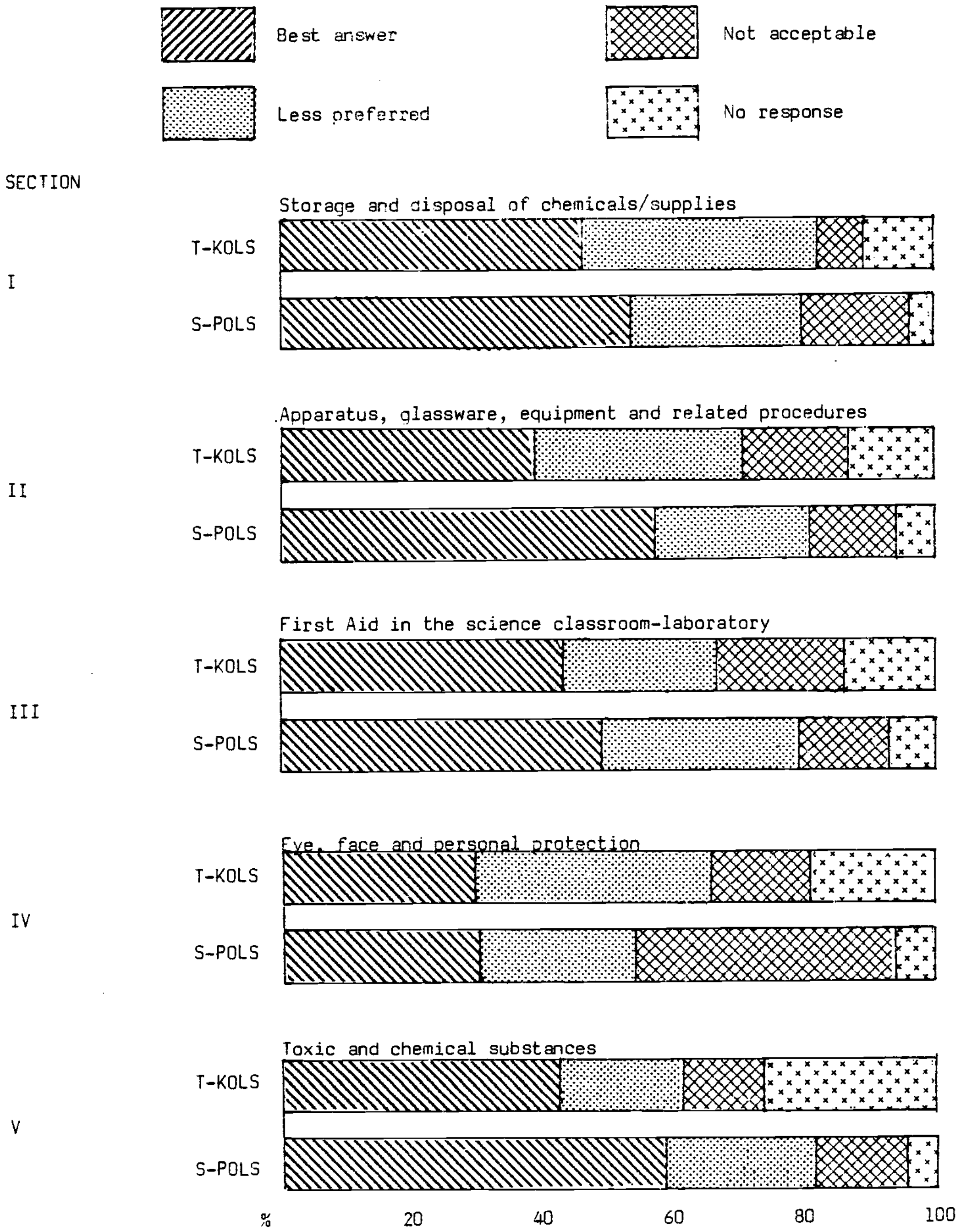
2. The lowest *best answer* and highest *less preferred* or *nonacceptable* response frequencies for both knowledge and practice were found in Section IV (Eye, face and personal protection)

3. Teachers selected the *nonacceptable* alternative more often for items in Section III (First aid in the science classroom-laboratory) while students checked either the *best answer* or the *less preferred* item alternatives most frequently for this section.

4. Both teachers and students responded to more items in Section I (Storage and disposal of chemicals/supplies) than in any other section

5. Fewer teachers responded to items in Section V (Toxic and chemical substances) and fewer students to items in Section VIII (Electrical, radiation and other physical hazards) than to other section items

Figure 4.4 depicts differences in T-KOLS and S-POLS mean frequencies for the three response alternatives. While the "less preferred" alternative shows only small differences between the knowledge and practice frequencies, this is not true for the "best answer" and "nonacceptable" modes. The "best answer" mean response frequencies for Section II (Apparatus, glassware, equipment and related procedures) and Section V (Toxic and chemical substances) were 15% to 20% higher for practice than for knowledge in these areas. On the other hand, the "best answer" mean response frequency for Section VI (Your responsibility and liability) was 12.4% higher for knowledge than for practice.



(continued)

FIGURE 4.3 T-KOLS and S-POLS: Response Frequencies to Item Alternatives

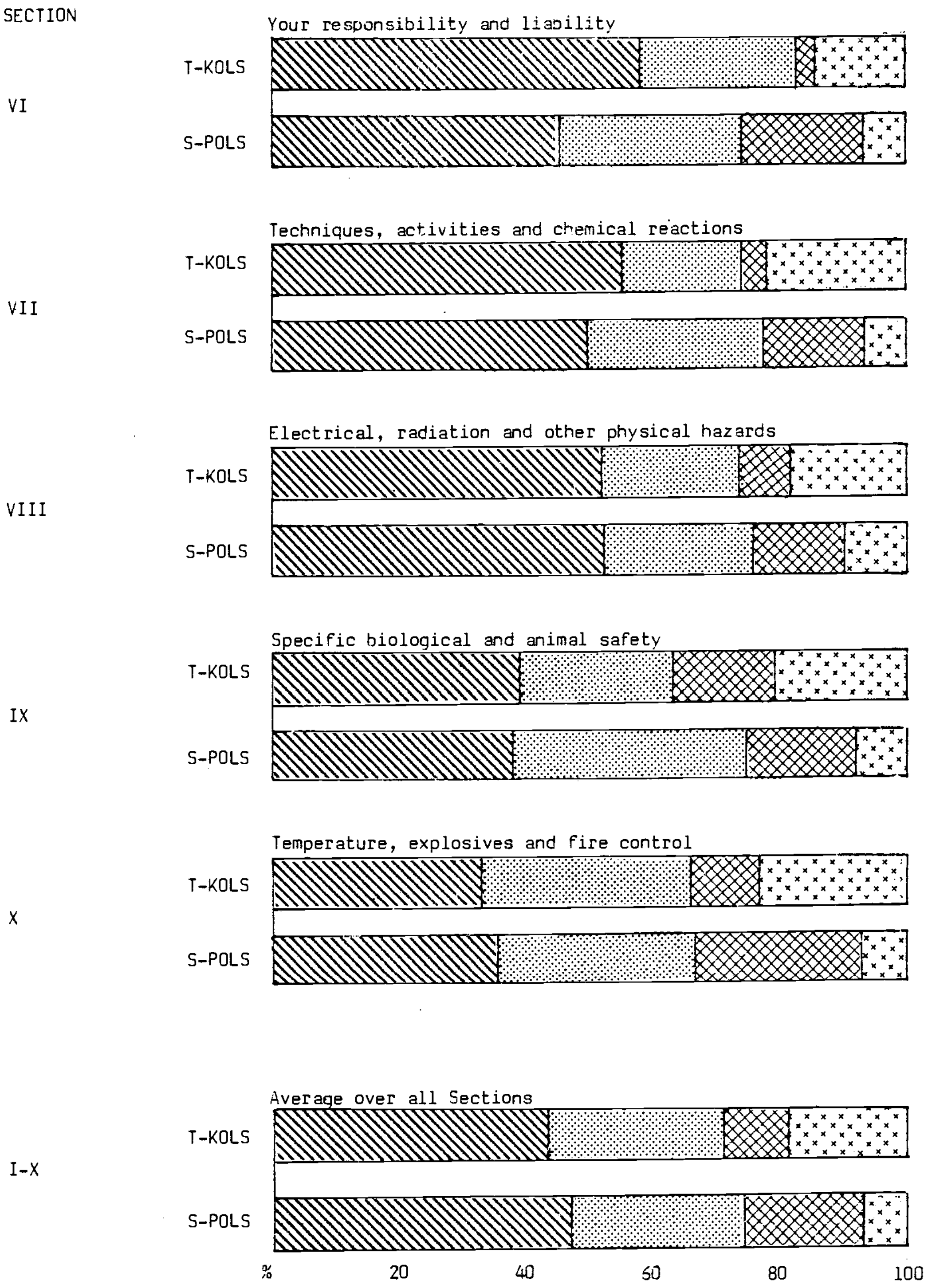


FIGURE 4.3 T-KOLS and S-POLS: Response Frequencies to Item Alternatives (*continued*)

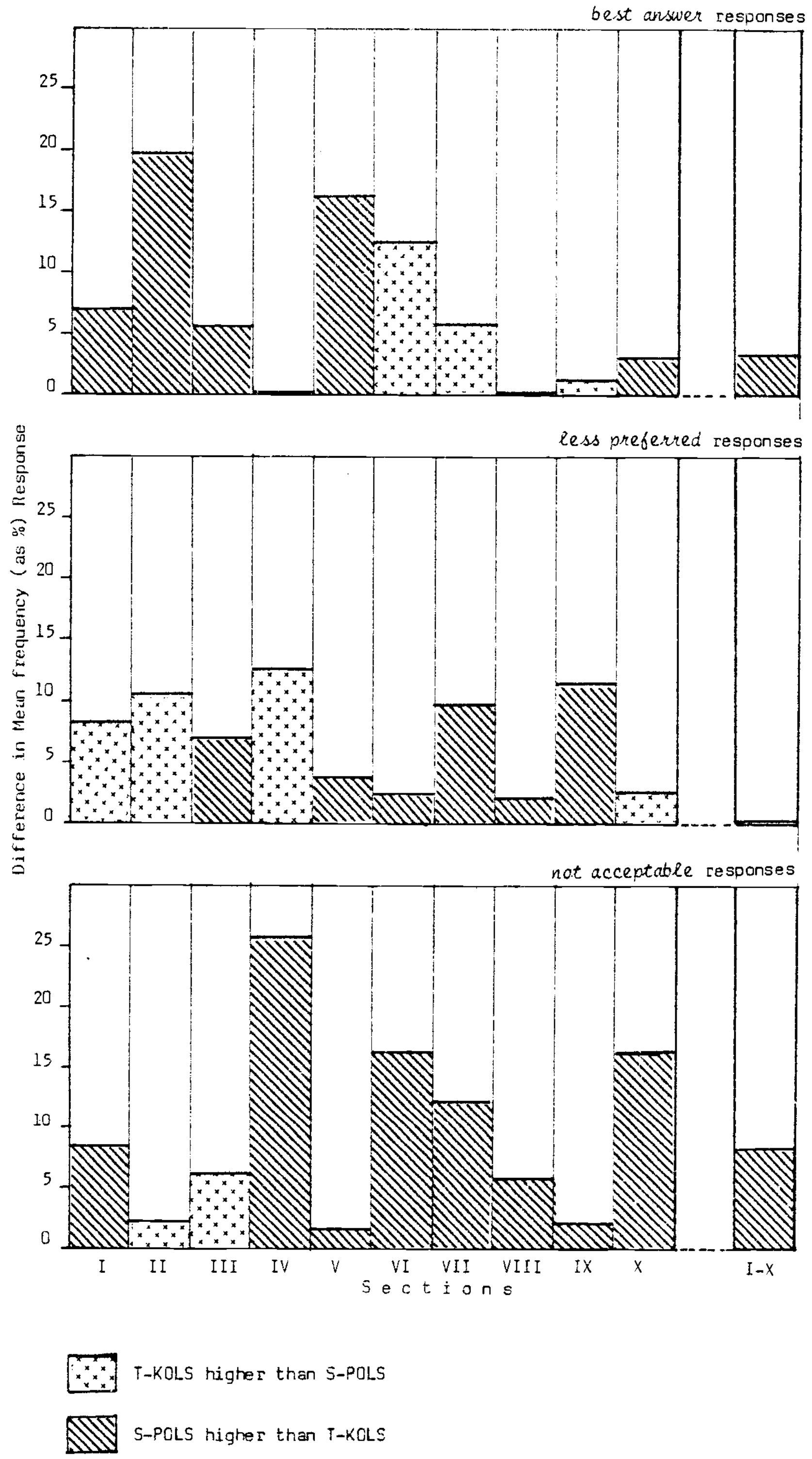


FIGURE 4.4 T-KOLS and S-POLS: Differences in Mean Response Frequencies

Nonacceptable mean response frequencies were 26% higher for practices than for knowledge for Section IV (Eye, face and personal protection) and approximately 16% higher for practices for Sections VI (Your responsibility and liability) and X (Temperature, explosives and fire control) respectively.

The similarities between the "best answer" and "less preferred" response alternatives for the T-KOLS and S-POLS totals are apparent from both Figures 4.3 and 4.4. The lack of correspondence between the "nonacceptable" and the "no response" modes could reflect differences in the two instruments, or demonstrate a reluctance on the part of respondents to select the "wrong" or "less desirable" alternative.

The nature of S-POLS (inventory form), the method of administration (class groups) and the length of the instrument (division into sets) made it unlikely that students would fail to respond to the ten items. In addition, a large number of items were subject specific, and students had the option of checking the "nonapplicable" response alternative. These items were then excluded from the tabulations. Although the possibility remained that students would check the "nonapplicable" alternative in preference to recording a "nonacceptable" response, this occurrence was not likely, since they also had the option of explaining the classroom behavior by completing a "fill-in" response.

Conversely, the teacher group had a longer test (100 items) and a self-imposed time limitation. Since the test was not group administered, the teachers were not a "captive audience." For these reasons, failure to respond to T-KOLS items could have been either a reflection of these factors, low motivation, or a lack of knowledge.

"Best answer" response

In order to further examine the relationship between the knowledge and practice items, the "best answer" response was studied independently. Response to this alternative is given in Table 4.9 and is divided into four quadrants according to the percentage of respondents selecting the *best answer* for each of the one hundred T-KOLS and S-POLS items. Although certain differences are apparent in the selection of the "best answer" alternative for T-KOLS and S-POLS items, the many similarities in the response patterns of the two instruments appear to support the contention that there is some association between the safety knowledge and practices of teachers based on the frequency of response to the instruments.

Summary

Instrument response patterns

T-KOLS. Findings showed that the largest percentage of teachers completed all ten items for four T-KOLS sections; nine items were completed by the majority in five sections; while eight items were completed by the greatest number of teachers for Section III (First aid ...). A relatively small difference was found between the number of teachers failing to complete any of the T-KOLS section items and those responding to less than five section items. This finding would appear to support the use of the scoring scheme used for T-KOLS whereby items were scored only where section response was obtained for five items or more.

S-POLS. Student response was examined by the random selection of one participating teacher from each of the six training areas. The responses from students in all classes of the selected teachers were plotted on a grid representing each of ten items for Sets A-J (100 items). Analysis was concerned with (*a*) the frequency of item responses, and (*b*) the response variability for each item. Findings showed that approximately 90% of the common items were applicable over all subject areas and grade levels represented by the sample. On an average, each set of ten items was completed by six students with a range of four to eight over all sets. Since

TABLE 4.9 T-KOLS and S-POLS: Number of "best answer" Item Responses by Frequency Quadrants

Section	Response Frequencies							
	<25%		25%-50%		50%-75%		>75%	
	T-KOLS	S-POLS	T-KOLS	S-POLS	T-KOLS	S-POLS	T-KOLS	S-POLS
	n	n	n	n	n	n	n	n
I	1	1	4	2	5	6		1
II			8	3	2	7		
III		2	6	3	3	3	1	2
IV	5	5	3	3	2	2		
V	2	1	5	1	3	6		2
VI		3	3	2	7	4		1
VII			3	5	7	5		
VIII			4	4	6	6		
IX	2	1	4	7	4	1		1
X	3	2	7	7		1		
Total	13	15	47	37	39	41	1	7

it had been anticipated that at least fifty percent of the items would be applicable over all science areas and grade levels, the resulting range of 81% to 100% over the six samples exceeded the original projection.

Item analysis. The response frequencies for each of the T-KOLS and S-POLS item alternatives was analyzed independently. Examples were given which suggested that these findings had some implication for the purpose of training teachers in laboratory safety.

Comparative analysis. The T-KOLS and S-POLS frequency (as %) response mean values were examined by section and total. Overall, the total (I-X) showed a strong relationship between knowledge and practice based on the "best answer" and "less preferred" response modes. Various reasons were suggested for the lack of agreement found between the "nonacceptable" and the "no response" categories. Section differences revealed a lack of knowledge on Sections II and V in comparison with practices, while practice skills were low on Sections IV, VI and X compared with knowledge in these areas.

Best answer response. The relationship between safety knowledge and practice was also examined by the independent item analysis of the "best" response alternatives. Again, findings pointed to a strong relationship between knowledge and practice. In other words, the practices of highly knowledgeable teachers (based on selection of the *best answer*) were perceived by their students to be exemplary.

The Scored Instruments

Raw Scores

A safety knowledge score for each T-KOLS section was obtained for each teacher. Similarly, a safety practice score was derived for each teacher from an aggregate of the ten-item S-POLS Set (A-J) scores for that teacher's students. Section, section combinations and total T-KOLS and S-POLS scores for a given teacher were categorized as "matched" scores. Scores from partially completed or single instruments were identified as "partials." "Matched" and "partial" scores were considered as "all" scores when combined.

The following ranges were obtained from a maximum section score of twenty and possible instrument score of two hundred:

Section	T-KOLS Score Range	S-POLS Score Range
I	6 - 19	4 - 17
II	7 - 18	3 - 20
III	7 - 18	6 - 17
IV	6 - 15	1 - 15
V	8 - 19	8 - 18
VI	10 - 20	5 - 14
VII	10 - 20	5 - 17
VIII	8 - 20	5 - 16
IX	6 - 19	5 - 18
X	7 - 18	3 - 16
Total (I-X)	114 -161	71 -148

A maximum range of 1 to 20 was obtained for practice compared to a range of 6 to 20 for knowledge. Based on the score ranges, a teacher would probably attain a higher percentile rank for knowledge than for practice if the same score was obtained for each element.

Comparison of *Matched* and *All* scores

In order that inferences made on the basis of results from the "matched" scores could be generalized to the total sample, an examination of "matched" and "all" scores was made by section and total for each training area. The standard deviation, mean values and sample numbers were compiled for each area and are shown for the total in Table 4.10 and Figure 4.5.

Comparative examination showed negligible differences between "matched" and "all" scores for either the section or total scores. This is true for both individual training areas and for all training areas combined. Although in several instances the "matched" practice scores tended to be slightly higher than the "all" scores

TABLE 4.10 T-KOLS and S-POLS: Section Means for "Matched" and "All" Scores

	Score Type	T-KOLS			S-POLS		
		n	$\bar{X}$	s	n	$\bar{X}$	s
I	Matched	118	13.64	2.72	118	12.70	2.17
	All	126	13.68	2.73	138	12.61	2.29
II	Matched	116	11.95	2.74	116	13.72	2.09
	All	124	11.90	2.70	138	13.60	2.34
III	Matched	111	12.49	2.39	111	12.44	2.00
	All	118	12.47	2.40	138	12.30	2.03
IV	Matched	109	11.23	2.19	109	8.20	2.61
	All	116	11.21	2.27	138	8.25	2.60
V	Matched	98	13.61	2.80	98	14.27	1.65
	All	102	13.69	2.87	138	14.12	1.81
VI	Matched	112	16.20	2.50	112	10.17	1.83
	All	118	16.19	2.48	138	10.13	1.83
VII	Matched	103	16.10	2.44	103	13.15	2.15
	All	108	16.11	2.45	138	12.99	2.25
VIII	Matched	108	14.75	2.55	108	12.31	1.83
	All	115	14.74	2.63	138	12.30	1.88
IX	Matched	103	12.89	3.38	103	10.64	1.95
	All	109	12.92	3.33	138	10.56	1.94
X	Matched	104	12.23	2.87	104	9.90	2.16
	All	108	12.30	2.85	138	9.76	2.38
Total	Matched	87	138.20	11.56	87	117.37	12.91
	All	91	138.36	11.54	138	116.63	13.68

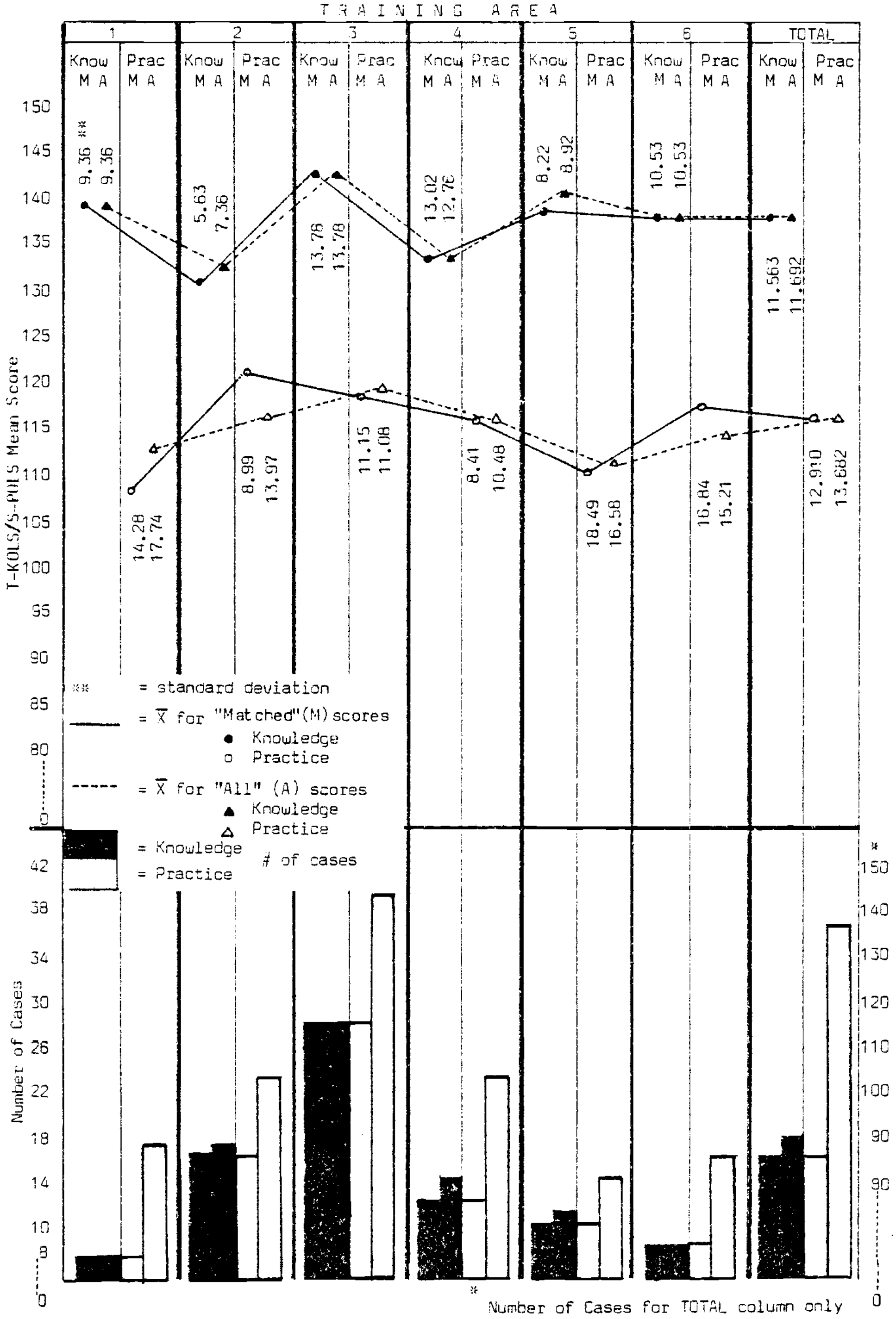


FIGURE 4.5 T-KOLS and S-POLS: Comparison of "Matched" and "All" Scores

these differences did not vary unduly. From examination of these findings, this investigator felt satisfied that results obtained from either set of scores were representative of the total sample of teachers or students participating in the study.

Figure 4.5 shows highest knowledge mean scores for Training Areas 1 and 3, and lowest means for Training Areas 2 and 4. Practice means were highest for Training Areas 2 and 3 and lowest for Training Areas 1 and 5. Training Area 3 showed relatively consistent mean scores with relatively high values for both knowledge and practice.

Analysis of Variance

The F-statistic was employed to determine whether the training area differences in mean T-KOLS and S-POLS scores were statistically significant. Analysis was based on "all" section scores and total scores for each instrument across training areas. The LSD multiple range test was employed to determine the source of variation when a significant F-ratio was obtained.

Tables 4.11 and 4.12 give the mean scores, F-ratio and significant probabilities for T-KOLS and S-POLS by section and section combination. Combo 1 includes those sections dealing with specific chemical hazards (I. Storage and Disposal ...; II. Apparatus, glassware ...; IV. Eye, face and personal protection; V. Toxic and chemical substances; VII. Techniques, activities ...; X. Temperature, explosives ...). Combos 2, 3 and 4 include Section VI (Your responsibility and liability) and each of Sections VIII (Electrical, radiation and other physical hazards), IX (Specific biological and animal safety) and III (First aid in the science classroom-laboratory) respectively.

Significant ($P<.05$) F-ratios were found for T-KOLS score variations among the training areas for Sections I, VIII and Combos 1 and 2. Also a significant ($P<.05$) F-ratio was found for score variations among training areas for S-POLS Section II.

TABLE 4.11 T-KOLS: Analysis of Variance by Training Areas

Section	Training Areas												F-ratio	Source of Variation (LSD)
	1		2		3		4		5		6			
	$\bar{X}$	n	$\bar{X}$	n	$\bar{X}$	n	$\bar{X}$	n	$\bar{X}$	n	$\bar{X}$	n		
I	12.78	18	12.70	20	14.76	37	13.73	22	12.87	15	14.21	14	2.578**	TA3 and each of TAs 1,2 and 5
II	11.35	17	11.52	21	12.67	36	11.71	21	11.33	15	12.07	14	0.966	
III	11.40	15	13.05	20	12.06	24	12.57	21	13.27	15	12.85	13	1.465	
IV	10.62	13	10.60	20	11.82	34	11.55	20	11.53	15	10.29	14	1.626	
V	13.45	11	13.17	18	14.00	30	12.39	18	15.43	14	13.82	11	2.082*	TA5 and each of TAs 1,2 and 4 TA3 and TA 4
VI	15.50	16	15.65	23	16.88	32	15.53	19	16.33	15	17.15	13	1.676	
VII	14.87	15	15.89	18	16.48	31	16.17	18	16.93	14	16.00	12	1.286	
VIII	14.14	14	14.47	19	15.33	33	13.41	22	15.93	14	15.23	13	2.450**	TA4 and each of TAs 3,5 and 6
IX	12.46	13	13.00	21	13.84	31	11.32	19	13.71	14	12.45	11	1.653	
X	11.36	14	11.89	19	12.72	32	12.32	19	12.50	14	12.70	10	0.562	
Total	139.13	8	133.28	18	142.79	29	133.73	15	140.50	12	138.44	9	2.210*	TA3 and each of TAs 2 and 4 TA2 and TA5
Combo 1	82.56	9	76.50	18	83.73	30	78.94	17	81.00	13	80.40	10	2.501**	TA2 and each of TAs 1 and 3 TA3 and TA4
Combo 2	30.29	14	30.37	19	32.28	32	29.26	19	32.29	14	32.38	13	2.500**	TA4 and each of TAs 3,5 and 6
Combo 3	28.69	13	28.90	21	30.68	31	26.59	17	30.14	14	29.91	11	2.055*	TA4 and each of TAs 3 and 5
Combo 4	27.71	14	29.15	20	29.00	32	28.42	19	29.60	15	30.33	12	0.985	

*P <.10 **P <.05

TABLE 4.12 S-POLS: Analysis of Variance by Training Areas

Section	Training Areas												F-ratio	Source of Variation (LSD)
	1		2		3		4		5		6			
	$\bar{X}$	n	$\bar{X}$	n	$\bar{X}$	n	$\bar{X}$	n	$\bar{X}$	n	$\bar{X}$	n		
I	11.90	18	12.19	23	13.45	40	12.10	23	12.28	15	12.96	17	2.039*	TA3 and each of TAs 1, 2, 4 and 5
II	12.93	18	13.91	23	14.36	40	13.54	23	11.92	15	13.68	17	2.942**	TA1 and TA3 TA5 and each of TAs 2, 3, 4 and 6
III	11.56	18	12.14	23	12.50	40	12.65	23	12.54	15	12.28	17	0.771	
IV	7.50	18	8.63	23	8.92	40	7.33	23	8.04	15	8.35	17	1.616	
V	13.71	18	14.53	23	14.29	40	14.00	23	14.16	15	13.63	17	0.734	
VI	10.38	18	10.50	23	10.16	40	10.42	23	9.51	15	9.47	17	1.148	
VII	13.00	18	13.50	23	13.14	40	13.21	23	11.50	15	12.98	17	1.670	
VIII	11.88	18	12.43	23	12.31	40	12.47	23	12.74	15	11.92	17	0.523	
IX	10.87	18	11.28	23	10.34	40	10.75	23	9.89	15	10.03	17	1.473	
X	9.58	18	9.49	23	10.26	40	9.51	23	10.00	15	9.30	17	0.632	
Total	113.29	18	118.61	23	119.72	40	115.99	23	112.44	15	114.62	17	1.094	
Combo 1	68.61	18	72.26	23	74.41	40	69.69	23	67.76	15	70.91	17	1.737	
Combo 2	22.28	18	22.93	23	22.47	40	22.90	23	22.25	15	21.39	17	0.616	
Combo 3	21.25	18	21.79	23	20.50	40	21.17	23	19.40	15	19.50	17	1.906*	TA5 and TA6 and each of TAs 1, 2 and 4
Combo 4	21.94	18	22.64	23	22.65	40	23.07	23	22.06	15	21.75	17	0.540	

*P <.10 **P <.05

Analysis of Individual Class Scores

The measurement of teacher knowledge was obtained by direct administration of T-KOLS to the teacher sample, whereas the assessment of teacher practices was based on student perceptions and was not measured directly. Moreover, examination of the pattern shown by the S-POLS scoring grids for six randomly selected samples (Table 4.6) revealed that only 11% of the 600 items showed an identical response from an average of six student respondents per item.

In order to further assess the validity of S-POLS, additional analyses were conducted in relation to (*a*) student responses within the same subject and different subject area classes, and (*b*) the possible effect of sexual bias in the student response to S-POLS items. Class information (S-info) consisting of subject area, grade level and number of male and female students in the class was provided by teachers on the S-POLS return packets.

In this section, the term *cluster* is used to identify those classes (included in the sample) taught by the same individual. In previous analyses, the teacher score for practices was derived by aggregating the class scores within a cluster. In the present case, class scores are independently examined. Although an average teacher/student ratio of 1:55 was attained, the number of classes within a cluster varies according to the total students within each class.

The following organization is used in analyzing these data:

A. Distribution of classes by subject area

B. Ratio of students to classes at each instructional level

C. Categorization and score differences of classes within clusters--

1. Categorization scheme
2. *Like* and *Unlike* subject class differences

3. *Like* subject class differences
4. Comparison of *Like* subject class differences with overall score range

D. Analysis of S-POLS scores by Subject--

1. Pooled t-test
2. Analysis of variance

E. S-POLS class scores and student sex

A. Distribution of classes by subject area

When one of the five major subject areas (biology, chemistry, physics, general science or earth science) was not applicable to the class in question, teachers were requested to provide the appropriate subject area in the space provided on S-info. Subjects included by teachers were divided into the following four minor areas areas:

1. Physics sciences:
   astronomy, IPS (Intermediate Physical Science) and electricity
2. General biological sciences:
   oceanography, life science, ecology and wildlife, ecosystems, forestry and environmental science
3. Practical science:
   health occupations and flight
4. ISCS (Intermediate Science Curriculum Study)

The subject distribution of classes and students by training area and instructional level was previously given in Table 4.4. Instructional level assignment of Grade 9 students was based on the grade level of other classes taught by the cluster teacher. For example, the Grade 9 classes were included at the lower instructional level if 7th and/or 8th grade classes were also taught by the teacher in question.

Although the number of students within each instructional level varied by training area, the upper secondary students comprised two-thirds of the 372 classes included in the total sample. All major subject areas were represented at both secondary levels for the combined training areas. The student count ranged from 17 (physics) to 1019 (general science) at the lower instructional level, and 138 (earth science) to 1988 (biology) at the upper level. Biology students comprised the largest group (2318 students in 116 classes) with general science a close second. The 2000 general science students were split between upper and lower secondary levels, however, whereas only one-sixth of the biology group was in the lower secondary level. The percentage distribution of major and minor subject groupings, was previously provided in Figure 4.1 of this chapter.

B. Ratio of students to classes at each instructional level

The ratio of students to classes was examined in order that subject areas could be compared across training areas and instructional levels. The following results were obtained from application of the Pearson-r correlation coefficient to the ratio of students to class groups in each training area at each instructional level. The statistics are based on the data provided in Table 4.4.

Lower secondary level (7-9)	r-value: 0.98	$P < 0.001$
Upper secondary level (9-12)	r-value: 0.99	$P < 0.001$

Since the ratio of teachers to students averaged approximately the same (1:55) across all instructional levels, these findings led this investigator to conclude that results based on the analysis of class scores at either instructional level are applicable to the total sample.

C. Categorization and score differences of classes within clusters

The differences in class scores within clusters was examined in order to determine the extent of variation between subject areas.

Since many of the items in S-POLS were subject-specific, the score differences between classes of the same subject were expected to be less than differences between unlike subject classes taught by the same teacher. The S-info data showed three pattern types for subject areas within clusters. For the purposes of this study these were categorized as "LIKE," "UNLIKE" and "MIXED" classes.

1. Categorization scheme

The scheme used in calculating the differences in class scores within clusters is given in Figure 4.6. Only two clusters in the sample showed a double pattern (e.g. two biology and three general science classes). In these cases the differences between the high and low scores for LIKE classes gave two values, and the UNLIKE classes gave one value.

2. *Like* and *Unlike* subject class differences

Utilizing the above scheme, score differences between classes within clusters were determined and mean differences calculated by training area. Out of a total of 115 class group differences, the largest category was that of LIKE subjects (n=81). In other words, S-POLS was administered more often to classes (within clusters) studying the same subject. UNLIKE (n=13) and MIXED (n=21), which included both LIKE and UNLIKE class groups, comprised the other difference groupings. Single class returns were submitted by twenty-one teachers, and by their nature were excluded from this analysis. The cluster distribution for each category is given in Table 4.13.

Findings revealed that in three of the six training areas the mean differences between LIKE classes were less than differences between UNLIKE classes within clusters. The total mean difference for all training areas combined was $\overline{X}$ = 21.89 for UNLIKE compared to $\overline{X}$ = 17.60 for LIKE class groups. Application of the t-statistic showed this difference to be statistically significant.

3. *Like* subject class differences

Having established that the responses of students in the

LIKE classes	Score	Score differences	Method
Biology	120.89		Two or more classes of the same subject.
Biology	132.23		Score differences calculated between highest
Biology	122.65	132.23 - 120.89 = 11.34	and lowest scores over two or more subjects.
UNLIKE classes	Score	Score differences	Method
Biology	120.89		Two or more classes of different subjects.
Earth Science	130.60		Score differences calculated between highest
Chemistry	126.98	130.60 - 120.89 = 9.71	and lowest scores over two or more subjects.
MIXED classes	Score	Score differences	Method
Chemistry	133.75		Three or more classes which included at least
Biology	120.89		two classes of the same subject.
Biology	132.23		Score differences calculated by two methods:
MIXED UNLIKE classes			
Chemistry	133.75		Score differences calculated between highest
Biology	120.89	133.75 - 120.89 = 12.86	and lowest over different subjects
MIXED LIKE classes			
Biology	132.23		Score differences calculated between highest
Biology	120.89	132.23 - 120.89 = 11.34	and lowest over the same subject

FIGURE 4.6 Scheme for Categorization of Cluster Class Score Differences

TABLE 4.13 *t*-test Ratios for Categorized Cluster Class Score Differences

		LIKE/MIXED LIKE							UNLIKE/ MIXED- UNLIKE	t-ratio	UNLIKE	LIKE	t-ratio	MIXED- UNLIKE	ALL (total) CATEGORIES	Single Subjt.
		B^{θ}	C	P	GS	ES	Other	Total								
1	$\bar{X}$	25.61	20.64		28.32	20.72		23.06	25.17	0.31	14.47	21.83	1.00**	35.87	22.78	
	s	13.83			6.14	0.87		10.05	13.39		2.57	9.41		8.55	10.25	
	n	6	1		3	2		12	4		2	10		2	14	4
2	$\bar{X}$	12.40[a]	9.20		21.90[a]	22.75		17.81	27.55	1.74*	22.78	18.41	0.44	29.14	22.07	
	s	7.89	6.36		11.73			11.46	15.22		14.36	11.59		16.47	13.58	
	n	6	2		7	1	3	19	8		2	12		6	20	3
3	$\bar{X}$	16.19	18.41	34.69	16.87	28.83		15.81	35.09	3.93***	35.80	15.89	3.86***	34.66	20.41	
	s	7.26	1.15	6.97	5.20	6.77		9.33	18.94		6.02	8.37		24.68	14.05	
	n	11	2	2	4	2	10	31	8		3	26		5	34	6
4	$\bar{X}$	7.56	6.30		22.26	15.85		14.38	17.10	0.62	17.02	15.76	0.18	17.21	16.33	
	s	4.98			15.32			9.69	11.19		15.46	11.08		3.93	10.87	
	n	5	1		4	1	6[a]	17	9		5	12		4	21	2
5	$\bar{X}$	24.72	19.18	17.32	17.60			17.85				17.85			17.85	
	s	16.94	6.12		6.85			9.72				9.72			9.72	
	n	2	3	1	3		3	12	-	-	-	12	-	-	12	3
6	$\bar{X}$	11.13			26.69	14.52		16.03	20.48	0.83**	17.62	18.88		21.20	19.45	
	s	9.52			10.83	6.80		9.72	9.32			11.09		10.60	10.15	
	n	6			4	2	1	13	5		1	9	-	4	14	3
Tot	$\bar{X}$	15.56	15.52	28.90	21.21	20.84		17.04	25.24	3.54***	21.89	17.60	3.12***	27.31	19.86	
	s	10.57	6.75	11.17	9.95	6.85		10.25	15.12		13.14	9.82		16.19	12.09	
	n	36	9	3	25	8	23	104	34		13	81		21	115	21

[a] Includes two classes that contain two "pairs" of LIKE subjects

$^{***}P < .001$ $^{**}P < .05$ $^{*}P < .10$

θMajor subject areas: B=Biology; C=Chemistry; P=Physics; GS=General Science; ES=Earth Science

Other (minor subject areas): Physical sciences, General biological sciences, Practical sciences and Intermediate Science Curriculum Study (ISCS) same subject classes within clusters were more alike than the responses of students in different classes (based on score differences between classes) these differences were examined across subject areas. Only the LIKE/MIXED-LIKE class score differences were analyzed since the variety of subjects within the UNLIKE group made the individual sample sizes too small to yield significant information.

Table 4.13 also shows the calculated mean differences by training area for each of the five major subject areas within the LIKE/MIXED-LIKE grouping. Examination reveals that approximately the same differences were obtained for biology and chemistry ($\overline{X}$=15.56 and $\overline{X}$=15.52) and the same differences for general science and earth science ($\overline{X}$=21.21 and $\overline{X}$=20.84). In both cases these differences were shown to be less than the calculated mean ($\overline{X}$=25.24) obtained for the combined UNLIKE/MIXED-UNLIKE groups (Table 4.13). Although the mean difference for physics was somewhat greater than for the other four subject areas, the smaller sample size made this result inconclusive.

The class LIKE/MIXED-LIKE scores were graphically plotted by major subject area in order to determine how these varied within clusters. Visual examination not only revealed that the cluster scores varied substantially within subject areas, but also that these differences were not subject specific.

4. Comparison of *Like* subject class differences with score range for major subject areas

For comparative purposes, the highest and lowest class scores were compiled for each major subject by training area. These are given in Table 4.14 together with the differences between the highest and lowest scores at each secondary level (the subject range). In order to establish that the score differences between same subject (LIKE/MIXED-LIKE) classes within clusters did not approach the highest and lowest subject score range given in Table 4.14, these

TABLE 4.14 S-POLS: Class Score Range by Subject and Instructional Level

Trng Area	Grades 9 - 12				Grades 7 - 9				Grade 7 - 12	
	n[‡]	High	Low	Diff.	n	High	Low	Diff.	n	Diff.
Biology										
1	19	146.50	87.87	58.64	3	94.02	52.08[b]	41.94	22	94.42
2	13	134.33	87.05	47.28	7	119.00[a]	89.89	29.11	20	47.28
3	31	156.86[a]	88.78	68.08	3	112.52	90.81	21.71	34	68.08
4	15	132.24	99.97	32.27	3	106.88	93.17	13.71	18	39.07
5	7	135.69	99.00	36.69		-	-	-	7	36.69
6	15	139.38	83.48[b]	55.90		-	-	-	15	55.90
All	100	156.86	83.48	73.38	16	119.00	52.08	66.92	116	89.94
Chemistry										
1	5	145.40	94.37	51.03		-	-	-	5	51.03
2	10	141.22	77.80[b]	63.42		-	-	-	10	63.42
3	9	146.65[a]	106.37	40.28		-	-	-	9	40.28
4	4	135.52	133.75	1.77	3	131.00	102.22[b]	28.78	7	33.30
5	6	134.33	95.15	39.17	3	136.82[a]	122.56	14.26	9	41.67
6	3	122.57	103.44	19.13		-	-	-	3	19.13
All	37	146.65	77.80	68.85	6	136.90	102.22	34.60	43	68.85
Physics										
1	2	137.08[a]	94.85	42.23		-	-	-	2	42.23
2	2	120.68	-	-		-	-	-	2	-
3	7	112.68	64.67[b]	48.01		-	-	-	7	48.01
4	1	118.18	-	-	1	101.98	-	-	2	16.19
5	3	95.50	78.18	17.32		-	-	-	3	17.32
6	1	104.10	-	-		-	-	-		-
All	16	137.08	64.67	72.41	1				17	72.41
General Science										
1	7	136.08	104.22	31.86	3	128.60	113.40	15.19	10	31.86
2	18	142.90	67.08[b]	75.81	8	136.91	104.21	32.70	26	75.81
3	13	147.05[a]	98.35	48.70	2	124.90	113.09	11.81	15	48.70
4	1	116.68	-	-	14	140.44	97.35	43.09	15	43.09
5		-	-	-	10	138.38	66.85[b]	71.53	10	71.53
6	3	122.00	95.69	26.31	9	151.89[a]	105.10	46.79	12	56.20
All	42	147.05	67.08	79.97	46	151.89	66.85	85.09	88	85.09
Earth Science										
1	1	121.51	-	-	7	132.00	91.47	40.53	8	40.53
2	5	153.61[a]	98.94[b]	54.66	1	129/93	-	-	6	54.66
3		-	-	-	6	143.216[a]	109.60	33.61	6	33.61
4	2	104.84	103.00	1.84	4	127.31	107.06	20.26	6	24.31
5	1	107.44	-	-		-	-	-	1	-
6	1	100.25	-	-	7	119.76	65.79[b]	53.97	8	53.97
All	10	153.61	98.94	54.66	25	143.21	65.79	77.42	35	87.82

[a] highest score for instructional level [b] lowest score for instructional level

[‡] n=number of classes

values were compared graphically.

Figure 4.7 shows the range between the highest and lowest major subject area scores by instructional level together with the minimum and maximum cluster score differences obtained for the same subject areas. The mean differences within clusters for LIKE/MIXED-LIKE classes (from Table 4.13) is also given as a further basis for comparison. Examination showed the cluster differences to be substantially smaller than the subject score range. Although no additional statistical analysis was conducted, this investigator is satisfied that despite the diversity of scores within clusters, these differences are relatively small in comparison with the maximum range of scores over all classes within each specific subject area.

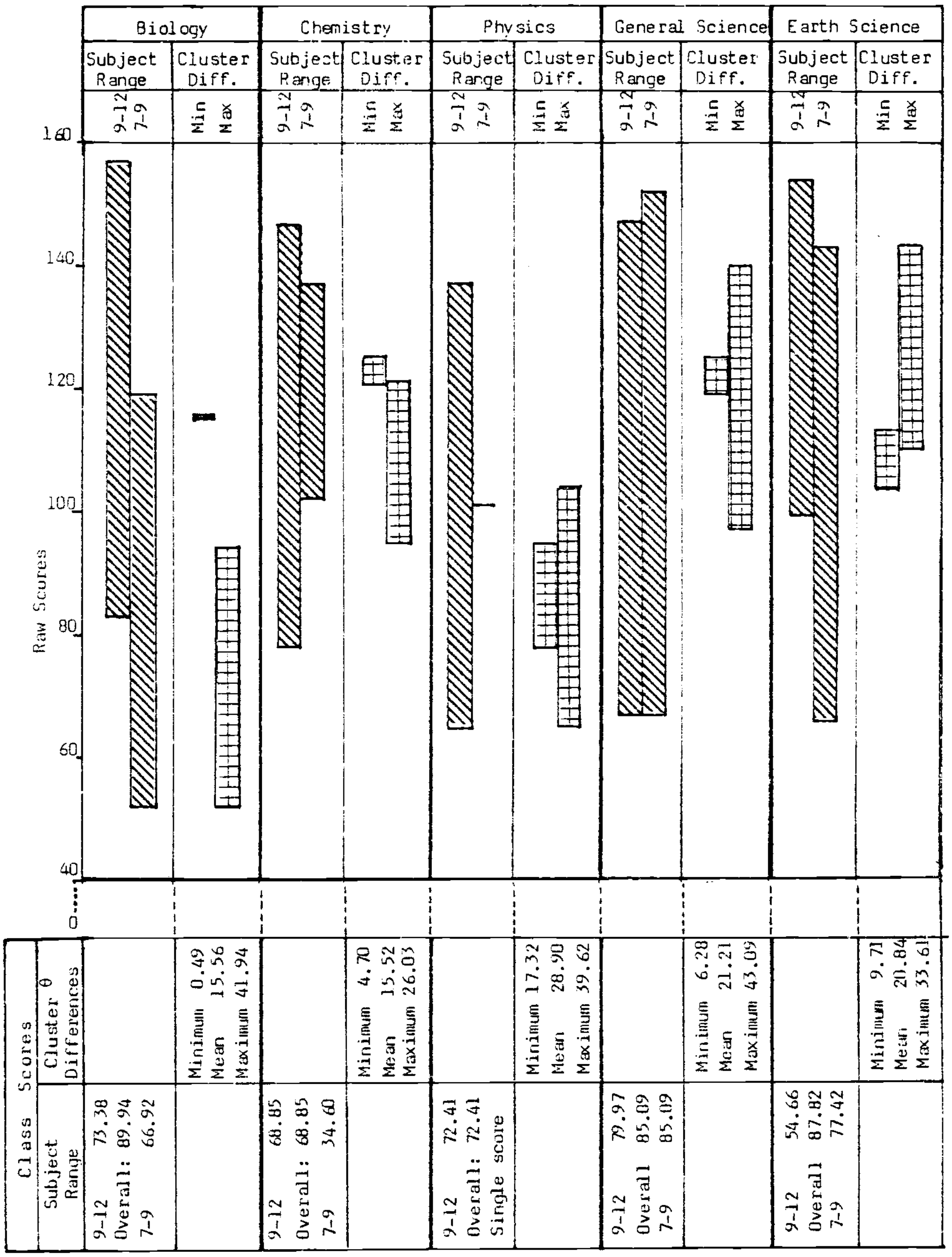
D. Analysis of S-POLS scores by Subject

1. Pooled *t*-test

The mean score for each subject area was compared to the mean score for all other subjects and a *t*-statistic applied. The mean values, pooled *t*-test ratios, and P-values for each section and total are given in Table 4.15 for each of eight subject areas. Mean values are also illustrated in Figure 4.8 where each of the major subject areas is shown by section and total in relation to the subject grouping of all others. The following brief overview for the five major subject areas supplements the tabular and graphical results:

a) Biology. With the exception of Section IX (Specific biological ...), biology scores were significantly lower than "other" scores over six sections.

b) Chemistry. Scores were higher than others over all sections with the exception of IX (Specific biological ...) where they were significantly lower. They were significantly lower than others for I (Storage and disposal ...), V (Toxic and chemical ...), and Total (I-X) S-POLS score.



θ*Like/Mixed Like* class differences

FIGURE 4.7 S-POLS: Cluster Class Score Differences and Class Score Range by Subject

TABLE 4.15 S-POLS: Pooled *t*-test Ratios for Classes by Subject

	BIOL$^{\Phi}$	Other	t-	P-	CHEM	Other	t-	P-	PHYS	Other	t-	P-	C.S.,	Other	t-	P-
n=	110	247			44	315			21	338			87	272		
	$\bar{X}$	$\bar{X}$			$\bar{X}$	$\bar{X}$			$\bar{X}$	$\bar{X}$			$\bar{X}$	$\bar{X}$		
I	12.28	12.74	-1.48	.141	14.60	12.31	5.46	.000**	12.94	12.57	.62	.538	12.42	12.64	- .67	.502
II	13.54	13.66	- .32	.751	13.81	13.61	.39	.696	11.80	13.75	-2.74	.006**	13.63	13.64	- .02	.981
III	11.79	12.55	-2.19	.029**	12.67	12.27	.81	.418	11.37	12.38	-1.48	.140	12.49	12.27	.60	.550
IV	7.24	8.37	-3.09	.002**	9.16	7.89	2.46	.014	6.83	8.12	-1.77	.077*	8.44	7.92	1.30	.194
V	13.72	14.26	-1.79	.074*	14.72	14.02	1.66	.099*	13.75	14.13	- .64	.524	14.11	14.10	.03	.979
VI	9.47	10.39	-3.24	.001**	10.53	10.07	1.14	.256	9.17	10.18	-1.79	.074*	10.33	10.06	.89	.374
VII	12.82	13.13	- .99	.323	13.43	12.98	1.00	.318	12.46	13.07	- .97	.332	12.97	13.06	- .27	.790
VIII	11.87	12.44	-1.66	.099*	12.31	12.27	.07	.941	12.08	12.27	- .31	.757	12.89	12.08	2.21	.028**
IX	10.74	10.54	.62	.535	9.70	10.76	-2.36	.019**	8.67	10.75	-3.34	.001**	10.91	10.54	1.08	.280
X	9.13	9.94	-2.28	.023**	10.27	9.61	1.31	.192	8.42	9.77	-1.94	.052*	10.53	9.43	2.90	.004**
TOTAL	112.60	118.02	-2.91	.004**	121.19	115.79	2.05	.041**	107.50	117.01	-2.59	.010**	118.72	115.73	1.48	.141

	E.S.	Other	t-	P-	P.S.$^{\Theta}$	Other	t-	P-	GBS	Other	t-	P-	ISCS	Other	t-	P-
n=	36	323			47	312			15	344			13	346		
	$\bar{X}$	$\bar{X}$			$\bar{X}$	$\bar{X}$			$\bar{X}$	$\bar{X}$			$\bar{X}$	$\bar{X}$		
I	11.46	12.71	-2.67	.008**	12.74	12.56	.42	.671	11.67	12.63	-1.34	.182	13.98	12.54	1.90	.058
II	13.93	13.60	.59	.557	14.28	13.54	1.49	.138	14.39	13.60	.94	.350	13.12	13.66	- .60	.548
III	12.03	12.35	- .60	.550	13.34	12.18	2.48	.014**	12.88	12.30	.72	.471	13.81	12.26	1.80	.072**
IV	7.95	8.06	- .19	.852	8.31	8.00	.61	.541	9.07	8.00	1.25	.212	10.03	7.97	2.26	.025**
V	14.08	14.11	- .05	.957	14.32	14.07	.60	.549	15.67	14.04	2.38	.018**	15.40	14.06	1.81	.071**
VI	10.51	10.08	.97	.331	10.20	10.11	.22	.825	12.45	10.02	3.74	.000**	10.82	10.10	1.03	.306
VII	13.58	12.98	1.23	.220	12.98	13.05	- .15	.885	14.41	12.98	1.95	.052**	11.05	13.11	-2.64	.009**
VIII	11.59	12.35	-1.45	.147	13.11	12.15	2.06	.040**	12.95	12.24	.89	.374	12.58	12.26	.38	.707
IX	11.76	10.50	2.56	.011**	10.24	10.69	-1.03	.303	11.73	10.58	1.55	.486	10.12	10.65	- .66	.510
X	9.47	9.72	- .45	.653	9.92	9.66	.53	.594	10.24	9.67	.70	.486	10.91	9.65	1.43	.153
TOTAL	116.36	116.47	- .04	.971	119.44	116.00	1.34	.183	125.46	116.06	2.18	.030**	121.82	116.25	1.20	.232

**P < .05 *P < .10

$^{\Phi}$Major subject areas:
BIOL=Biology
CHEM=Chemistry
PHYS=Physics
G.S.=General Science
E.S.=Earth Science

$^{\Theta}$Minor subject areas:
P.S.=Physical sciences
GBS =General biological sciences
ISCS=Intermediate Science Curriculum Study

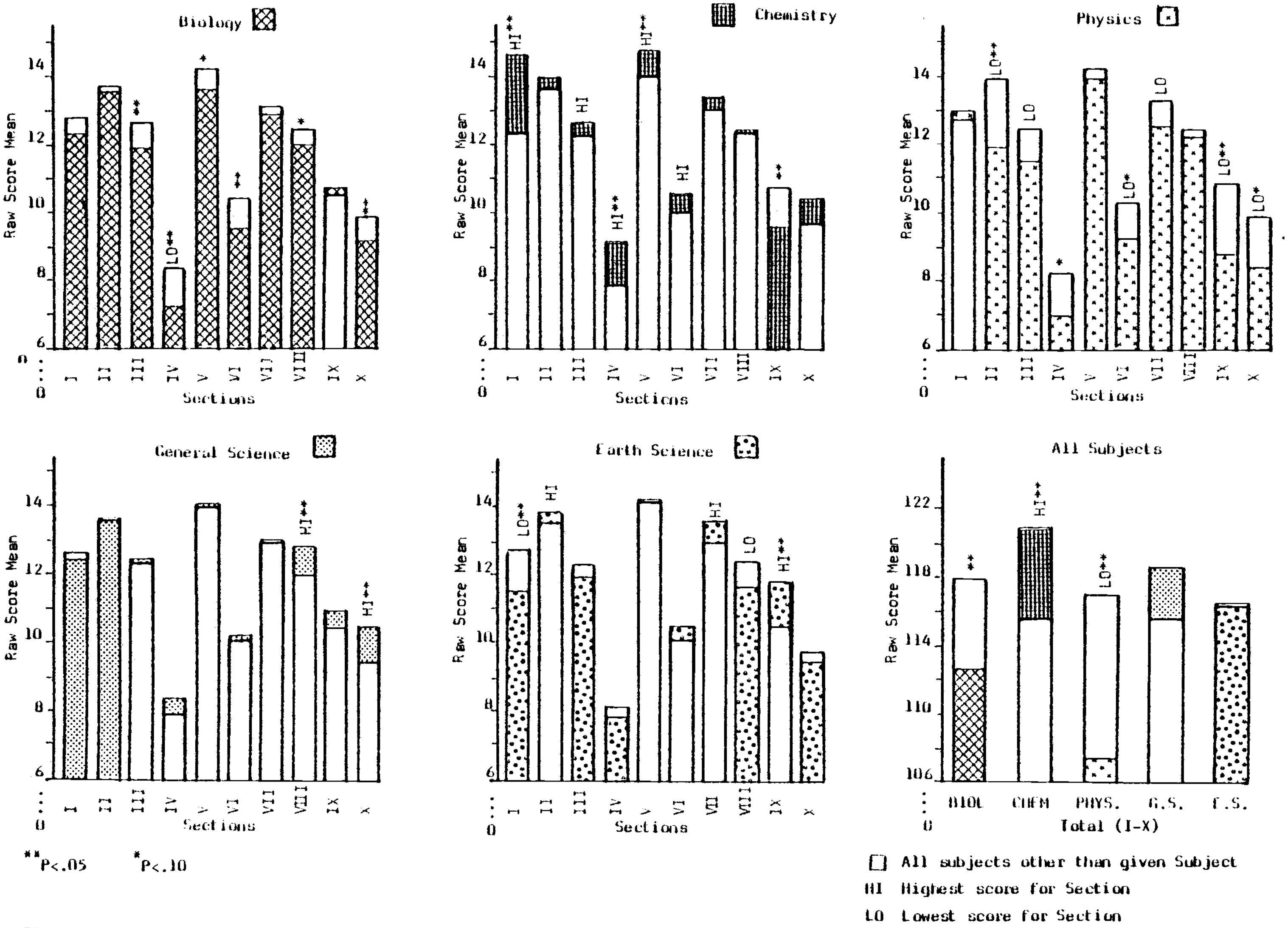


FIGURE 4.8 S-POLS: Pooled *t*-test ratios for Classes by Subject

c) Physics. Scores were lower than others for all sections except I (Storage and disposal ...). They were significantly lower than others for five sections, and total.

d) General Science. Apart from I (Storage and disposal ...), II (Apparatus, glassware ...) and VII (Techniques, activities ...), general science scores were higher than others on all sections and the total. They were significantly higher for VIII (Electrical, radiation ...) and X (Temperature, explosives ...).

e) Earth Science. Scores were higher than others on three sections and significantly higher for IX (Specific biological ...). For all other sections, earth science scores were lower than others with significance shown for I (Storage and disposal ...).

2. Analysis of Variance

Differences in S-POLS scores by subject area were examined by applying an analysis of variance to class scores. The LSD (Least Squares Difference) multiple range test was used to identify the source of variation where significance was found. Mean scores, *F*-ratios, probability values and sources of variation are shown in Table 4.16.

To aid interpretation an ordered arrangement of the subject area mean S-POLS scores is shown graphically in Figure 4.9. Significant differences ($P < .05$) among subject class scores were found for seven of the ten sections, the total instrument score and each Combo.

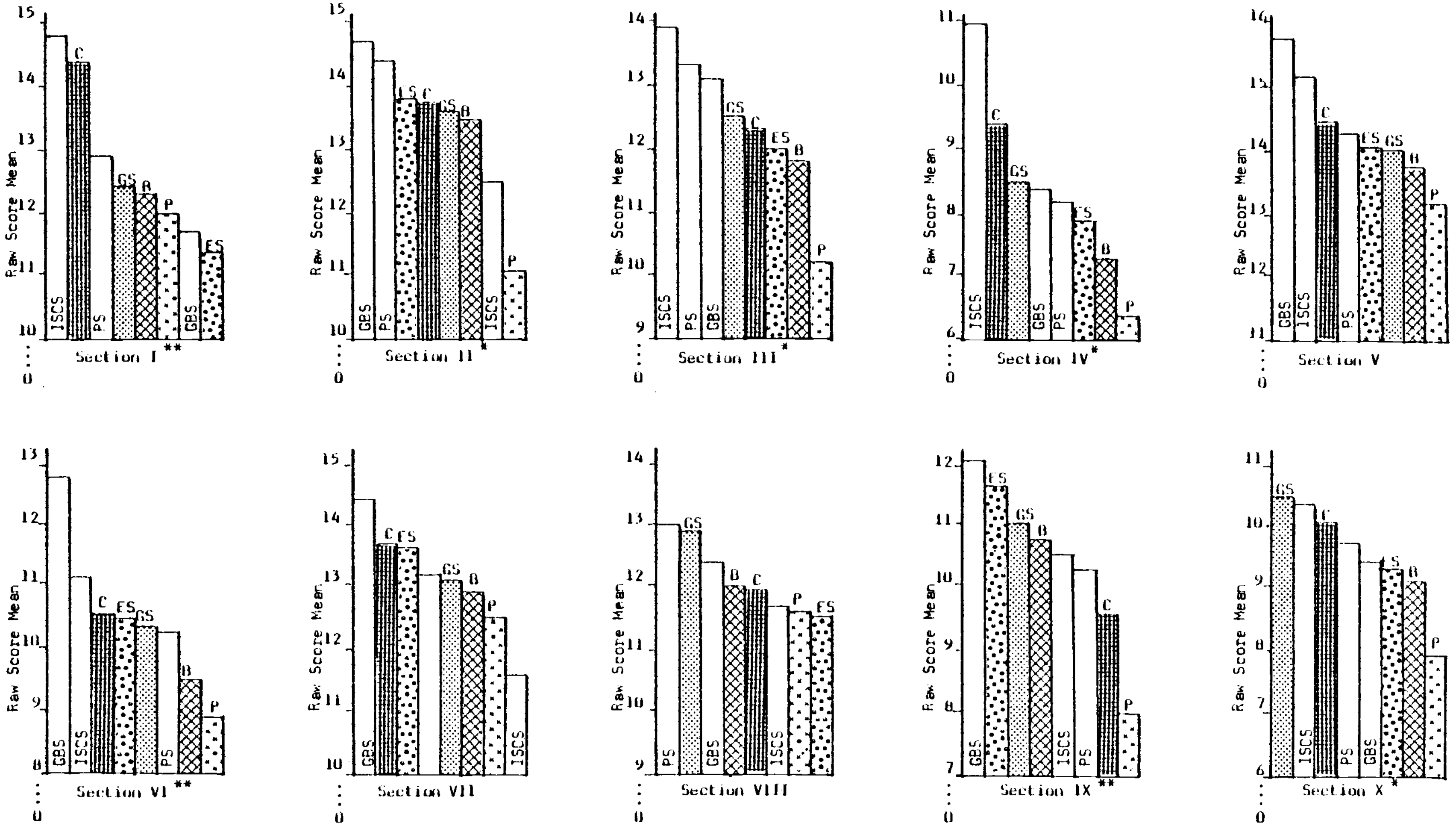
The major findings based on student perceptions of teacher safety practices in the classroom-laboratory show that (*a*) chemistry teachers scored higher than other teachers on all sections that relate specifically to the area of chemistry, (*b*) students scored biology teachers higher overall than physics teachers on science safety practices, (*c*) physics teachers received lower scores than did teachers of all other subjects, (*d*) general science teachers were scored higher than both biology and physics teachers, and (*e*) scores for earth science teachers were variable over the ten S-POLS sections.

TABLE 4.16 S-POLS: Analysis of Variance for Classes by Subject

	Subject Areas								F-ratio	P-value	Source of Variation (LSD)
	Major					Minor					
	BΦ	C	P	GS	ES	PS	GBS	ISCS			
	110	36	16	84	35	42	11	8			
	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$			
I	12.28	14.45	11.96	12.37	11.41	12.88	11.73	14.81	5.118	.000**	C and each of B,P,GS and ES
II	13.54	13.81	11.14	13.63	13.82	14.36	14.70	12.53	2.076	.046*	P and each of B,C,GS and ES
III	11.79	12.35	10.23	12.49	11.96	13.26	13.06	13.89	2.658	.011*	P and each of C and GS
IV	7.24	9.29	6.28	8.43	7.78	8.06	8.31	10.85	3.597	.001*	C and each of B,P and ES GS and each of B and P
V	13.72	14.38	13.06	14.02	14.03	14.22	15.66	15.12	1.433	.191	
VI	9.47	10.50	8.85	10.30	10.48	10.17	12.66	11.15	3.886	.000**	C and P
VII	12.82	13.62	12.37	12.991	13.57	13.10	14.35	11.51	1.342	.230	
VIII	11.87	11.87	11.46	12.83	11.49	12.92	12.34	11.59	1.633	.125	
IX	10.74	9.59	8.01	10197	11.63	10.32	11.97	10.54	4.161	.000**	B and each of C and P P and each of B, GS and ES
X	9.13	10.05	7.86	10.44	9.34	9.66	9.63	10.30	2.183	.035*	GS and each of B and P
TOTAL I-X	112.60	119.90	101.23	118.46	115.50	118.95	124.40	122.29	4.019	.000**	P and each of B,C,GS and ES
COMBO.1	68.72	75.59	62.67	71.88	69.94	72.27	74.37	75.12	3.554	.001*	C and each of B and ES P and each of B,C,GS and ES
COMBO.2	21.35	22.38	20.31	23.12	21.97	23.10	25.00	22.74	2.448	.019*	GS and each of B and P
COMBO.3	20.21	20.09	16.87	21.27	22.11	20.49	24.63	21.69	4.586	.000**	ES and each of B,C and P P and each of B,C,GS and ES
COMBO 4	21.27	22.85	19.09	22.78	22.43	23.44	25.72	25.04	4.261	.000**	P and each of C,GS and ES

**P <.001 *P <.05

Φ (B=Biology; C-Chemistry; P-Physics; GS=General science; PS=Physical science, GBS=General biological sciences; ISCS=Intemediate Science Curriculum Study)



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**P<.001 *P<.05

FIGURE 4.9 S-POLS: Analysis of Variance for Classes by Subject

(*continued*)

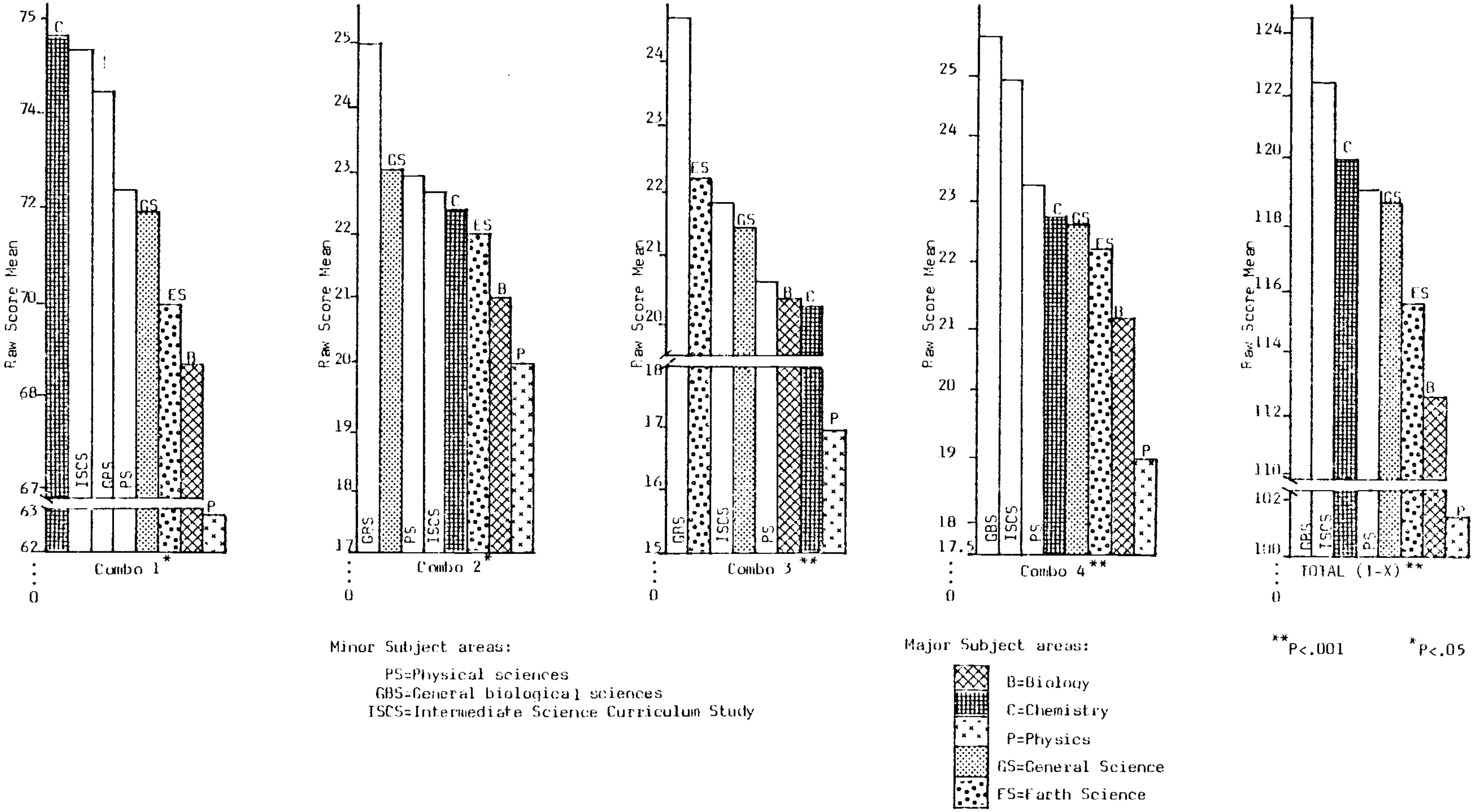


FIGURE 4.9 S-POLS: Analysis of Variance for Classes by Subject (*continued*)

E. S-POLS class scores and student sex

In order to eliminate any possibility of sexual bias in the S-POLS items, the class scores were analyzed on the basis of student sex. Table 4.17 summarizes by training area the information provided on S-info in relation to the number of male and female students within each class. Data was obtained for 231 of the 359 classes representing approximately sixty percent of the students. Although the number of boys exceeded the number of girls by two hundred, this difference was spread over the six training areas and the average number of boys and girls was comparable in each case.

Using the percentage of male and female students in each training area (based on the sixty percent figure for which this information was provided) a chi-square test of significance was conducted. The sex of students was found to be independent of training area with a χ^2 value of 7.60 (df=5) against a Table value of $\chi^2_{.05,5} = 11.070$.

A Pearson-*r* correlation coefficient was obtained in which the percentage of male/females in the sample was tested against the S-POLS section scores for each class (n=359). Probability values based on the *r*-coefficient ranged from P = .238 to P = .969 over the ten sections, indicative of no correlation between the class scores and the sex of students.

Summary

Safety knowledge and practice scores were compiled by section, section combinations and total (I-X) for each teacher. Based on score ranges obtained, it appeared probable that a teacher would attain a higher percentile rank for knowledge than for practice if the same score was obtained for each element.

T-KOLS and S-POLS scores for each teacher were categorized as *matched* scores. *All* scores included scores from partially completed or single instruments in addition to the matched scores. In

TABLE 4.17 Sex of Students by Training Areas

	Number of classes		Number of students				Students as % of Trng. Area Total	Average number of males and females in class			
	Trng. Area	Known sex of students	Trng. Area	Known sex of students		Total		Males		Females	
				Male	Female			$\bar{X}$	s	$\bar{X}$	s
1	48	31	1070	336	287	623	58.22	10.84	9.73	9.26	5.23
2	69	45	1306	405	382	787	60.26	9.00	4.59	8.49	4.26
3	101	69	2417	784	752	1536	63.55	11.36	6.49	10.90	5.51
4	61	41	1177	417	327	744	63.21	10.17	4.18	8.38	4.78
5	38	24	849	253	244	497	58.54	10.54	4.96	10.17	3.87
6	42	21	952	227	230	457	48.00	10.81	5.55	10.95	6.22
Total	359	231	7771	2422	2222	4644	59.76	10.45		9.96	

order that inferences made on the basis of results from the matched scores could be generalized for the total sample, the two sets of scores were comparatively examined and differences found to be negligible.

The T-KOLS and S-POLS scores were also examined by training area. An analysis of variance revealed significant (P<.05) F ratios in the case of only three sections overall.

The teacher practice score used in analysis of data relating to the study hypotheses and other findings was derived by aggregating the scores for each class taught by the teacher in question. In order to further validate both the instrument and the data obtained by student response to S-POLS items, the independent class scores were analyzed by subject area.

Prior to analysis it was necessary to group the subject areas into manageable units. In addition to the five major subject areas (biology, chemistry, physics, general science and earth science), various other less common science subjects were included in four minor areas. In order that subject differences could be compared, the ratio of students at each instructional level (7-9/9-12) was analyzed. Grade 9 students were included in the grade level consistent with other classes taught by the participating teacher. It was established that the ratio of students to teachers, and students to class groups, was comparable and that findings based on results obtained for either level were applicable to the total sample.

The variability in student responses to S-POLS described in the analysis of the instrument response pattern suggested that scores should be analyzed across subject areas. A categorization scheme was used to classify *cluster* subject areas (classes taught by the same teacher) into *like*, *unlike* and *mixed* subject groupings. Score differences were obtained for classes in each category and graphical and tabular results analyzed. Results showed that in the majority of cases the class returns for a participating teacher represented the same subject area. Findings revealed that student responses in same subject classes taught by a participating teacher were more alike than student responses in different subject classes. It was also found that the mean differences for biology and chemistry classes were similar, as were the differences for general science and earth science classes.

The maximum and minimum score differences between classes studying the same subject within clusters were also examined in relation to the overall score range for the major subject areas. In all cases, the cluster differences were shown to be substantially smaller.

Analysis of variance and *t*-test statistics were conducted in order to substantiate the results obtained from the analysis of variance applied to the teacher practice scores by the teaching subject specialty area. Although the teacher practice score was a composite of the subject classes completing S-POLS and the class scores were pure subject measures, nevertheless if S-POLS was in fact measuring what it purported to measure, it was essential that there be some correspondence between the results. This indeed was found to be the case based on a comparative examination of the results. Chemistry scores were higher than other subjects for all sections except Section IX (Specific biological ...) where they were significantly lower. Physics scores were typically lower than others with biology scores generally second only to physics. General science scores were for the most part higher than earth science. Although these findings were not true over all sections, this represented the general trend. However, it was not the results themselves that were of major interest but the consistency of the results over the three analyses.

In order to eliminate student sex as a possible bias in the S-POLS items, the class score results were analyzed statistically. There did not appear to be any evidence that the majority sex of the students influenced either the section, total (I-X) or training area scores.

This investigator concluded from these findings that the T-KOLS scores and the class scores representing the student response to S-POLS items, were in fact providing valid data and that the use of the instruments in testing the hypotheses of the study was justified.

CHAPTER V

RESULTS OF THE STUDY

This study was undertaken to determine the relationship, if any, between the safety knowledge and the student perception of safety practices of science teachers in Oregon secondary schools. In addition, various questions of a demographic nature were studied in relation to teacher safety knowledge and classroom-laboratory safety practices. Two instruments entitled Teacher Knowledge of Laboratory Safety (T-KOLS) and Student Perception of Laboratory Safety (S-POLS) were developed and used to obtain data to test the study hypotheses. A Teacher Background Information Form (T-info) was independently prepared to obtain the required demographic information.

Chapter IV was concerned with an analysis of the field study data which provided support for the validity of the instruments that were constructed for this investigation. This chapter is concerned specifically with tests of the hypotheses which formed the experimental aspect of the study.

This chapter is divided into three main sections:

1. The relationship between the safety knowledge and perceived safety practices of teachers
    a) Tests of correlation
    b) The *t*-statistic
2. Teacher Background Information (T-info)
3. Demographic analysis
    a) Analysis of Variance
    b) Mean Rank Order

Since the data used to test the hypotheses were obtained through the use of newly constructed instruments, the decision was made to accept a ten percent significant level in rejecting the null hypotheses.

Relationship between Knowledge and Practice

Two statistics were employed to assess a possible relationship between knowledge and practice.

> $H_0 1$: There is no relationship between teacher safety knowledge and student perception of classroom-laboratory safety practices of Oregon secondary school science teachers

The degree of association between the teacher knowledge and practice scores was determined by application of the Pearson-*r* correlation coefficient. Scattergrams were also obtained in order to visually examine the findings. The *t*-statistic was applied to the knowledge and practice data to assess the comparability of the mean scores.

Tests of correlation

The degree to which teacher safety knowledge and practice are related was examined by means of scattergrams and the Pearson-*r* correlation coefficient. The criterion measures were the *matched* scores derived from Teacher Knowledge of Laboratory Safety (T-KOLS) and Student Perception of Laboratory Safety (S-POLS). The T-KOLS score was a direct measure, while the teacher safety practice score was an aggregate of student perception scores on S-POLS Sets A-J obtained from students taught by the participating teachers.

The *r*-values obtained for sections and total are shown in Table 5.1 by training areas. Only two section totals showed significance. Section I (Storage and disposal ...) and Section VIII (Electrical, radiation ...).

A significant correlation (P<.10) was shown for Training Areas 2 and 6 for Section X and Training Areas 2 and 3 for Sections II and

TABLE 5.1 T-KOLS and S-POLS: Pearson-r Correlation Coefficients by Training Area

Sect.	Training Area							
	1		2		3		4	
	r-	P-	r-	P-	r-	P-	r-	P-
I	.327	.200	-.062	.801	.138	.423	.133	.599
II	-.167	.536	-.441	.059*	.043	.807	.027	.915
III	-.246	.397	-.348	.145	.344	.058*	-.259	.299
IV	-.261	.412	-.089	.718	.083	.647	-.138	.597
V	-.318	.340	-.255	.385	.203	.281	-.031	.910
VI	.353	.197	.168	.465	.030	.869	.266	.302
VII	-.097	.741	-.374	.139	.038	.840	-.216	.422
VIII	.442	.131	.344	.175	.175	.329	.397	.103
IX	-.081	.803	.175	.460	-.075	.689	-.338	.200
X	-.348	.223	.530	.024**	-.090	.624	-.015	.956
Total	-.091	.830	-.165	.528	.132	.494	-.269	.374

Sect.	Training Area							
	5		6				TOTAL	
	r-	P-	r-	P-			r-	P-
I	.277	.338	.161	.583			.234	.011**
II	-.378	.182	.343	.230			.001	.993
III	.396	.161	.073	.814			.013	.891
IV	.374	.188	.330	.249			.056	.565
V	.010	.975	-.033	.923			-.049	.629
VI	.113	.700	.024	.938			.115	.226
VII	-.175	.567	-.170	.598			-.161	.104
VIII	-.016	.959	-.234	.442			.171	.077*
IX	.014	.963	.085	.803			-.104	.298
X	.120	.696	-.587	.074*			-.074	.456
Total	.456	.159	.017	.966			.024	.825

**P <.05 *P <.10

III respectively.

Since few significant correlations between T-KOLS and S-POLS scores were found for a majority of the sections, totals, or training area scores, the scattergrams, although available, are not reproduced for examination.

Paired-*t* ratio

Means, *t*-ratios and probabilities for section and total scores are shown by training area and for all training areas combined in Table 5.2. Probabilities are at the .01 level or lower for all training areas except Training Area 6 which has a probability of .013. Furthermore, the section totals also show high significant values except for Section III. Although significance levels for individual training areas vary, they are high in most instances.

In studies where interest lies in looking for differences between the averages of two measurements, a null hypothesis of no difference is used and a significant *t*-statistic then allows the investigator to conclude that differences do in fact exist. In this case, however, interest lies in showing that there *is* a relationship between the two measures, which may be interpreted as the two measures having equal means. Thus, a significant *t*-statistic for this study suggests that the means were not equal, and the conclusion is drawn that there is *no relationship* between the two measures.

Tests of Hypothesis H_O1

Based on both the tests of correlation and the paired-*t*, the null hypothesis H_O1 of no relationship between teacher safety knowledge and student perception of classroom-laboratory safety practices of Oregon secondary school science teachers is not refuted.

Teacher Background Information: T-info

The T-info data, converted to percentage response, is displayed in Table 5.3.

TABLE 5.2 T-KOLS and S-POLS: Paired Sample *t*-test Ratios by Training Areas

	Know Mean	Pract Mean	t-	P-	d.f.	Know Mean	Pract Mean	t-	P-	d.f.	Know Mean	Pract Mean	t-	P-	d.f.
							Training Area								
			1					2					3		
I	12.65	12.02	.76	.456	16	12.47	12.29	.31	.758	18	14.69	13.44	2.33	.026**	35
II	11.38	13.01	-1.58	.135	15	11.84	14.71	-5.07	.000**	18	12.63	14.30	-2.88	.007**	34
III	11.21	11.80	- .57	.577	13	12.95	12.42	.62	.543	18	12.06	12.66	-1.43	.162	32
IV	10.92	7.43	2.56	.026**	11	10.42	8.63	2.42	.026**	18	12.03	8.95	5.44	.000**	32
V	13.45	13.69	- .20	.844	10	12.88	14.93	-2.34	.033**	16	14.00	14.34	- .62	.537	29
VI	15.33	10.45	6.77	.000**	14	15.76	10.29	9.02	.000**	20	16.88	10.31	12.06	.000**	31
VII	14.86	13.02	1.54	.147	13	15.76	14.36	1.92	.073*	16	16.48	13.20	6.88	.000**	30
VIII	13.92	12.05	3.01	.011**	12	14.28	12.26	3.62	.002**	17	15.33	12.09	7.42	.000**	32
IX	12.58	10.59	1.59	.140	11	13.00	11.57	2.17	.043**	19	13.84	10.19	5.40	.000**	30
X	11.36	9.92	1.04	.317	13	11.72	9.87	3.18	.005**	17	12.72	9.91	4.93	.000**	31
Total	139.13	108.55	4.87	.002**	7	132.12	122.43	3.51	.003**	16	142.79	119.24	7.67	.000**	28
							Training Area								
			4					5					6		
I	13.83	12.42	2.23	.040**	17	12.86	12.26	.63	.538	13	14.21	12.98	1.53	.151	13
II	11.61	13.76	-2.99	.008**	17	11.36	11.66	- .25	.805	13	12.07	13.62	-2.08	.058*	13
III	12.94	12.49	.56	.580	17	13.21	12 56	1.15	.270	13	12.85	12.36	.52	.610	12
IV	11.47	7.14	6.14	.000**	16	11.36	7.67	5.39	.000**	13	10.29	8.34	2.51	.026**	13
V	12.38	14.26	-2.20	.044**	15	15.15	14.14	1.16	.268	12	13.82	13.79	.04	.967	10
VI	15.47	10.47	7.38	.000**	16	16.21	9.41	10.09	.000**	13	17.15	9.72	9.54	.000**	12
VII	16.25	13.25	3.01	.009**	15	16.85	11.47	5.44	.000**	12	16.00	13.13	3.19	.009**	11
VIII	13.56	12.64	1.42	.175	17	15.92	12.73	3.99	.002**	12	15.23	12.31	2.49	.028**	12
IX	10.94	11.04	- .08	.937	15	13.54	10.03	3.53	.004**	12	12.45	10.39	1.62	.137	10
X	12.24	9.76	3.24	.005**	16	12.31	10.05	2.02	.066*	12	12.70	9.95	1.59	.147	9
Total	134.23	117.22	3.55	.004**	12	139.27	111.08	5.68	.000**	10	138.44	117.54	3.18	.013**	8
							TOTAL (All Training Areas)								
I	13.64	12.70	3.32	.001**	117										
II	11.95	13.72	-5.53	.000**	115										
III	12.49	12.44	.17	.863	110										
IV	11.23	8.20	9.55	.000**	108										
V	13.61	14.27	-1.95	.054*	97										
VI	16.20	10.17	21.83	.000**	111										
Section															
VII											16.10	13.15	8.55	.000**	102
VIII											14.75	12.31	8.84	.000**	107
IX											12.89	10.64	5.62	.000**	102
X											12.23	9.90	6.40	.000**	103
TOTAL											138.20	117.37	11.34	.000**	86

** P < .05   *P < .10

TABLE 5.3 T-Info: Percentage Response to Demographic Items

1. Amount of Safety Instruction

	Percent Response			
	(a) None	(b) Minimal	(c) Adequate	(d) Extensive
Undergraduate/graduate	27%	42%	28%	1%
Pre-service	52%	33%	11%	0.75%
In-service	49%	31%	14%	3.73%
Personal reading	8%	41%	42%	6%

2. Recency of Safety Instruction

	Percent Response
(a) Within the last 3 years	40%
(b) 3-10 years ago	21%
(c) More than 10 years ago	10%
(d) Never	29%

3. The number of classroom-laboratory accidents

	Percent Response	
	Teacher	Student
(a) Never	40%	22%
(b) Minimal	44%	51%
(c) Several Minor	13%	23%
(d) Serious	0.75%	0.75%
(e) Minor and Serious	1.49%	3.75%

4. Years of Teaching Experience

	Percent Response
(a) 1-3 years	16%
(b) 4-6 years	16%
(c) 7-10 years	13%
(d) 11-20 years	34%
(e) More than 20 years	21%

5. Present science teaching specialty*

Biology	28%
Chemistry	16%
Physics	11%
General Science	28%
Earth Science	17%

6. Instructional Level

(a) Grades 7-9	34%
(b) Grades 9-12	66%

7. Size of School System

(a) Less than 1000 students	41%
(b) 1000 to 3000 students	45%
(c) More than 3000 students	14%

8. Percentage of class time devoted to student "hands on" science activities

(a) 0-25%	22%
(b) 25% to 50%	38%
(c) 50% to 75%	28%
(d) 75% to 100%	12%

*Major subject areas

Response to the T-info items include the following:

1. Half of the teachers reported no safety instruction in their preservice or in-service training. Moreover, forty-nine percent indicated no more than minimal reading in the area of science safety.

2. Although forty percent of respondents recorded some safety training within the last three years, twenty-nine percent revealed that they had never received any safety instruction.

3. Responses in relation to personal and student accidents showed that forty percent of the participating teachers had experienced no personal laboratory accidents, and twenty-two percent reported that no accidents had occurred to students in their classroom. Although a majority of the teachers reported a minimal accident rate for both themselves and their students, a greater frequency of student accidents was reported than teacher accidents.

4. Although few in number, some serious teacher and student accidents were reported.

5. Seventy-eight percent of the teachers reported that they spent at least twenty-five percent of class time on student "hands on" type activities.

Differences in Safety Knowledge of Science Teachers Grouped by Safety-Related Demographic Factors

The F-statistic was applied to T-KOLS scores to test the second study hypotheses--

$H_0 2$: There is no difference between the safety knowledge of Oregon secondary school science teachers and--

1. amount of safety instruction;
2. recency of safety instruction;
3. the number of classroom-laboratory accidents;
4. years of teaching experience;
5. present science teaching specialty;
6. instructional level (Grades 7-9 or 9-12);
7. size of school system;
8. percentage of class time devoted to student "hands on" science activities.

Demographic data were analyzed by section, section combinations and total by means of an analysis of variance applied to the T-KOLS scores. Although relatively few items were shown to be statistically significant, the educational significance of these findings may have implications for the safety training of science teachers. The statistics are presented for T-KOLS in the following manner:

1. Statistical significance:

F-statistic reported for item totals (Sections I-X) only. Statistical significance obtained for section items is summarized in tabular form.

2. Possible educational significance:

Mean rank order of items (from ANOVA) is reported by both sections and total.

The Least Squares Difference (LSD) multiple range test was applied to items where statistical significance was obtained in order to identify the source of group variation.

Statistical Significance

Teacher Knowledge of Laboratory Safety (T-KOLS)

The mean values, sample numbers, F-ratio and level of probability for eight T-info items are given in Table 5.4. Statistical significance was obtained for teacher self-report responses dealing with (*a*) the amount and type of safety instruction, (*b*) years of teaching experience, and (*c*) size of school system. These findings are summarized as follows:

1. Amount and type of safety instruction:

Scores for teachers reporting no undergraduate/graduate safety instruction, no in-service safety instruction and no personal reading in the area of science safety, were significantly lower ($P<.10$) than scores recorded for other groups.

TABLE 5.4 T-KOLS: Analysis of Variance by Demographic Factors

		n	Mean	F-ratio	P-value	Source of Group Variation $^{\Phi}$
1. Amount of Safety Instruction						
(a) Undergraduate/Graduate	None (1)	25	136.52			
	Minimal (2)	39	136.36			
	Adequate (3)	25	142.52			
	Extensive (4)	2	148.50	2.232	.0902 *	Grp 3 and each of Grps 1 & 2
(b) Pre-service	None	52	137.87			
	Minimal	26	138.58			
	Adequate	10	141.10			
	Extensive	1	151.00	.638	.5925	
(c) In-service	None (1)	48	135.90			
	Minimal (2)	24	140.42			
	Adequate (3)	14	142.64			
	Extensive (4)	3	147.33	2.478	.0667 *	Grp 1 and each of Grps 2,3 & 4
(d) Personal Reading	None (1)	8	133.50			
	Minimal (2)	36	136.06			
	Adequate (3)	37	140.76			
	Extensive (4)	8	144.75	2.563	.0601 *	Grp 1 and each of Grps 3 & 4 Grp 2 and Grp 3
2. Recency of Safety Instruction						
Within the last 3 years		35	140.49			
3-10 years ago		20	139.20			
More than 10 years ago		7	136.57			
Never		29	135.66	.992	.4006	
3. The number of classroom-laboratory accidents						
(a) Teacher	Never	38	137.50			
	Minimal	38	138.66			
	Several Minor	10	143.60			
	Serious	1	129.00			
	Minor and Serious	2	128.50	1.055	.3838	
(b) Students	Never	20	136.10			
	Minimal	46	138.37			
	Several Minor	21	138.86			
	Serious	1	156.00			
	Minor and Serious	3	144.00	.397	.4464	
4. Years of Teaching Experience						
1 - 3 years (1)		18	136.39			
4 - 6 years (2)		11	134.18			
7 - 10 years (3)		14	132.57			
11 - 20 years (4)		31	142.81			
More than 20 years (5)		17	139.82	2.717	.0349 **	Grp 4 and each of Grps 2 & 3

(continued)

TABLE 5.4 T-KOLS: Analysis of Variance by Demographic Factors (*continued*)

		n	Mean	F-ratio	P-value	Source of Group Variation $^{\Phi}$
5. Present science teaching specialty						
(a) Biology	Subject	38	138.18			
	Others	53	138.49	.015	.9027	
(b) Chemistry	Subject	28	140.07			
	Others	63	137.60	.863	.3555	
(c) Physics	Subject	16	136.13			
	Others	75	138.84	.709	.4021	
(d) General Science	Subject	46	137.04			
	Others	45	139.711	1.187	.2790	
(e) Earth Science	Subject	21	135.24			
	Others	70	139.30	1.971	.1639	
6. Instructional Level						
Grades 7 - 9		29	135.93			
9 - 12		61	139.69	2.049	.1558	
7. Size of School System						
Less than 1000 students (1)		35	134.60			
1000 to 3000 students (2)		38	140.05			
More than 3000 students (3)		18	142.11	3.294	.0417 **	Grp 1 and each of Grps 2 & 3
8. Percentage of class time devoted to student "hands on" science activities						
0 to 25%		20	135.45			
25% to 50%		37	138.12			
50% to 75%		25	141.12			
75% to 100%		9	138.22	.880	.4548	

$^{**}P < .05$ $^{*}P < .10$ $^{\Phi}$Identified by Least Significant Difference (LSD) test
Group = ( ) for significant items

2. Years of teaching experience:

Teachers with 4-10 years of experience scored significantly lower ($P<.05$) than teachers reporting 11-20 years in the classroom.

3. Size of school system:

Teachers from schools with less than 1000 students scored significantly lower ($P<.05$) than those employed in larger schools.

Differences in Student Perceptions of Classroom-Laboratory Safety Practices of Science Teachers Grouped by Safety-Related Demographic Factors

The *F*-statistic was applied to S-POLS scores to test the third study hypothesis--

$H_0 3$: There is no difference between student perceptions of classroom-laboratory safety practices of Oregon secondary school science teachers and--

1. amount of safety instruction;
2. recency of safety instruction;
3. the number of classroom-laboratory accidents;
4. years of teaching experience;
5. present science teaching specialty;
6. instructional level (Grades 7-9 or 9-12);
7. size of school system;
8. percentage of class time devoted to student "hands on" science activities.

The demographic data were analyzed by section, section combinations, and total by means of an analysis of variance applied to the S-POLS raw scores. Also, a mean rank order of S-POLS scores was obtained.

Statistical Significance

Student Perception of Laboratory Safety (S-POLS)

The mean values, sample numbers, *F*-ratio and level of probability for eight T-info items are given in Table 5.5. Statistical significance was obtained for teacher self-report responses dealing with (*a*) the amount and type of safety instruction, (*b*) the number of classroom-laboratory accidents experienced by the teacher, and (*c*)

TABLE 5.5 S-POLS: Analysis of Variance by Demographic Factors

		n	Mean	F-ratio	P-value	Source of Group Variation Φ
1. Amount of Safety Instruction						
(a) Undergraduate/Graduate	None	36	116.35			
	Minimal	51	115.87			
	Adequate	35	118.38			
	Extensive	3	117.51	.236	.8709	
(b) Pre-service	None	66	115.22			
	Minimal	40	117.82			
	Adequate	16	118.29			
	Extensive	1	121.16	.425	.7353	
(c) In-service	None	60	114.81			
	Minimal	40	116.04			
	Adequate	19	122.44			
	Extensive	5	120.99	1.656	.1802	
(d) Personal Reading	None (1)	12	113.32			
	Minimal (2)	50	115.48			
	Adequate (3)	53	116.66			
	Extensive (4)	8	128.45	2.316	.0793 *	Grp 4 and each of Grps 1,2 & 3
2. Recency of Safety Instruction						
Within the last 3 years		54	117.34			
3-10 years ago		26	117.65			
More than 10 years ago		10	118.72			
Never		37	114.40	.483	.6948	
3. The number of classroom-laboratory accidents						
(a) Teacher	Never (1)	52	113.91			
	Minimal (2)	54	119.20			
	Several Minor (3)	16	115.45			
	Serious (4)	1	136.37			
	Minor and Serious (5)	2	130.36	2.094	.0857 *	Grp 1 and each of Grps 2 & 5
(b) Students	Never	30	114.94			
	Minimal	64	116.77			
	Several Minor	27	117.56			
	Serious	1	123.20			
	Minor and Serious	5	119.22	.237	.9170	
4. Years of Teaching Experience						
1 - 3 years		21	113.86			
4 - 6 years		18	117.64			
7 - 10 years		18	113.67			
11 - 20 years		43	118.55			
More than 20 years		27	117.18	.647	.6301	

(continued)

TABLE 5.5 S-POLS: Analysis of Variance by Demographic Factors (*continued*)

		n	Mean	F-ratio	P-value	Source of Group Variation Φ
5. Present science teaching specialty						
(a) Biology	Subject	59	115.46			
	Others	68	117.69	.813	.3690	
(b) Chemistry	Subject	33	121.21			
	Other	94	115.06	4.959	.0277 **	
(c) Physics	Subject	25	116.59			
	Other	102	116.67	.001	.9774	
(d) General Science	Subject	56	117.36			
	Other	71	116.10	.256	.6137	
(e) Earth Science	Subject	35	117.72			
	Other	92	116.25	.284	.5949	
6. Instructional Level						
Grades 7 - 9		41	70.46			
9 - 12		84	71.76	.473	.4929	
7. Size of School System						
Less than 1000 students		53	116.47			
1000 to 3000 students		55	116.18			
More than 3000 students		19	118.55	.211	.8097	
8. Percentage of class time devoted to student "hands on" science activities						
0 to 25%		26	113.32			
25% to 50%		48	116.53			
50% to 75%		37	116.83			
75% to 100%		16	122.05	1.323	.2699	

**P < .05 *P < .10

$^{\Phi}$Identified by Least Significant Difference (LSD) test
Group = ( ) for significant items

the teaching specialty area. Findings are summarized as follows:

1. Amount and type of safety instruction:

Significance was obtained only for the item dealing with personal reading, when teachers reporting extensive reading in the area of safety scored significantly (P<.10) higher than the other groups reporting lesser degrees, or no reading.

2. The number of classroom-laboratory accidents:

The scores for teachers reporting minimal personal accidents were significantly (P<.10) higher than those shown for teachers listing no accidents.

3. Present science teaching specialty area:

Teachers reporting chemistry as their teaching specialty scored significantly (P<.05) higher than teachers of all other subjects grouped together as one.

Summary of tests of hypotheses H_o2 and H_o3

The rejection of the null hypotheses H_o2 and H_o3 of no difference between the safety knowledge or the student perception of classroom-laboratory safety practices of Oregon secondary school science teachers and each of eight demographic variables is summarized by section and totals in Table 5.6.

Table 5.7 lists this information together with levels of significance for the T-KOLS and S-POLS total scores.

Educational Significance

The mean rank order of safety-related T-info items is reported and compared by section and total for T-KOLS and S-POLS in Table 5.8. This method of data presentation is judged easier to evaluate than a listing of mean values and facilitates comparison of the knowledge and practice findings. Although a rank sum is provided, it is emphasized that this value is not statistically derived, but

TABLE 5.6 T-KOLS and S-POLS: Tests of H_o2 and H_o3 by Section

H_o2: There is no difference between the safety knowledge of Oregon secondary school science teachers based on--

	I.Storage and disposal of chemicals/supplies	II.Apparatus, glassware, equipment and related procedures	III.First aid in the science classroom-laboratory	IV.Eye, face and personal protection	V.Toxic and chemical substances	VI.Your responsibility and liability	VII.Techniques, activities and chemical reactions	VIII.Electrical, radiation and other physical hazards	IX.Specific biological and animal safety	X.Temperature, explosives and fire control	Combo.1: Sections I,II,IV,V,VII and X	Combo 2: Sections VI and VIII	Combo 3: Sections VI and IX	Combo 4: Sections III and VI	TOTAL: Sections I-X
1. amount of safety instruction			☒		☒		☒	☒	☒		☒		☒	☒	☒
2. recency of safety instruction	☒				☒										
3. the number of classroom-laboratory accidents		☒		☒				☒							
4. years of teaching experience	☒							☒				☒			☒
5. present science teaching specialty			☒		☒				☒	☒			☒	☒	
6. instructional level (Grades 7-9 or 9-12)					☒										
7. size of school system	☒				☒		☒				☒	☒			☒
8. percentage of class time devoted to student "hands-on" science activities							☒	☒			☒				

H_o3: There is no difference between the student perception of classroom-laboratory safety practices of Oregon secondary school science teachers based on--

	I.Storage and disposal of chemicals/supplies	II.Apparatus, glassware, equipment and related procedures	III.First aid in the science classroom-laboratory	IV.Eye, face and personal protection	V.Toxic and chemical substances	VI.Your responsibility and liability	VII.Techniques, activities and chemical reactions	VIII.Electrical, radiation and other physical hazards	IX.Specific biological and animal safety	X.Temperature, explosives and fire control	Combo.1: Sections I,II,IV,V,VII and X	Combo 2: Sections VI and VIII	Combo 3: Sections VI and IX	Combo 4: Sections III and VI	TOTAL: Sections I-X
1. amount of safety instruction	☒					☒		☒		☒		☒	☒	☒	☒
2. recency of safety instruction				☒											
3. the number of classroom-laboratory accidents						☒		☒				☒		☒	☒
4. years of teaching experience															
5. present science teaching specialty	☒	☒	☒	☒		☒	☒		☒	☒	☒	☒	☒		☒
6. instructional level (Grades 7-9 or 9-12)			☒			☒			☒						
7. size of school system	☒														
8. percentage of class time devoted to student "hands-on" science activities	☒		☒											☒	

LEGEND:

Rejection of H_o2 = ☒

Rejection of H_o3 = ☒

TABLE 5.7 T-KOLS and S-POLS: Tests of H_o2 and H_o3

Demographic Variable	H_o2 (knowledge)	H_o3 (practice)
1. Amount of safety instruction		
a) Undergraduate/graduate	rejected*	
b) Pre-service		
c) In-service	rejected*	
d) Personal reading	rejected*	rejected*
2. Recency of safety instruction		
3. The number of classroom-laboratory accidents		
a) Teacher		rejected*
b) Students		
4. Years of teaching experience	rejected**	
5. Present science teaching specialty		
a) biology		
b) chemistry		rejected**
c) physics		
d) general science		
e) earth science		
6. Instructional Level		
7. Size of school system	rejected**	
8. Percentage of class time devoted to student "hands on" science activities		

* $P < .10$

** $P < .05$

TABLE 5.8 T-KOLS and S-POLS: Group Mean Rank by Demographic Factors

	Sections											Rank Sum
	I	II	III	IV	V	VI	VII	VIII	IX	X	TOTAL	
	ΦR(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n*)	
1. Amount of Safety Instruction: Undergraduate/Graduate (T-KOLS)												
None	3(34)	1(33)	3(32)	2(32)	1(28)	3(32)	2(30)	3(33)	1(29)	3(31)	2(25)	24
Minimal	2(52)	2(52)	4(49)	3(49)	2(41)	2(49)	1(45)	2(49)	2(48)	1(45)	1(39)	22
Adequate	4(35)	3(34)	2(32)	4(31)	3(30)	1(33)	3(29)	4(29)[b]	3(29)	2(28)	3(25)	32
Extensive	1(3)	4(3)	1(3)	1(3)	4(2)	4(3)	4(3)	1(3)	4(3)	4(3)[a]	4(2)[b]	32
Amount of Safety Instruction: Undergraduate/Graduate (S-POLS)												
None	3	2	2	2	1	1	4	4	1	3	2(36)	25
Minimal	2	1	4	1	3	2	3	1	2	1	1(51)	21
Adequate	4	3	1	4	2	3	2	3	4	4	4(35)	34
Extensive	1	4	3	3	4	4	1	2	3	2	3(3)	30
Amount of Safety Instruction: Pre-Service (T-KOLS)												
None	4(67)	2(64)	2(61)	2(62)	1(56)	2(63)	3(60)	3(64)	1(58)	3(60)	1(52)	24
Minimal	3(39)	3(41)	4(38)	1(37)	2(30)	3(36)	2(32)	2(36)	2(35)	2(32)	2(26)	26
Adequate	2(15)	1(14)	1(14)	3(13)	3(12)	1(15)	4(12)	1(11)	3(13)	1(12)	3(10)	21
Extensive	1(1)	4(1)	3(1)	4(1)	4(1)	4(1)	1(1)	4(1)	4(1)	4(1)[a]	4(1)	37
Amount of Safety Instruction: Pre-Service (S-POLS)												
None	3	2	2	2	2	4	3	2	3	2	2(66)	15
Minimal	4	4	1	2	2	4	3	2	4	2	2(40)	30
Adequate	2	3	3	4	3	2	1	3	3	3	3(16)	30
Extensive	1	1	4	3	4	1	4	4	1	4[b]	4(1)	31
Amount of Safety Instruction: In-Service (T-KOLS)												
None	2(64)	1(62)	3(61)	3(60)	1(53)	2(62)	1(57)	1(63)	1(59)	2(58)	1(48)	18
Minimal	3(37)	3(37)	4(33)	1(34)	3(29)	3(33)	3(30)	2(31)	2(29)	4(29)	2(24)	30
Adequate	4(18)	3(19)	2(18)	4(17)	2(15)	1(18)	2(16)	3(15)	3(16)	3(16)	3(14)	30
Extensive	1(4)	4(3)	1(3)	2(3)	4(3)[b]	4(3)	4(3)[a]	4(4)	4(3)[a]	1(3)	4(3)[b]	33

Φ Ranking, 1=Lowest

(continued)

TABLE 5.8 Group Mean Rank (R) *continued*

	Sections										TOTAL	Rank Sum
	I	II	III	IV	V	VI	VII	VIII	IX	X		
	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n*)	
Amount of Safety Instruction: In-Service (S-POLS)												
None	1	1	1	1	2	1	3	1	4	1	1(60)	17
Minimal	2	3	2	2	3	3	1	2	1	2	2(40)	23
Adequate	3	4	3	3	4	4	4	3	3	3	4(19)	38
Extensive	4[b]	2	4	4	1	2	2	4[a]	2	4	3(5)	32
Amount of Safety Instruction: Personal Reading (T-KOLS)												
None	1(11)	1(11)	1(11)	2(11)	2(9)	1(11)	2(10)	2(11)	2(10)	3(11)	1(8)	18
Minimal	3(50)	2(49)	3(48)	1(48)	1(41)	2(50)	1(44)	1(49)	1(46)	1(44)	2(36)	18
Adequate	2(53)	3(52)	4(48)[a]	4(47)	3(42)	3(47)	3(44)	3(45)	3(43)	2(43)	3(37)	33
Extensive	4(8)	4(8)	2(8)	3(8)	4(6)	4(8)	4(8)	4(8)	4(8)[a]	4(8)	4(8)[b]	41
Amount of Safety Instruction: Personal Reading (T-KOLS)												
None	1	1	1	1	3	3	1	3	1	1	1(12)	17
Minimal	2	2	2	2	2	2	4	1	3	2	2(50)	24
Adequate	3	3	3	3	1	1	3	2	2	3	3(53)	27
Extensive	4	4	4	4	4	4[a]	2	4	4	4	4(8)[b]	42
2. Recency of Safety Instruction (T-KOLS)												
< 3 years	4(49)[a]	1(49)	3(45)	4(43)	2(40)	3(45)	4(40)	1(42)	3(39)	1(41)	4(35)	30
3-10 years	2(27)	4(27)	2(25)	1(25)	3(22)	2(26)	2(25)	4(26)	4(25)	2(24)	3(20)	29
> 10 years	1(12)	3(10)	1(11)	2(10)	4(9)[a]	1(9)	3(8)	3(10)	2(9)	4(8)	2(7)	26
Never	3(38)	2(38)	4(37)	3(38)	1(31)	4(38)	1(35)	2(37)	1(36)	3(35)	1(29)	25
Recency of Safety Instruction (S-POLS)												
< 3 years	4	3	3	4[b]	1	1	1	2	1	4	2(26)	26
3-10 years	2	4	2	2	3	3	3	3	4	2	3(48)	31
> 10 years	3	2	4	3	4	4	2	4	3	3	4(37)	36
Never	1	1	1	1	2	2	4	1	2	1	1(16)	17

(*continued*)

TABLE 5.8 Group Mean Rank (R) *continued*

	Sections											Rank
	I	II	III	IV	V	VI	VII	VIII	IX	X	TOTAL	Sum
	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n*)	
3. The number of classroom-laboratory accidents: Teacher (T-KOLS)												
Never	3(49)	5(41)[b]	3(47)	3(45)	2(41)	4(48)	4(42)	2(47)	4(45)	2(44)	3(38)	35
Minimal	1(55)	2(55)	2(51)	4(50)	3(43)	5(51)	2(48)	3(50)	3(47)	3(48)	4(38)	34
Several Minor	2(17)	4(17)	4(15)	2(16)	5(13)	3(14)	3(48)	5(13)[b]	5(12)	4(11)	5(10)	42
Serious	4(1)	3(1)	1(1)	1(1)	4(1)	1(1)	5(13)	4(1)	2(1)	5(1)	2(1)	32
Minor and Serious	5(2)	1(2)	5(2)	5(1)[a]	1(2)	2(2)	1(2)	1(2)	1(2)	1(2)	1(2)	24
The number of classroom-laboratory accidents: Teacher (S-POLS)												
Never	1	1	1	1	2	1	1	1	3	2	1(52)	15
Minimal	4	4	3	3	4	3	3	2	2	3	3(54)	34
Several Minor	5	2	2	2	1	2	2	3	1	1	2(16)	23
Serious	2	3	5	5	5	5[b]	4	4	5	5	5(1)[b]	48
Minor and Serious	3	5	4	4	3	4	5	5[a]	4	4	4(2)	45
The number of classroom-laboratory accidents: Students (T-KOLS)												
Never	3(26)	4(26)	1(26)	5(25)	1(22)	2(26)	4(22)	1(24)	4(24)	2(24)	1(20)	28
Minimal	3(63)	1(62)	3(59)	3(57)	3(51)	3(62)	1(57)	2(60)	3(57)	1(57)	2(46)	25
Several Minor	4(31)	2(30)	2(28)	1(29)	4(24)	1(25)	2(24)	4(26)	2(24)	4(22)	3(21)	29
Serious	5(1)	5(1)	5(1)	2(1)	5(1)	5(1)	5(1)	3(1)	1(1)	5(1)	5(1)	46
Minor and Serious	1(5)	3(5)	4(4)	4(4)	2(4)	4(4)	3(4)	5(4)	5(3)	3(4)	4(3)	38
The number of classroom-laboratory accidents: Students (S-POLS)												
Never	1	2	1	3	2	1	1	2	5[b]	4	1(30)	23
Minimal	3	4	2	2	3	2	2	4	2	3	2(64)	29
Several Minor	2	3	3	4	1	4	3	5	3	2	3(27)	33
Serious	5	1	5	1	5	5	5	3	4	1	5(1)	40
Minor and Serious	4	5	4	5	4	3	4	1	1	5	4(5)	40

(continued)

TABLE 5.8 Group Mean Rank (R) *continued*

	Sections											Rank Sum
	I	II	III	IV	V	VI	VII	VIII	IX	X	TOTAL	
	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n*)	
4. Years of Teaching Experience (T-KOLS)												
1 - 3 years	3(21)	2(21)	1(21)	5(20)	2(18)	4(21)	2(19)	1(19)	5(20)	3(19)	3(18)	31
4 - 6 years	2(18)	1(18)	5(16)	4(16)	4(13)	2(17)	1(13)	2(17)	2(15)	4(15)	2(11)	29
7 -10 years	4(17)	3(17)	2(15)	1(16)	1(14)	1(17)	3(16)	3(16)	3(16)	1(15)	1(14)	21
11-19 years	5(44)[a]	4(42)	4(41)	3(39)	5(35)	5(38)	5(37)	4(40)	4(37)	2(37)	5(31)	46
> 20 years	1(27)	5(26)	3(25)	2(25)	3(22)	3(25)	4(23)	5(23)[a]	3(21)	5(22)	4(17)	38
Years of Teaching Experience (S-POLS)												
1 - 3 years	1	1	1	2	2	3	1	1	1	3	1(21)	17
4 - 6 years	5	5	2	1	4	1	5	4	5	1	4(18)	37
7 -10 years	3	3	4	3	1	2	4	2	2	4	3(18)	31
11-19 years	4	4	5	4	5	5	3	5	4	5	5(43)	49
> 20 years	2	2	3	5	3	4	2	3	3	2	2(27)	31
5. Present Science Teaching Specialty												
T-KOLS: Biology	2(55)	2(53)	1(51)	1(49)	1(39)	2(48)	1(41)	1(45)	2(48)	1(43)	1(38)	15
Non Biology	1(71)	1(71)	2(67)	2(67)	2(63)	1(70)	2(67)	2(70)[b]	1(61)	2(65)	2(53)	18
S-POLS: Biology	1	2	2	1	2	1	1	1	2	1	1(59)	15
Non Biology	2	1	1	2[b]	1	2[b]	2	2	1	2[b]	2(68)	18
T-KOLS: Chemistry	2(35)	1(35)	2(35)	2(34)	2(33)[b]	2(35)	2(35)	2(34)	2(30)	2(35)	2(28)	21
Non Chemistry	1(91)	2(89)	1(83)	1(82)	1(69)	1(83)	1(73)	1(81)	1(79)	1(73)	1(63)	12
S-POLS: Chemistry	2[a]	2	2[b]	2[a]	2	2	2[a]	2	1	2[a]	2(33)[a]	21
Non Chemistry	1	1	1	1	1	1	1	1	2	1	1(94)	12
T-KOLS: Physics	1(25)	1(25)	2(24)	1(24)	2(24)	1(25)	2(24)	2(25)	1(18)	2(24)	1(16)	16
Non Physics	2(101)	2(99)	1(94)	2(92)	1(76)	2(93)	1(84)	1(90)	2(91)	1(84)	2(75)	17
S-POLS: Physics	2	1	1	1	1	2	2[a]	2	1	1	1(25)	15
Non Physics	1	2	2	2	2	1	1	1	2	2	2(102)	18

(continued)

TABLE 5.8 Group Mean Rank (R) *continued*

	Sections										TOTAL	Rank Sum
	I	II	III	IV	V	VI	VII	VIII	IX	X		
	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n*)	
Present Science Teaching Specialty *continued*												
T-KOLS: General Sc.	2(58)	1(57)	1(54)	2(53)	2(49)	1(54)	1(52)	2(53)	1(50)	1(50)	1(46)	15
Non General Sc.	1(68)	2(67)	2(64)	1(63)	1(53)	2(64)	2(56)	1(62)	2(59)	2(58)	2(45)	18
S-POLS: General Sc.	1	1	1	2	1	2	2	2	2	2^b	2(56)	18
Non General Sc.	2	2	2	1	2	1	1	1	1	1	1(118)	15
T-KOLS: Earth Sc.	1(35)	2(35)	1(32)	1(31)	1(26)	1(32)	1(29)	2(29)	1(28)	1(29)	1(21)	13
Non Earth Sc.	2(91)	1(89)	2(86)^a	2(85)	2(76)^a	2(86)	2(79)	1(86)	2(81)^b	2(79)	2(70)	20
S-POLS: Earth Sc.	1	2	2	1	2	2	2	2	2	1	2(35)	19
Non Earth Sc.	2^b	1	1	2	1	1	1	1	1	2^b	1(92)	14
6. Instructional Level (T-KOLS)												
Grades 7-9	1(42)	2(40)	1(38)	1(38)	1(32)	1(39)	1(36)	2(40)	1(38)	1(36)	1(29)	13
Grades 9-12	2(82)	1(82)	2(79)	2(77)	2(69)^b	2(78)	2(71)	1(74)	2(70)	2(71)	2(61)	20
Instructional Level (S-POLS)												
Grades 7-9	1	1	2	1	2	2^b	1	1	2^a	1	1(41)	15
Grades 9-12	2	2	1	2	1	1	2	2	1	2	2(84)	18
7. Size of School System (T-KOLS)												
< 1000	1(52)	2(51)	2(49)	1(46)	1(42)	1(49)	1(46)	1(48)	1(44)	1(47)	1(35)	13
1000-3000	2(55)	1(54)	1(51)	2(52)	3(42)^a	2(51)	2(44)	2(49)	2(47)	3(43)	2(38)	22
> 3000	3(19)^a	3(19)	3(18)	3(18)	2(18)	3(18)	3(18)^b	3(18)^b	3(18)	2(18)	3(18)^a	31
Size of School System (S-POLS)												
< 1000	1	1	2	1	3	3	3	1	3	1	2(53)	21
1000-3000	2	2	1	2	1	1	2	2	2	3	1(55)	19
> 3000	3^b	3	3	3	2	2	1	3	1	2	3(19)	26

(continued)

TABLE 5.8 Group Mean Rank (R) *continued*

	Sections										TOTAL	Rank Sum
	I	II	III	IV	V	VI	VII	VIII	IX	X		
	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n)	R(n*)	
8. Percent of class time devoted to student "hands on" science activities (T-KOLS)												
0 -25%	1(26)	4(27)	3(26)	1(26)	1(20)	1(27)	1(25)	1(26)	1(26)	1(23)	1(20)	16
25%-50%	4(49)	2(49)	1(48)	2(47)	3(42)	2(47)	2(41)	3(46)	3(44)	4(43	2(37)	28
50%-75%	3(35)	3(32)	2(30)	4(29)	4(28)	3(31)	3(29)	2(29)	2(28)	3(29)	4(25)	33
75%-100%	2(16)	1(16)	4(14)	3(14)	2(12)	4(13)	4(13)^{a}	4(14)^{a}	4(11)	2(13)	3(9)	33
Percent of class time devoted to student "hands on" science activities (S-POLS)												
0 -25%	1	1	1	1	2	1	3	2	4	1	1(26)	18
25%-50%	2	4	3	2	3	3	4	1	1	2	2(48)	27
50%-75%	3	2	2	3	1	2	1	3	3	3	3(37)	26
75%-100%	4^{a}	3	4^{a}	4	4	4	2	4	2	4	4(16)	39

$^{a}p < .05$ $^{b}p < .10$

*Number of cases for S-POLS Sections as shown for Total is merely the addition across section and total columns of the rank order numbers. Section and total mean differences which were found to be statistically significant are identified at both P<.10 and P<.05 levels respectively.

Since the rank order tabulations are relatively self-explanatory, the following overview will be restricted to a general summary of the results shown by the ranked means. In order to avoid textual repetition, reference is made to the practice and knowledge scores respectively, and not to the *mean rank order* or *mean rank sum* as the case may be.

1. Amount of Safety Instruction:

In all four areas (*a*) undergraduate/graduate laboratory courses, (*b*) pre-service teacher education, (*c*) in-service teacher education and (*d*) personal reading, the teachers recording *minimal* or *no* safety instruction attained lower practice and knowledge scores overall than did the group checking *adequate* instruction. Although the sample numbers were too small for conclusive results to be obtained for the group reporting *extensive* safety instruction, both the knowledge and practice scores were higher overall for these teachers.

2. Recency of Safety Instruction:

The knowledge scores for teachers reporting safety instruction *within the last ten years* were somewhat higher overall than those checking instruction *more than ten years* previously. This was not true for practices, however, although the group with *over ten years* of experience showed higher scores both overall and for the total. In this case, teachers reporting instruction *within the last three years* attained high scores on those sections related more specifically to chemical hazards.

3. Classroom-laboratory accidents:

The knowledge scores were higher for teachers recording *several* personal *minor* accidents than they were for those checking *minimal* or *no* accident occurrences. Although this was also true in the case of student accidents, the differences were not as great. Teachers reporting *no* personal or student occurrences showed the lowest practice scores in each case. The highest practice and knowledge scores overall were in most instances attained by those teachers recording *serious* accidents, although the sample numbers were generally too small for the findings to be conclusive.

4. Years of Teaching Experience:

The lowest knowledge scores were shown for teachers listing *7 - 10* years of teaching experience and the highest for the groups recording *more than ten* years in the classroom. This differed for practices, where the *1 - 3* year teachers showed the lowest scores both overall and for the total. For both knowledge and practice the *11 - 19* year group scored substantially higher than others overall.

5. Present Science Teaching Specialty:

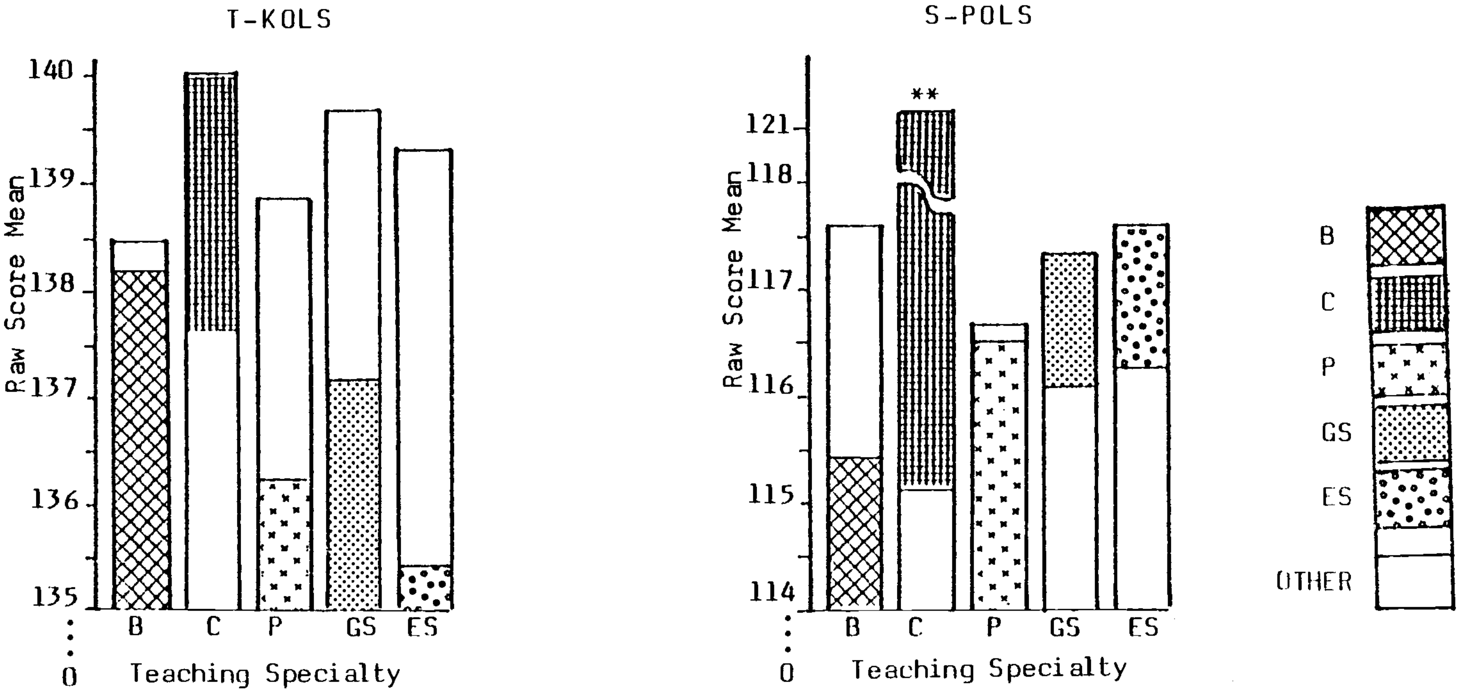
Although both *general science* and *earth science* teachers scored higher than teachers of *all other subjects* except the given subject areas for practices, *chemistry* teachers were the only group which scored higher than *others* for both knowledge and practice. A graphical representation of the subject groupings is shown for the total in Figure 5.1.

6. Instructional Level:

The *9 - 12* level teachers scored higher than the *7 - 9* group both overall and for the knowledge and practice total.

7. Size of School system:

In general, the knowledge scores reflected the size of the school system, with teachers from smaller (< *1000*) systems scoring lower than those from larger (> *3000*) schools. However, although the practices of teachers from the larger schools were higher overall, the group teaching in smaller schools (< *1000*) scored somewhat higher than the middle group (*1000 - 3000*) over several sections and the total.



$^{**}P<.05$

(B=Biology; C=Chemistry; P=Physics; GS=General Science; ES=Earth Science; OTHER=All subjects other than given subject)

FIGURE 5.1 T-KOLS and S-POLS: Analysis of Variance by Teaching Specialty

8. Percentage of Class Time devoted to Student *hands on* Science Activities:

In the case of both knowledge and practice, the scores appeared to be directly related to the amount of class time devoted to laboratory or "hands on" science activities. The highest scores were attained by teachers recording the greatest amount of practical activity during the scheduled class period. However, for knowledge, there was little difference in the scores of the two groups reporting more than *fifty percent* practical activity, while for practices there was little difference in the scores of teachers devoting between *twenty-five* to *seventy-five percent* of class time on laboratory type work.

Summary

The results obtained from testing the three hypotheses forming the experimental phase of the study showed that:

1. There was no relationship ($P<.05$) between the safety knowledge of secondary school science teachers in Oregon and, based on student perceptions, their safety practices in the classroom-laboratory .... H_o1

2. There was a difference in the safety knowledge scores of secondary school science teachers in Oregon and *(a)* the amount of safety instruction received in undergraduate/graduate laboratory science classes ($P<.10$), *(b)* the amount of safety instruction received during in-service training ($P<.10$), *(c)* the amount of personal reading relating to safety ($P<.10$), *(d)* the years of teaching experience ($P<.05$) and *(e)* the size of school system ($P<.05$) .... H_o2

3. There was a difference in the student perception of safety practices of secondary school science teachers in Oregon and *(a)* the amount of personal reading relating to safety ($P<.10$), *(b)* the number of classroom-laboratory accidents experienced by the teacher ($P<.10$) and *(c)* the teaching subject specialty area of chemistry ($P<.05$) .... $H_0 3$

Significant findings for section items for T-KOLS and S-POLS were provided in tabular form. In addition to statistical significance, the possible educational significance of the findings was shown by a ranked ordering of mean knowledge and practice values for each of the eight demographic factors.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this study was to investigate the relationship, if any, between the safety knowledge and student perception of the classroom-laboratory safety practices of secondary school science teachers. It was further concerned with relationships that may exist between selected demographic factors and both (*a*) teacher safety knowledge, and (*b*) student perceptions of their teachers' classroom-laboratory safety practices.

No satisfactory safety knowledge or practice tests were available to be adapted for use in this investigation. For this reason, a major focus of the study was the preparation of appropriate data-collecting instruments.

An Instructor's Resource Guide prepared by the Council of State Science Supervisors (CS^3) in conjunction with the National Institute for Occupational Safety and Health (NIOSH) provided criteria for the safety topics. A Delphi exercise was conducted to refine the assessment instruments thereby helping to assure instrument validity and reliability.

The resulting Teacher Knowledge of Laboratory Safety (T-KOLS) and Student Perception of Laboratory Safety (S-POLS) tests were pilot tested in the state of Washington. A field study was conducted in Oregon to obtain data for use in testing the experimental hypotheses.

Preparation of the Instruments

Two instruments were developed for this investigation. These were (*a*) Teacher Knowledge of Laboratory Safety (T-KOLS) and (*b*) Student Perception of Laboratory Safety (S-POLS). An Instructor's

Resource Guide (IRG) prepared by NIOSH in conjunction with CS^3 was the criterion used in the identification of safety topics to be measured by the two instruments.

The acronym SAFETY TEST was coined from the first letter of each of ten safety areas measured by the instruments. This acronym related T-KOLS to S-POLS and provided a common theme in their construction. Each instrument was comprised of ten 10-item sections which represented the following safety areas:

	Section
Storage and disposal of chemicals/supplies	I
Apparatus, glassware, equipment and related procedures	II
First aid in the science classroom-laboratory	III
Eye, face and personal protection	IV
Toxic and chemical substances	V
Your responsibility and liability	VI
Techniques, activities and chemical reactions	VII
Electrical, radiation and other physical hazards	VIII
Specific biological and animal safety	IX
Temperature, explosives and fire control	X

A bank of 500 objective items was prepared and formed the Preliminary T-KOLS draft. These items were written as topic statements with three possible response alternatives. One hundred related items were constructed in "likert-scale" format as the Preliminary S-POLS draft. These were later re-written as multi-choice items and divided into ten 10-item student Sets, A-J. Each of the ten items of a set represented each of the ten safety areas, I-X.

Preliminary drafts of T-KOLS and S-POLS were reviewed by science teachers and graduate students attending classes in science education at Oregon State University. Following this initial review, the instruments were revised and the Round 1 draft prepared for mailing to the Delphi Panel.

The Delphi Panel was composed of three groups: (a) CS^3 members, (b) science educators, and (c) safety professionals. A letter mailed to one hundred selected individuals inviting their participation in the Delphi exercise also contained the Round 1 material for their perusal. A forty-two percent Delphi Panel response was obtained for Round 1 and a fifty-two percent response for Round 2. An eighty-one percent response was obtained for Round 3 which included only those individuals who had participated in at least one previous round. Thirty-seven panelists served on all three rounds, thirteen on two rounds, and five on one round only.

Between group and within group panel concensus was sought in relation to the major tasks of the Delphi Panel over the three rounds. These tasks included--

1. selection of the 100 "best" items from the 500 item bank constituting the Round 1 draft of T-KOLS;
2. review, selection and/or substitution of the 100 S-POLS items included in the Round 1 draft;
3. confirmation of the "best answer" and other response alternatives for both instruments;
4. constructive feedback in response to recommendations and/or critique elicited by panelists over previous rounds.

Pilot studies involving the use of both instruments were conducted in Washington state during the latter stages of the Delphi exercise. Information and critique obtained from these pre-trials were important both to the final selection of items and to the logistics involved in planning the Oregon field study.

The Field Study

Using the population of science teachers within the state of Oregon as the target group, cluster sampling with probability proportional to size was conducted. The forty-five geographic/demographic areas, identified as providing appropriate teacher groupings for proposed safety training workshops to be conducted by the Department of Education, were utilized to identify teachers for this study. Students of the selected teachers were identified by school personnel.

Statistical requirements of the study were met by a sample of ninety-one, ten percent of the science teachers employed in Oregon public secondary schools for the 1979-80 school year. This was double the minimum five percent requirement recommended for a study of this nature.

To ensure maximum cooperation from both the selected teacher sample and school administrators, the utmost care was taken in the preparation and packaging of all materials. Xerox photocopy reproductions were used throughout and each set of instruments and related information was placed in separate envelopes within an outer envelope appropriately labelled. The pre-coded packets were hand-delivered to, and collected from, the schools concerned, thereby providing personal contact with school personnel. This permitted the necessary discussion regarding the purposes of the study.

Teacher and student responses to T-KOLS and S-POLS together with related demographic information were coded and transferred to computer punch cards for scoring and data analysis. Computer programs available from the SPSS Library at Oregon State University were used to obtain frequency distributions, correlation coefficients, t-ratios, analysis of variance, and other test statistics.

Analysis of the Field Study Data

A total of 145 teachers was obtained from a twenty percent sample draw from the Oregon Secondary School science teachers. Of this number, 89 teachers returned the set of two instruments fully completed. Single and or partially completed instruments were submitted by 56 teachers. These were utilized where section or total knowledge or practice scores were independently analyzed.

Student returns totalled 8003 or approximately 55 students per teacher. This number also met the statistical requirements of the study based on a projected five-student response minimum to each of ten items in each S-POLS set (A-J) by students of each teacher.

For practical purposes, therefore, with a total of 145 teachers and approximately 55 students per teacher, the aim of producing a sample of Oregon science teachers and students representative of the target population was achieved.

Item analysis, based on the frequency response/no response to each of the 200 items comprising the two instruments was conducted and the results tabulated for the three item response alternatives. Comparative analysis of the T-KOLS and S-POLS item response frequencies was also conducted by section and Total (I-X). Graphical and tabular examination revealed similarities in the knowledge and practice response alternatives over several sections.

Frequency tabulations of the scored instruments were analyzed in order to ensure that item responses were adequate and that the weighted scoring scheme was appropriate. In order to establish that the instruments were measuring what they purported to measure, the training area scores were analyzed independently on the basis of their demographic nature.

Since the teacher safety practice score was an indirect measure based on student perceptions, the class scores were independently analyzed. Classes were divided into five major subject areas (biology, chemistry, physics, general science and earth science) and four minor areas. Classes taught by the same participating teacher (clusters) were analyzed for S-POLS score differences by subject area. Analysis also included examination of student returns based on subject and instructional level, and the possible effect of student sex on the class scores. All findings appeared to support the adequacy, and thus the validity of the student instrument, S-POLS.

Results of the Study

Appropriate statistical measures were used to test the three study hypotheses:

$H_0 1$: There is no relationship between teacher safety knowledge and student perception of classroom-laboratory safety practices of Oregon secondary school science teachers.

Pearson-*r* correlation coefficients for matched T-KOLS and S-POLS scores were not statistically significant. Only two test sections showed a significant correlation.

A paired-*t* test was applied to mean T-KOLS and S-POLS scores. This test showed the test scores to be significantly $(P<.10)$ different which is interpreted to mean no statistically significant relationship between safety knowledge and practice. Thus hypothesis H_o1 is not refuted.

H_o2: There is no difference between the safety knowledge of Oregon secondary school science teachers and--

1. amount of safety instruction;
2. recency of safety instruction;
3. the number of classroom-laboratory accidents;
4. years of teaching experience;
5. present science teaching specialty;
6. instructional level (Grades 7-9 or 9-12);
7. size of school system;
8. percentage of class time devoted to student "hands-on" science activities.

An analysis of variance test (the *F*-statistic) revealed significance $(P<.10)$ in the total mean T-KOLS scores for the following demographic factors:

1. Amount of safety instruction in undergraduate/graduate science classes

2. Amount of in-service safety instruction

3. Amount of personal reading related to laboratory safety

4. Years of teaching experience

5. Size of school system

Hypothesis H_o2 is thus refuted for these five demographic factors.

There is no difference between student perceptions of classroom-laboratory safety practices of Oregon secondary school science teachers and--

7. amount of safety instruction;
2. recency of safety instruction;
3. the number of classroom-laboratory accidents;
4. years of teaching experience;
5. present science teaching specialty;
6. instructional level (Grades 7-9 or 9-12);
7. size of school system;
8. percentage of class time devoted to student "hands-on" science activities.

The *F*-statistic revealed significance ($P<.10$) in the total mean S-POLS scores for the following demographic factors:

1. Amount of personal reading related to laboratory safety

2. The number of personal laboratory accidents experienced by the teacher

3. Scores of chemistry teachers compared to teachers of all other subjects

Hypothesis $H_0 3$ is thus refuted for these three demographic factors.

Instrument Reliability

The internal consistency of the instruments was determined by split-half techniques. A full-test Spearman-Brown reliability coefficient of .64 was calculated for T-KOLS and .77 for S-POLS. Reliability estimates that reflect stability of performance over a short time as provided by the test-retest or alternate-form procedure are recommended (Wesman 1958) as being more important for most educational purposes. Unfortunately, the logistics of the present study did not permit testing to be followed by retesting.

Reliability coefficients of .64 and .77 were judged to be adequate for newly constructed instruments. Travers (1978) contends that newly constructed instruments "must be reworked over years of use to continually improve both their reliability and validity."

Instrument Validity

Content validity of T-KOLS and S-POLS may be inferred from (*a*) the close correlation between the instrument items and the IRG recently developed by the Council of State Science Supervisors in conjunction with NIOSH, and (*b*) the Delphi exercise in which a panel of science "safety experts" consisting of CS^3 members, science educators and safety-professionals reacted to the instruments, the test items, and keying of the instruments.

Analyses of field study data resulted in significant *F*-ratios between mean T-KOLS scores and teacher self-assessment of (*a*) amount of safety training in undergraduate and graduate science classes, (*b*) amount of in-service safety instruction, and (*c*) amount of personal reading on science safety. Furthermore, similar rank sum means for safety knowledge (T-KOLS) and practice (S-POLS) scores for several safety related demographic items suggests that these two instruments may be measuring the same thing. These findings along with apparently parallel findings for certain demographic items in this study and studies by Brennan (1970) and Young (1970) provide support for the content validity of T-KOLS and S-POLS.

Relationship of the findings to other studies

Although in most instances not statistically significant, there appears to be some parallel between the results obtained in the present investigation and the findings of other researchers. Young (1970) for example, reported that the highest frequency of accidents occurred during the first four years of teaching. In the present study, this investigator found the lowest mean S-POLS scores for teachers reporting 1-3 years of teaching experience.

Brennan, however, reported a gradual increase in the accident rate for teachers with 1-10 years of experience, followed by a sharp decline for those with 11-25 years of experience. A second increase in accidents then occurred after that time. These findings are also not inconsistent with results obtained in this study which revealed that teachers with 7-10 years of experience not only attained the lowest knowledge mean scores overall, but that a definite increase in both knowledge and practice scores occurred for teachers reporting 11-19 years of experience. In addition, a decrease was shown in both knowledge and practice mean scores of teachers with over twenty years of teaching experience.

In view of Brennan's finding that chemistry is a high hazard area of the science program, it was gratifying to note that substantially higher knowledge and practices scores were attained by chemistry teachers in comparison with teachers of other subjects.

Brennan also reported a significant relationship between the number of years of teaching experience and the frequency of laboratory accidents reported by teachers who had not participated in safety programs. In this study, both knowledge and practice mean scores tended to be lower for those teachers who had received little, or no, safety instruction. A nonsignificant relationship was found between recency of safety instruction and practice mean scores which may have educational relevance.

Conclusions

The Instruments

Two instruments designed to measure teacher knowledge of laboratory safety (T-KOLS) and student perception of laboratory safety (S-POLS) were prepared as a major part of this investigation. Based on (*a*) the methods used in preparation of the instruments, (*b*) analysis of the field study data, and (*c*) results of the study, the investigator concludes that these instruments satisfactorily met the requirements of content validity. Instrument reliability coefficients computed by the use of Spearman-Brown and other formulae were considered to be at acceptable levels.

The Field Study

The sample number of 145 science teachers and 8003 of their students exceeded the statistical requirements recommended for the study. This investigator concludes that the hand delivery and subsequent collection of materials to and from the schools contributed substantially to the relatively high percentage returns. In addition, the production and packaging of instruments that teachers and administrators perceived to be of professional quality provided an additional incentive to both school administrators and teachers to participate in the study. Evidence of administrative interest in the nature of the project was also borne out by the fact that teachers employed in fifty-six of the fifty-nine schools within the sampled areas contributed to the study.

The Findings

This investigator concludes from Pearson-*r* correlation coefficients between matching T-KOLS and S-POLS scores and a paired-*t* test applied to mean T-KOLS and S-POLS scores obtained for this study that there is no significant relationship between safety knowledge and safety practices of Oregon secondary school science teachers.

Significant ($P<.10$) *F*-ratios between mean T-KOLS scores and teacher self-reporting of selected safety-related demographic factors permit this investigator to conclude that the science safety knowledge of teachers may be related to (*a*) the amount of safety instruction received in undergraduate and graduate science courses, (*b*) amount of in-service safety instruction, (*c*) amount of personal reading related to safety, (*d*) years of teaching experience, subject taught, and (*e*) size of school system.

Recommendations

This study dealt largely with the development and field testing of instruments to measure the safety knowledge and practices of secondary school science teachers. Two sets of recommendations that follow pertain to further use and refinement of T-KOLS and S-POLS. The safety status of Oregon secondary school science teachers and need for further research in this area are subjects of two sets of recommendations.

Refinement of the data collecting materials

It is recommended that--

1. Items of T-KOLS be re-written in conventional objective-type format and results of the use of this revised instrument be compared with the results obtained in the immediate study.

2. S-POLS be prepared as two separate fifty-item inventories (one for the 7-9 and the other for the 9-12 level) and that findings of studies using the 50-item instruments be compared to the present study using the 100-item instrument.

3. S-POLS be revised with a shorter stem and multiple response alternatives requiring students to check one or more responses as necessary for each item stem. This form of instrument would require a revised scoring scheme.

4. T-info be revised to include more items relating specifically to the findings of earlier studies, e.g. the school or class accident rate over a set period of time; severity of accidents based on the type of treatment or first aid required.

Statistical analysis of the study data

It is recommended that--

1. Multivariate analysis be applied to the data obtained in the immediate study.

2. Factor analytic techniques be used to assess item topics on the basis of the instrument sections.

3. Statistical analysis include assessment of the "best answer" response only for T-KOLS and S-POLS, and that these data be compared to data obtained in this study using a weighted scoring technique.

Further research in the area of safety in the secondary school science laboratory

Based on the findings of the immediate study, it is recommended that--

1. The experimental phase of the present study be repeated in Oregon using the same instruments. Replication could be done by using (*a*) the same training area sample, (*b*) the sampling frame used in the present study to select a different set of training areas, or (*c*) a random sample as opposed to cluster sampling of Oregon secondary school science teachers.

2. The experimental phase of the present study be conducted using the same, or revised instruments in a different state or states of the United States or overseas.

3. The experimental phase of the study be repeated in Oregon as a pre- and post- assessment of the effectiveness of safety training workshops.

Safety status of Oregon secondary school science teachers

It is recommended that safety training workshops be offered for Oregon science teachers at the earliest possible opportunity, and that pre-service and in-service training include safety instruction. This recommendation is based on the following:

1. Teacher responses to demographic items, which revealed that--

   a) teachers reporting little, if any, safety instruction devoted a relatively large amount of time to "hands on" or laboratory type science activities;

   b) university science laboratory courses are not providing adequate safety instruction for teachers;

   c) accidents are occurring in the science classroom-laboratories in Oregon secondary schools.

2. A relatively large number of teachers failed to respond to, and may not have known answers to T-KOLS items dealing with general safety information

3. Safety practice scores were substantially lower than

safety knowledge scores

4. Evidence that chemistry teachers were not knowledgeable regarding biological safety; likewise biology teachers demonstrated a low knowledge base in relation to chemical hazards.

Conversation with science teachers in Oregon and Washington during the course of the pilot studies and collection of field study data, led this researcher to the conclusion that teachers want to be well-informed and frequently up-dated regarding safety factors important to secondary school science teaching.

The fact that so many respondents in the immediate study indicated that they did little personal reading in the area of laboratory safety could reflect the lack of adequate information on the subject, and not their desire to avoid reading such material. Instruments such as those prepared for the immediate study could also be used effectively as a means of self-assessment. Self-scoring of the instruments could provide science teachers with positive feedback regarding recommended safety practices.

Unfortunately, there has been little research in the area of safety in the secondary school science classroom, and for this reason, the safety needs of the science teacher are largely unknown. The present study has, to some extent, revealed these needs. Only further research will determine if and when they have been fully met.

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APPENDICES I

Appendix A

Teacher Knowledge of Laboratory Safety (T-KOLS)

S A F E T Y T E S T ..... consists of a total of 100 topic statements relating to hazardous/non-hazardous items which might possibly be encountered during the course of science instruction in the secondary school

CONTENT is divided into ten sections, each relating to a particular aspect of safety in science education. Each section contains 10 statements judged to be representative of general knowledge specific to safety in that area.

	Section No.
S TORAGE and DISPOSAL of CHEMICALS/SUPPLIES	I
A PPARATUS, GLASSWARE, EQUIPMENT and RELATED PROCEDURES	II
F IRST AID in the SCIENCE CLASSROOM-LABORATORY	III
E YE, FACE and PERSONAL PROTECTION	IV
T OXIC and CHEMICAL SUBSTANCES	V
Y OUR RESPONSIBILITY and LIABILITY	VI
T ECHNIQUES, ACTIVITIES and CHEMICAL REACTIONS	VII
E LECTRICAL, RADIATION and other PHYSICAL HAZARDS	VIII
S PECIFIC BIOLOGICAL and ANIMAL SAFETY	IX
T EMPERATURE, EXPLOSIVES and FIRE CONTROL	X

EACH STATEMENT requires a response indicating whether the procedure/reaction/account/condition ... and so on, is:

a) extremely hazardous and generally not appropriate for school use
b) permissible under controlled conditions or circumstances only
c) comparatively non-hazardous and generally acceptable for all purposes of school science education

COLOR INDICATORS ...

Ⓡ RED
Ⓨ YELLOW
Ⓖ GREEN are used to identify the response modes

ALL ITEMS INCLUDED ...

a) are intended to refer to the school situation in either the science laboratory or in the conventional classroom as part of the 'hands-on' approach to teaching science (that is, to school safety and NOT industrial safety).

b) have been judged by safety experts and school science professionals to be appropriate and applicable to science education. That is, all teachers of science should be familiar with the content of the item and possible associated hazards and/or safety factors.

RESPONDENTS are asked to individually work through each item as quickly as possible WITHOUT using reference material or discussing the statements with others.

It is expected in this regard, however, that certain of the topics will be easier to assess than others depending on the science background, and/or specific teaching experience of each test-taker.

INSTRUCTIONS for categorizing each topic statement are given overleaf.

SAFETY TEST

Teacher Knowledge of Laboratory Safety (T-KOLS)

ANSWERING

	permissible and recommended Ⓖ	permissible with qualifications Ⓨ	not permissible under any circumstances Ⓡ
Consider and categorize each item according to the following SELECTION SCHEME*			
NOT PERMISSIBLE UNDER ANY CIRCUMSTANCES: extremely unsafe/permanent injury (or death) could result/practice unsafe/risk of negative health effects extremely high/carcinogenic/ high risk of teacher (and/or) administrative liability/ ...			x
PERMISSIBLE WITH QUALIFICATIONS: acceptable under very careful supervision/extreme caution necessary/ permissible for demonstration only/health hazard potential moderate to high/ ...		x	
PERMISSIBLE AND RECOMMENDED: preferred and acceptable/harmful only under unusual circumstances/ protection adequate/teacher action justified and approved/ ...	x		

This 'test' is somewhat different from most objective-type instruments, in that although there are three answer categories, there are essentially only TWO choices to consider.

The procedure outlined below should assist you in selecting the preferred response:

a) first consider whether the topic statement* refers to something you feel should NOT be a part of science education under any circumstances. Reading the SELECTION SCHEME above, this would place your response in the <u>red</u> column - "NOT PERMISSIBLE UNDER ANY CIRCUMSTANCES".

b) if the item does <u>not</u> belong in the 'red' column, then you should next consider whether the topic statement relates to something you feel is acceptable to science education <u>under most normal conditions of care and supervision</u>. That is, is it appropriate without need for additional precaution or control? Read the SELECTION SCHEME above under the heading "PERMISSIBLE AND RECOMMENDED". If you feel the item fits this category then you would check the <u>green</u> column.

c) Items that do not seem to 'belong' in either of the above two categories should by process of elimination fall into the <u>yellow</u> column "PERMISSIBLE WITH QUALIFICATION". If after reading this classification you still feel unsure of your selection - then repeat the procedure in (a) and (b) above, making certain that you are considering your response with regard to the statement below:

*NOTE: In all topics given, assume adequate safety measures have been employed EXCEPT those described in the statement

Since there is a broad range of topics included in each Section, it is suggested that you keep the above SELECTION SCHEME in front of you as you consider each item.

Teacher Knowledge of Laboratory Safety (T-KOLS)......SCORING SCHEME

SAFETY TEST

(Revised version)

Consider and categorize the following items according to the SELECTION CODE provided:

NOTE: In all topics given below, assume adequate safety measures have been employed EXCEPT those described in the statement

		Ⓖ permissible and recommended	Ⓨ permissible with qualifications	Ⓡ not permissible under any circumstances
I.	STORAGE and DISPOSAL of CHEMICALS/SUPPLIES ...			
1.	Disposal of milliliter quantities of certain dilute acids/bases by flushing down sink with large quantities of water	2	1	0
2.	Storage of all chemicals within a single alphabetized scheme of organization	0	1	2
3.	Replacement of metal caps with bakelite/plastic caps on all glass containers	2	1	0
4.	Storage of ethyl ether, acetone, alcohols or other low boiling point liquids in conventional household refrigerator	0	1	2
5.	Placement of reducing and oxidizing agents in same general storage location	0	1	2
6.	Storage of oxidizing materials next to organic materials	0	1	2
7.	Installation of an inside storage room exhaust system capable of at least two changes of room air per hour	1	2	0
8.	Substitution of polyethylene bottles for glass bottles where contents compatible	2	1	0
9.	Sewer disposal of discarded and/or inoculated media following sterilization by adequate steam heat	2	1	0
10.	Use of horizontal bins for support and storage of glass tubing	2	1	0
II.	APPARATUS, GLASSWARE, EQUIPMENT and RELATED PROCEDURES ...			
11.	Carrying of two "gallon" jugs with firm grip by each hand on neck and glass finger loops	0	1	2
12.	Application of continuous flame heat to bottom of pyrex test-tube when heating contents	0	1	2
13.	Utilization of silicon oil lubricant for insertion of glass in rubber stoppers	2	1	0
14.	Use of conventional bell-jar without protective screening (or shielding) for vacuum experiments	0	1	2
15.	Removal of large pieces of broken glass with fingers prior to use of whisk broom and dust pan to clean up remainder	0	1	2

(continued on next page)

T-KOLS (continued)

		G	Y	R
16.	Tight clamping of test tubes and flasks in reaction apparatus	0	1	2
17.	Use of erlenmeyer flask for class demonstration of "ammonia" fountain	0	1	2
18.	Assembly of acid-spill control kits (consisting of sand and soda ash mixture in pail) as part of student involvement in safety	2	1	0
19.	Provision of single lab table receptacle for chemical waste (glass, filter paper, matches, litmus paper and/or other similar items)	0	1	2
20.	Operation of pressure cooker with gauge pressure limit of twenty pounds for sterilization purposes	2	1	0
	III. <u>FIRST AID in the SCIENCE CLASSROOM-LABORATORY</u>* ...			
21.	Application of pressure around wound to control bleeding where laceration contains foreign material (e.g. glass etc.)	2	1	0
22.	Application of continuous eye-wash stream of water for minimum of 15-minutes in treatment of acid/base splash	2	1	0
23.	Placement of loose clean dressings (without pressure) over single eye injured by flying fragments	0	2	1
24.	Immediate use of tourniquet where injury results in extensive and/or deep wounds with rapid bleeding (welling or spurting)	0	1	2
25.	Immediate removal of burned clothing from casualty suspected of suffering extensive third-degree burns	0	1	2
26.	Application of first-aid kit burn ointment to small first degree thermal burns	1	2	0
27.	Removal of splashed clothing of chemical burn victim at time of immediate first-aid water wash	2	1	0
28.	Immediate use of very large quantities of cold water applied with hard spray to wash off victim of chemical burns	1	2	0
29.	Use of CPR where electric shock has resulted in possible heart fibrillation	2	1	0
30.	Removal of victim to fresh air and encouragement to take several rapid and deep breaths following gas inhalation	2	1	0

* NOTE: First aid is the immediate care given to a person who has been injured or suddenly taken ill (American National Red Cross). This Section is not intended to cover extended or final treatment.

(continued on next page)

	T-KOLS (continued)	G	Y	R
	IV. EYE, FACE and PERSONAL PROTECTION ...			
31.	Wearing of approved eye protection by students in dual-purpose laboratory-classroom only when experiments are in progress	1	2	0
32.	Substitution of impact-resistant prescription lenses for approved chemical goggles	0	1	2
33.	Substitution of contact lenses for prescription glasses when worn under approved chemical goggles	0	1	2
34.	Emergency use of 5-foot length of ½" rubber hose with aerated nozzle for eye-wash treatment	2	1	0
35.	Care of caustic chemical eye splash within 30 seconds with acceptable eye wash	1	2	0
36.	Collection of safety goggles and immediate bulk storage following each laboratory session	1	2	0
37.	Direct viewing of laser beam permitted only if wearing goggles prescribed for wavelength concerned	0	1	2
38.	Use of plexiglass or polycarbonate plastic barrier shield for ordinary demonstrations	2	1	0
39.	Use of velometer to measure face velocities in fume hood system	2	1	0
40.	Installation of non-clogging deluge type safety showers within 35-ft of each laboratory user	2	1	0
	V. TOXIC and CHEMICAL SUBSTANCES ...			
41.	Contact of small amount of anhydrous perchloric acid ($HClO_4$) with paper	0	1	2
42.	Use of liquid bromine (Br_2) when confined to fume hood	0	1	2
43.	Occasional use of solid iodine (I_2) in various student laboratory activities	0	2	1
44.	Use of benzene (C_6H_6) in laboratory-classroom where fume hood available	0	1	2
45.	Rinsing of glassware with acetone (CH_3COCH_3) on intermittent basis in laboratory-classroom without open flame	0	2	1
46.	Grinding of potassium chlorate ($KClO_3$) with organic substances	0	1	2
47.	Heating of finely powdered metal and sulfur (S)	0	1	2
48.	Ingestion of methyl alcohol (methanol - CH_3OH)	0	1	2
49.	Brief exposure of students to diethyl ether ($CH_3CH_2OCH_2CH_3$) in room without open flame	1	2	0
50.	Use of carbon tetrachloride (CCl_4) where fume hood available	0	1	2

(continued on next page)

T-KOLS (continued)

		G	Y	R
	VI. <u>YOUR RESPONSIBILITY and TEACHER LIABILITY</u> ...			
51.	Administrative substitution of conventional classroom for over-crowded science laboratory	0	1	2
52.	Assignment of responsible student to supervise laboratory work for part of period during teacher absence	0	1	2
53.	Failure of teacher to ascertain potential hazards associated with demonstration or student activity	0	1	2
54.	Maintenance of equipment contained in science laboratory as part of teacher responsibility	2	1	0
55.	Wearing of loose, baggy or unconventional clothing permitted during laboratory activities on special school occasions	0	1	2
56.	Assignment of properly trained student "safety assistant" to help with routine activities and alert teachers to special problems	2	1	0
57.	Student use of reagent carrying partially obliterated label	0	1	2
58.	Periodic inspections of specific items of laboratory equipment by students as part of involvement in safety program	2	1	0
59.	Accommodation of more students than designed capacity of laboratory where student movement minimized and clear aisles mandatory	0	1	2
60.	Consumption of food and drink in those science classroom-laboratories where refrigerator storage available	0	1	2
	VII. <u>TECHNIQUES, ACTIVITIES and CHEMICAL REACTIONS</u> ...			
61.	Dilution of acid by slow addition of acid to water with continuous mixing	2	1	0
62.	Heating mixture of small quantities of potassium chlorate and manganese dioxide in preparation of oxygen	0	1	2
63.	Immediate use of water to wash off spill of acid or other corrosive material from laboratory table or floor	2	1	0
64.	Return of chemicals thought to be uncontaminated to stock bottles following laboratory period	0	1	2
65.	Application of heat to test tube above level of liquid contents	0	1	2
66.	Mouth-pipetting of chemical/biological materials permitted following demonstrated mastery of technique	0	1	2

(continued on next page)

T-KULS (continued)

		G	Y	R
67.	Dislodgement of solids (crystals) from bottom of test-tube by gentle blowing action	0	1	2
68.	Student preparation of chlorine water from chlorine gas	0	1	2
69.	Pulverization of mixture of charcoal, sulfur and potassium chlorate with iron mortar and pestle	0	1	2
70.	Use of gasoline to wash hands following laboratory activity involving various machine parts	0	1	2
	VIII. <u>ELECTRICAL, RADIATION and other PHYSICAL HAZARDS</u> ...			
71.	Substitution of 12-volt car battery for 12-volt dry cell	0	1	2
72.	Reflection of direct sunlight in micruscope mirror	0	1	2
73.	Viewing of solar eclipse by projection onto "student-made" screen of paper or cardboard	1	2	0
74.	Use of ether restricted to laboratory containing items of electrical equipment (pH meter, hot plate etc.) but no open flame	0	1	2
75.	Purchase of items of electrical equipment carrying approval by Underwriters' Laboratories Incorporated	2	1	0
76.	Connection of power apparatus to lighting circuit (bulb socket) to avoid use of double adaptors	0	1	2
77.	Student use of sun lamp in observation of animal response mechanisms during biology laboratory exercise	0	2	1
78.	Utilization of grow-lux tubes (grow-lite) in biology laboratory	0	2	1
79.	Replacement of extension cord by temporary wiring where device used continuously in single location	0	1	2
80.	Direct viewing of infra-red light sources	0	1	2
	IX. <u>SPECIFIC BIOLOGICAL and ANIMAL SAFETY</u> ...			
81.	Student examination of open petrie dish cultures produced by touching media with "clean" hands	0	1	2
82.	Preservation of biological specimens in formaldehyde solution	0	2	1
83.	Utilization of blood lancets sterilized in alcohol both before and after use	0	1	2
84.	Short-term housing of <u>wild</u> mammals in laboratory where sanitary conditions and facilities for controlled access exist	0	1	2

(continued on next page)

T-KOLS (continued)		G	Y	R
85.	Housing of animals obtained from questionable sources permitted in laboratory after innoculation against rabies	0	1	2
86.	Student handling of specimens preserved in formaldehyde where gloves unavailable but tongs used for removal from solution	0	1	2
87.	Permitting eating of edible plants grown in class as part of "relevant" science curriculum	0	2	1
88.	Practice of exposing agar plates to school environment during study of microorganisms	0	2	1
89.	Laboratory sink disposal of cultures not exhibiting obvious growth	0	1	2
90.	Use of non-pathogenic organisms in practical laboratory experiments	1	2	0
91.	X. <u>TEMPERATURE, EXPLOSIVES and FIRE CONTROL</u> ...			
91.	Use of soda-acid fire extinguisher to adequately handle chemical flare-up	0	1	2
92.	Utilization of hot plate to heat beaker of alcohol in water bath	1	2	0
93.	Contact of oxidizing agents with substances such as sugars and celluloses	0	1	2
94.	Limit of one pint or less of any one type of flammable liquid stored on laboratory shelf	2	1	0
95.	Shelving of volatile solvents in locations where temperature 20°C	0	1	2
96.	Filling of alcohol burners in laboratory from plastic fuel storage container	0	1	2
97.	Provision of filled sand buckets for use on metal hydride and alkali metal fires	2	1	0
98.	Construction of inside storage room with single clear aisle width of three feet	2	1	0
99.	Check of extinguishers at regular six-month intervals to confirm placement, unbroken seals and accessibility	1	2	0
100.	Brushing of soapy water to test for suspected leak in compressed gas cylinder of hydrogen	2	1	0

Appendix B

SAFETY TEST

Student Perception of Laboratory Safety (S-POLS)

INSTRUCTIONS TO STUDENTS:

This is a type of survey QUIZ and is NOT a real test.

You will see that there are NO right or wrong answers.

> These statements are being considered by students who are taking science in secondary school to see whether the same things are important in each of the different science subject areas (biology, chemistry, physics, general science, earth science ... and so on).
>
> It is also important to find out how much ALIKE science classes are in the United States, and how these compare with science classes in other parts of the world.

Your help is very important if we are to get the information that is needed.

Answering:

You have only ten (10) statements to read on a single page.

Each of these has three choices, represented by the letters A, B and C.

Read CAREFULLY each of the three statements, and then select the letter that BEST DESCRIBES what happens MOST OFTEN (or most of the time) in YOUR science classroom - that is, the class that you are in at the present time.

> NOTE that all three statements may describe what has happened at one time or another in your class, but you are asked to select ONLY the letter that is CLOSEST to what happens in your science room MOST OF THE TIME

If NONE of the statements come close to the situation in your science class then you should select "D." Notice that some items have an asterisk (*) next to the "D" choice. These are judged to be general statements that should apply to all science classes and you MUST respond to these if at all possible.

Some items may not seem to apply to your class. For instance you may be in a biology class and the statement seems to relate to chemistry or physics. In this event you would also select the "D" option.

REMEMBER:

> TAKE YOUR TIME - READ EACH STATEMENT SLOWLY AND THINK CAREFULLY BEFORE SELECTING A, B or C. Other students in your class are considering these or similar items. If your selections are very different from theirs, the data you provide will not be useful.

THE FOLLOWING INFORMATION SHOULD BE PROVIDED:

Science Subject Area for each class taking part ______________________________

Grade Level ______________

Number of Students in class ______

ALL unused **S-POLS** tests should be returned

TO NOT WRITE NAME OF TEACHER OR STUDENTS ON TEST PAPERS OR ON OTHER RELATED MATERIALS.

SAFETY TEST (A)

S-POLS
(Revised version)

REMEMBER: Select the letter that describes what happens MOST OFTEN (or is closest to what happens MOST OFTEN) in your class.

If NONE of the A, B or C choices are close to being right, OR you do not think the statement relates to your class, then you should select "D".

An asterisk (*) indicates an item that applies to all science classes and MUST be answered with an A, B or C choice if at all possible.

	Scoring scheme
1. When needing to use the fume hood in this science class students most often	
A. must clear away some of the materials and at times remove chemical (reagent) bottles stored there before they can start work	1
B. do not use it since it is always so cluttered that it would take them too long to clear a work space	0
C. find it clear with plenty of working space available for use	2
D. none of the above/does not apply	
2. When helping in this science class (or stockroom) and large gallon bottles (or jugs) containing chemicals must be moved students are most often	
A. allowed to move them carefully without any other special instruction	0
B. not permitted to carry them under any circumstances unless already placed in safety buckets by the teacher	2
C. instructed to hold the neck with one hand (with fingers through the glass loop when provided) and support the base with the other hand	1
D. none of the above/does not apply	
3. When getting a chemical in the mouth accidentally while working in this science class (before being sent to the office or school nurse if necessary) students are most often	
A. permitted or told to get a drink of water	0
B. instructed to immediately rinse the mouth with water and are then questioned as to the chemical and the amount involved	2
C. told only to rinse the mouth thoroughly with water	1
D. none of the above/does not apply	
4. When working in this science class on lab days students are most often	
A. required to use a laboratory apron (or coat) and the teacher wears one at all times also	2
B. instructed to wear a laboratory apron (or coat) whether or not the teacher does so OR, told to use one only when working on certain experiments	1
C. not required to wear a laboratory apron (or coat) since the teacher seldom or never uses one OR, permitted to please themselves whether or not they wear one	0
D. none of the above/does not apply	
5. When working in this science class and needing a drink of water students are most often	
A. permitted to use something that seems to be clean or has just been washed	1
B. not allowed to get a drink OR, instructed to use either the paper cup dispenser or the water fountain	2
C. allowed to drink directly from the water faucet in the room	0
*D. none of the above/does not apply	

Now turn the page ...

SAFETY TEST (A) S-POLS

Scoring scheme

6. *When discussing behavior in this science class students are <u>most often</u>*
   - A. given many warnings by the teacher that horseplay (pushing, jostling, etc.) will not be tolerated but some students fool around anyway and are seldom punished — 1
   - B. told by the teacher that horseplay (pushing, jostling, etc.) is not permitted under any circumstances and when it occurs they are disciplined — 2
   - C. allowed to have fun in science and the teacher does not generally care as long as they get their work done — 0
   - *D. none of the above/does not apply

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7. *When finishing work on one experiment or activity in this science class and preparing to start a new one students are <u>most often</u>*
   - A. not permitted to begin until they have carefully gone over the instructions with the teacher (pre-lab) and are told they may start — 2
   - B. allowed to begin any time they wish and the teacher expects them to read the instructions as they do their work — 0
   - C. permitted to begin only if the teacher is sure they have read the instructions in their books and understand exactly what they are to do — 1
   - *D. none of the above/does not apply

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8. *When using solid radioactive sources (alpha and beta) in this science class students are <u>most often</u>*
   - A. told they can handle the sources with their fingers but must do so carefully — 1
   - B. permitted to handle the sources with their fingers and nothing is said about being careful — 0
   - C. instructed to handle the sources with tongs or forceps and must not use their fingers — 2
   - D. none of the above/does not apply

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9. *When caring for animals in this science class students are <u>most often</u>*
   - A. told that the animals are their responsibility and the teacher does not care if the cages get dirty and smelly — 0
   - B. required to clean the cages and feed the animals each day or they are not permitted to keep them in the room — 2
   - C. expected to clean the cages and feed the animals each day but sometimes they do not have time or forget to do it — 1
   - D. none of the above/does not apply

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10. *When discussing fire safety in this science class the teacher <u>most often</u>*
   - A. checks at the beginning of the term to make sure students know where the fire extinguisher is located and how it should be operated — 2
   - B. tells students where the fire extinguisher is located but never shows them how it should be operated — 1
   - C. never talks about a fire extinguisher — 0
   - *D. none of the above/does not apply

SAFETY TEST (B)

S-POLS

REMEMBER: Select the letter that describes what happens MOST OFTEN (or is closest to what happens MOST OFTEN) in your class.

If NONE of the A, B or C choices are close to being right, OR you do not think the statement relates to your class, then you should select "D".

An asterisk (*) indicates an item that applies to all science classes and MUST be answered with an A, B or C choice if at all possible.

	Scoring scheme
1. *When disposing of waste material (but not liquids) in this science class students are most often*	
A. allowed to use the same bin for broken glass and solid chemical waste but must use a separate basket for waste paper	1
B. instructed to use separate containers for waste paper - for broken glass - and for solid chemical waste	2
C. told to place everything in a single bin OR, allowed to place broken glass in the waste paper basket but must use a separate container for solid chemical waste	0
*D. none of the above/does not apply	
2. *When using glass tubing or stirring rods in this science class students are most often*	
A. not told that glass ends should be fire-polished before use	0
B. instructed before starting an experiment to report glass ends that are not fire-polished OR, told to fire-polish the ends themselves	2
C. reminded only after starting an experiment to check that all glass ends are fire-polished	1
D. none of the above/does not apply	
3. *When receiving a small cut on finger(s) or hand from broken glass or rough glass edges (before being sent to the office or school nurse if necessary) students in this science class are most often*	
A. immediately treated by the teacher who applies antiseptic and Band-aid or dressing from the first-aid kit	1
B. given no treatment or instruction by the teacher OR, expected to take care of the injury themselves	0
C. instructed to immediately wash the cut area well with soap and water and then to hold it under running water for several minutes before dressing is applied	2
*D. none of the above/does not apply	
4. *When issuing chemical goggles (or other eye-protection devices) for use in this science class on lab days the teacher most often*	
A. requires that they be worn by students at all times during the period	2
B. tells students that they must be worn at all times during the period but this is not always enforced	0
C. instructs students to wear them only for certain experiments	1
D. none of the above/does not apply	
5. *When leaving this science room after working at the laboratory tables on an experiment students are most often*	
A. instructed to wash their hands whether they seem to need it or not	2
B. not required to wash their hands but sometimes do so without being told	0
C. required to wash their hands only if they have been handling certain materials	1
*D. none of the above/does not apply	

Now turn the page ...

	Scoring scheme
6. *When learning a new laboratory procedure in this science class the students are* ***most often***	
A. tested on the new procedure by the teacher who then places a report in the class record book	2
B. expected to discover for themselves the best way to carry out the new procedure and then continue with the laboratory exercise	0
C. required to hand in a lab report or "write-up" of the procedure but generally they are not tested on their work	1
D. none of the above/does not apply	
7. *When using Bunsen burners or alcohol lamps for the first time in this science class the correct lighting and adjusting procedures are* ***most often***	
A. demonstrated by the teacher and then each student is checked individually to make sure the procedures are understood	2
B. explained (or briefly demonstrated) by the teacher and then students learn by using them and/or helping each other	0
C. not explained or demonstrated by the teacher when the burners are given out and help is only given to students later as needed	1
D. none of the above/does not apply	
8. *When working on experiments in this science class which require "sunlight" the teacher* ***most often***	
A. sets up infra-red heat lamps or ultra-violet sun lamps for students to use	1
B. permits the students to set up either infra-red or ultra-violet lamps for the experiment	0
C. instructs the students to put the organisms or the material by the window or out-of-doors in the sunlight	2
D. none of the above/does not apply	
9. *When using petri dishes containing agar in this science class students are* ***most often***	
A. required to tape them closed after they have been exposed and are not permitted to remove the tape or open them under any circumstances	2
B. told that they should not open them when observing bacterial growth but they are never taped closed	1
C. allowed to open them to see what is growing on them and have never been told they should be kept closed	0
D. none of the above/does not apply	
10. *When taking chemicals that have been set out ready for use in an experiment in this science class the teacher* ***most often***	
A. permits students to get the chemical they need without reminding them to check the name on the label	0
B. trusts students to read carefully the name on the bottle when taking a chemical but reminds them to re-check the label again before use	1
C. reminds students to read chemical labels carefully before use and places similar chemicals in different groups to avoid mistakes	2
*D. none of the above/does not apply	

SAFETY TEST (C)

S-POLS

REMEMBER: Select the letter that describes what happens MOST OFTEN (or is closest to what happens MOST OFTEN) in your class.

If NONE of the A, B or C choices are close to being right, OR you do not think the statement relates to your class, then you should select "D".

An asterisk (*) indicates an item that applies to all science classes and MUST be answered with an A, B or C choice if at all possible.

Scoring scheme

1. *When putting away chemicals or other materials in this science class students are most often*
   - A. instructed to put away (or place on carts) those items that belong in the classroom and to put in a special place those things that are kept in the stockroom (back room) 2
   - B. expected to leave things for the teacher or lab assistant to take care of unless asked to put certain things away and/or want to help the teacher 0
   - C. told to put away those items that are kept in the classroom only if they know where they belong and to leave other things where they are 1
   - *D. none of the above/does not apply

2. *When starting work on a new experiment in this science class the procedure to be followed is usually explained and students are most often*
   - A. told to get started immediately and the teacher seldom if ever mentions laboratory safety rules or any special precautions that should be taken 0
   - B. permitted to start only after both general laboratory safety rules and special precautions related to the new work have been reviewed by the teacher 2
   - C. reminded of special precautions related to the new work but the teacher seldom reviews other general laboratory safety rules 1
   - *D. none of the above/does not apply

3. *When receiving a small bite or scratch from one of the animals housed in this science class (before being sent to the office or school nurse if necessary) students are most often*
   - A. instructed by the teacher to wash the wound and then antiseptic and/or Band-aid or other dressing is supplied as required 1
   - B. given no treatment by the teacher OR, permitted to get a Band-aid or other item(s) from the first-aid kit when needed 0
   - C. required to have the wound washed with soap and water and then instructed by the teacher to hold it under running water for several minutes before Band-aid or dressing is applied 2
   - D. none of the above/does not apply

4. *When observing a potentially dangerous demonstration in this science class students are most often*
   - A. required to observe it through a safety shield 2
   - B. told to move away from the apparatus and required to wear chemical goggles or face shields 1
   - C. instructed to move a safe distance away from the apparatus 0
   - D. none of the above/does not apply

5. *When using a pipette in this science class students are most often*
   - A. permitted to pipette by mouth at all times and nothing is said about using a suction bulb 0
   - B. allowed to pipette by mouth unless the solution they are using is poisonous and then required by the teacher to use a suction bulb 1
   - C. instructed to pipette using a suction bulb and never permitted to pipette by mouth 2
   - D. none of the above/does not apply

Now turn the page ...

SAFETY TEST (C) S-POLS

6. When working on an experiment in this science class that is not finished during the scheduled class period students are <u>most often</u>

	Scoring scheme
A. required to wait until the next class period to finish the work OR, permitted to complete it at a time when the teacher can be present in the science room with them	2
B. told to come in and finish their work whenever they have time and often the teacher is not able to be there while they are working	0
C. not allowed to work in the science room alone but certain students are sometimes permitted to finish their work if other people are in the room working at the same time	1
*D. none of the above/does not apply	

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7. When dealing with certain chemical reactions in this science class it is sometimes necessary to take additional precautions and the teacher <u>most often</u>

A. tells students to read their books and/or demonstrates (pre-lab) the correct procedure to be used but seldom mentions any special precautions	0
B. explains and/or demonstrates (pre-lab) the procedure to be used and then discusses special precautions or dangers	2
C. instructs students to read the procedure over carefully in their science books and then reminds them to note any special precautions they should take	1
D. none of the above/does not apply	

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8. When requiring the use of an item of electrical apparatus that was made by the teacher (or other person) for this science class students are <u>most often</u>

A. told they may use any apparatus in the room if they handle it carefully even if there are uncovered wires or exposed electrical parts	0
B. permitted to use it only if the apparatus is reasonably safe for students to handle with no uncovered wires or exposed electrical parts	2
C. allowed to use apparatus with uncovered wires or exposed electrical parts only if they first obtain special permission from the teacher	1
D. none of the above/does not apply	

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9. When working in this science class with agar plates and bacterial cultures students are <u>most often</u>

A. not permitted to leave the room until they have rinsed their fingers in the antiseptic solution provided <u>and</u> washed with soap and water	2
B. reminded only to wash their hands when they have completed their work	1
C. not told to wash their hands before leaving the room OR, expected to wash their hands only if they wish to do so	0
D. none of the above/does not apply	

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10. When using Bunsen burners or alcohol lamps for an experiment or activity in this science class students are <u>most often</u>

A. not permitted to leave them burning when they are not in use	2
B. permitted to use them as they see fit and it does not matter when they turn them off	0
C. told to leave them on during the entire class period	1
D. none of the above/does not apply	

SAFETY TEST (D)

S-POLS

REMEMBER: Select the letter that describes what happens MOST OFTEN (or is closest to what happens MOST OFTEN) in your class.

If NONE of the A, B or C choices are close to being right, OR you do not think the statement relates to your class, then you should select "D".

An asterisk (*) indicates an item that applies to all science classes and MUST be answered with an A, B or C choice if at all possible.

Scoring scheme

1. *When leaving this science room at the end of the class period students are* ***most often***
   - A. told either to place trash and waste material in the proper containers OR, required to clean the working areas before they go — 1
   - B. not permitted to go until the working areas are clean AND all trash and waste material is placed in the proper containers — 2
   - C. allowed to leave without either cleaning the working areas or discarding trash and/or waste material — 0
   - *D. none of the above/does not apply

2. *When working in this science class and the cutting and bending of glass tubing is required (even though the technique may have previously been learned) the teacher* ***most often***
   - A. demonstrates and explains the correct procedure (pre-lab) and then students are checked as they work on the activity — 2
   - B. permits students to proceed with the activity without additional instruction or demonstration — 0
   - C. instructs students to read carefully the procedure given in their books before starting the activity and then offers help as needed — 1
   - D. none of the above/does not apply

3. *When getting burned from hot glass or metal when heating things in this science class (before being sent to the office or school nurse if necessary) students are* ***most often***
   - A. given no treatment or instruction by the teacher OR, permitted to get what they need from the first-aid kit themselves — 0
   - B. treated by the teacher with burn cream or other item(s) from the first-aid kit — 1
   - C. instructed to put the burn immediately under cold water — 2
   - D. none of the above/does not apply

4. *When working in this science class with chemicals that may produce gases or vapors that are toxic (poisonous) the teacher* ***most often***
   - A. suggests to students that the fume hood be used for the experiment but seldom or never checks to make sure all students are using it — 1
   - B. instructs students to do the experiment under the fume hood and requires that everyone do so — 2
   - C. warns students to be careful not to breathe the gases or vapors though the fume hood is never used or is not in working order — 0
   - D. none of the above/does not apply

5. *When working at the laboratory tables in this science class and an acid or alkali is spilled students are* ***most often***
   - A. instructed to report the spill immediately to the teacher who then takes care of it right away OR, told to use the neutralizer provided and then report to the teacher — 2
   - B. allowed to mop up the spill with a lab cloth (or rag) OR, permitted to clean the area any way they wish — 0
   - C. expected to use the neutralizer provided for chemical spills and never told to report to the teacher — 1
   - D. none of the above/does not apply

Now turn the page ...

SAFETY TEST (D) S-POLS

Scoring scheme

6. *When reporting an accident for even a minor injury in this science class the teacher* *__most often__*

A. writes up a report and also requires the student(s) involved to write up an account of the accident which is then jointly signed — 2

B. does not discuss the accident with the student(s) involved — 0

C. talks to the student(s) involved to find out exactly what happened before writing up an accident report — 1

*D. none of the above/does not apply

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7. *When heating a solid or a liquid in a test tube in this science class students are* *__most often__*

A. reminded before starting the activity that a test tube holder should be used and the test tube should be kept moving in the burner flame — 1

B. checked by the teacher as they work to make sure they are using the test tube holder correctly and moving the test tube back and forth in the flame — 2

C. permitted to start work on the activity and not told or reminded of the correct way to heat the contents of a test tube — 0

D. none of the above/does not apply

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8. *When needing electrical hook-up for apparatus in this science class students are* *__most often__*

A. told to keep extension cords as short as possible and to tape down any cords that need to be run across the floor — 1

B. instructed to set up the apparatus near an electrical outlet and are not allowed to string extension cords around the room — 2

C. allowed to use extension cords any way they need to get the electrical power required — 0

D. none of the above/does not apply

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9. *When going on a field trip with this science class the teacher* *__most often__*

A. discusses the trip with the students before leaving and warns them of possible safety hazards — 2

B. plans the field trip without mentioning safety hazards — 0

C. waits until they arrive at their destination before discussing safety hazards — 1

* D. none of the above/does not apply

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10. *When working with open flame (Bunsen or alcohol burners) in this science class students are* *__most often__*

A. permitted to use the burners only after all unnecessary items are cleared from the tables and they have checked that no flammable substances are nearby — 2

B. not told to check for flammable substances or to clear the tables of unnecessary clutter before using the burners — 0

C. instructed to keep the tables clear when using the burners but seldom or never told to check for any flammable substances that might be nearby — 1

D. none of the above/does not apply

SAFETY TEST (E)

S-POLS

REMEMBER: Select the letter that describes what happens MOST OFTEN (or is closest to what happens MOST OFTEN) in your class.

If NONE of the A, B or C choices are close to being right, OR you do not think the statement relates to your class, then you should select "D".

An asterisk (*) indicates an item that applies to all science classes and MUST be answered with an A, B or C choice if at all possible.

	Scoring scheme
1. *When disposing of liquid chemical wastes in this science class students are most often*	
A. instructed to leave them for the teacher	1
B. permitted to wash only very small quantities of certain chemicals down the sink with plenty of water OR, told to pour them into the special waste containers provided	2
C. allowed either to put them back into the chemical (reagent) bottles OR, expected to pour them down the sink	0
D. none of the above/does not apply	
2. *When needing glassware for an experiment in this science class students most often*	
A. find sufficient clean glassware on the proper shelf or set out ready for their use	2
B. wash what they need since they can seldom find enough clean glassware in the room	0
C. must look for what they need though enough clean glassware for their use is usually available	1
* D. none of the above/does not apply	
3. *When aiding students who have been slightly injured while on a field trip with this science class (before calling for emergency medical help if necessary) the teacher most often*	
A. treats students with items from the first-aid kit if it happens to have been brought along	1
B. tells students that they must wait until help arrives or until they return to school	0
C. provides students with items from the first-aid kit which is always taken along for emergencies	2
D. none of the above/does not apply	
4. *When watching a demonstration or experiment given in this science class students are most often*	
A. told to remain in their seats but may move closer without permission when it is difficult to see what is going on	1
B. required to remain in their seats and/or allowed to move closer only when given special permission by the teacher	2
C. permitted to stand close in order to see the demonstration or experiment	0
* D. none of the above/does not apply	
5. *When bringing food into this science class for a demonstration or investigation and some of it is left over students are most often*	
A. allowed to eat it only if they first obtain permission from the teacher	1
B. permitted to eat it or take it home if it is something they like	0
C. required to throw it away before leaving the room OR, told to give it to the teacher for disposal	2
D. none of the above/does not apply	

Now turn the page ...

SAFETY TESTS (E) S-POLS

	Scoring scheme
6. *When planning a field trip in this science class students are <u>most often</u>*	
A. not required to get permission or acknowledgment slips signed but must inform their parents that they will be going on the class outing	1
B. permitted to go on the trip only after they obtain and return to school signed permission or acknowledgment slips from their parents	2
C. allowed to go even if they forget to bring back the signed permission or acknowledgment slips if they are sure that their parents agree to their going	0
*D. none of the above/does not apply	
7. *When doing an experiment in this science class where several students must use the same item of apparatus or equipment (balance, microscope, hot plate and so on) the teacher <u>most often</u>*	
A. places it where students must crowd around to use it and have little room to work but will not permit apparatus or equipment to be moved	1
B. allows students to move apparatus or equipment to a place where it can be used conveniently	0
C. places it in a part of the room where each student (or small group of students) can get to the apparatus or equipment readily and has room to work and move around	2
*D. none of the above/does not apply	
8. *When unplugging apparatus or an extension cord from the electrical outlets in this science class students are <u>most often</u>*	
A. reminded to use dry hands and to grip the plug rather than the cord with one hand and not to touch anything with the other hand	2
B. told that they should not pull on the electrical cord itself but should remember to grip the plug firmly	1
C. allowed to remove electrical or extension cords the quickest way possible and never discuss the way this should be done	0
*D. none of the above/does not apply	
9. *When using the microscope in this science class the teacher <u>most often</u>*	
A. tells students how they should adjust and handle the microscope during use	1
B. gives no special instructions on how to use or handle the microscope	0
C. provides a short unit or lesson on the microscope and students are then checked out on the correct use of the instrument before one is assigned to them	2
D. none of the above/does not apply	
10. *When wearing long loose flowing sleeves and/or clothing while working around open flame (Bunsen or alcohol burners) in this science class students are <u>most often</u>*	
A. told nothing about the dangers of fire when wearing this type of clothing	0
B. reminded frequently that clothing of this kind is not suitable for lab work and/or required to have sleeves rolled or pinned when necessary	1
C. told that they are not allowed to participate in lab since this type of clothing is not permitted	2
D. none of the above/does not apply	

SAFETY TEST (F)

S-POLS

REMEMBER: Select the letter that describes what happens MOST OFTEN (or is closest to what happens MOST OFTEN) in your class.

If NONE of the A, B or C choices are close to being right, OR you do not think the statement relates to your class, then you should select "D".

An asterisk (*) indicates an item that applies to all science classes and MUST be answered with an A, B or C choice if at all possible.

1. When helping the teacher in this science class (but not as a special student laboratory assistant) students are most often

	Scoring scheme
A. permitted to go into either the stockroom (or back room) whenever they need to do so	0
B. not allowed in either the stockroom (or back room) at any time	2
C. permitted to go into the stockroom (or back room) only if the teacher requests help or needs a special item	1
*D. none of the above/does not apply	

2. When working with the aquarium(s) in this science class students are most often

A. told what they are to do but not warned about working around electricity with wet hands	1
B. shown exactly what they are to do and then warned to be careful not to touch the pump, heater or other electrical items with wet hands	2
C. allowed to perform their work any way they wish and the dangers of electricity are not discussed by the teacher	0
D. none of the above/does not apply	

3. When receiving an acid (or alkali) splash on hands or arms while working in this science class (before being sent to the office or school nurse if necessary) students are most often

A. told to wash the splashed area with water or to use the first-aid bottle of chemical "neutralizer" on it	1
B. not told what to do but are expected to take care of it themselves without bothering the teacher	0
C. instructed to hold the splashed area under plenty of running water for at least five minutes	2
D. none of the above/does not apply	

4. When discussing laboratory safety in this science class students are most often

A. shown where the eye-wash fountain or other emergency eye-wash equipment is located and are then instructed on how this should be used	2
B. told to use the eye-wash fountain or other emergency eye-wash equipment in the room when necessary but not shown how this should be operated	1
C. not told about the use of any type of eye-wash equipment	0
D. none of the above/does not apply	

5. When keeping animals in this science class and one of them becomes sick the teacher most often

A. separates it from the other animals and it is given special care in this science room until it is well	1
B. leaves it with the other animals until it gets better	0
C. takes it out of the room as soon as it becomes sick	2
D. none of the above/does not apply	

Now turn the page ...

SAFETY TEST (F) S-POLS

6. *When needing to stay in (or return to) this science class to finish an experiment or other work after the regular class period students are most often*

	Scoring scheme
A. permitted to do so if there are few students involved and the teacher is able to come in and out to supervise if unable to remain in the room all the time	1
B. not allowed to do so unless the teacher is able to remain in the room with them the whole time	2
C. told they may work in the room whenever they need to and sometimes people are still in the room after the teacher leaves	0
*D. none of the above/does not apply	

7. *When adding acid to water (to dilute the acid) during an experiment in this science class students are most often*

A. expected to add the acid to water and are not reminded of the correct procedure to use	0
B. told to add the acid to water and also reminded to stir the water during the addition	2
C. reminded to add the acid to water but not told to stir the water during the addition	1
D. none of the above/does not apply	

8. *When using grow-lux tubes (grow-lights) in this science class that are not covered by glass or other shielding material students are most often*

A. allowed to work under them when they are on and are not told that they should not look directly at the light tubes	0
B. permitted to work under them when they are on but are also reminded not to look at the light tubes as they work	1
C. warned never to look directly at the light tubes and instructed to turn them off when working under them	2
D. none of the above/does not apply	

9. *When using dissecting instruments in this science class the teacher most often*

A. uses a numbering system and all instruments must be returned before students are permitted to leave the room	2
B. places the instruments the students will need on a laboratory table (or cart) and they are told to return them to that place before leaving	1
C. permits students to take out (and return to storage) those instruments that they need	0
D. none of the above/does not apply	

10. *When heating things in this science class students are most often*

A. told to work carefully when using heat so that they will not get burned when handling hot items	1
B. not reminded to be careful and/or sometimes people get burned before remembering that objects are too hot to handle immediately after heating	0
C. instructed to bring the back of the hand carefully toward heated objects to check before grabbing hold	2
D. none of the above/does not apply	

S A F E T Y T E S T
(G)

S-POLS

REMEMBER: Select the letter that describes what happens MOST OFTEN (or is closest to what happens MOST OFTEN) in your class.

If NONE of the A, B or C choices are close to being right, OR you do not think the statement relates to your class, then you should select "D".

An asterisk (*) indicates an item that applies to all science classes and MUST be answered with an A, B or C choice if at all possible.

Scoring Scheme

1. *When needing chemicals for an experiment in this science class students most often*
   A. find the chemical bottles filled and ready for use but must either look around the room and/or crowd around to get what they need 1
   B. have to ask for what they need and sometimes the chemicals are still in the stock-room (back room) or the bottles are empty 0
   C. find them ready for use and placed so that they can get what they need without crowding 2
   D. none of the above/does not apply

2. *When cutting glass tubing or rods in this science class the teacher goes over the correct procedure to use and students are then most often*
   A. required at all times to use a lab cloth (or rag) over the file-weakened area before making the final break with their fingers 2
   B. permitted to make the break any way they wish and are not told that they must use a lab cloth (or rag) 0
   C. reminded to use a lab cloth (or rag) when making the final break with their fingers whenever the teacher happens to notice that they are not doing so 1
   D. none of the above/does not apply

3. *When needing a Band-aid or other item from the first-aid kit in this science class students are most often*
   A. not permitted to take items from the first-aid kit and must always ask the teacher to get what they need 2
   B. allowed to get what they need from the first-aid kit without asking 0
   C. required to ask for what they need but are then often told they may get the items from the first-aid kit themselves 1
   *D. none of the above/does not apply

4. *When visiting this science class on lab days when protective devices such as goggles and aprons are being worn by students the teacher most often*
   A. does not ask or request guests (or visitors) to wear protective gear during the time they are in the room even though it is being worn by students 0
   B. hands protective gear to guests (or visitors) upon entering the room and they are required to wear it during the time they remain there 2
   C. asks guests (or visitors) if they would like to wear protective gear while they are in the room and/or has it available upon request 1
   D. none of the above/does not apply

5. *When identifying a chemical in this science class students are most often*
   A. allowed to use "taste" to identify a chemical if instructed by the science book and the teacher also gives permission 1
   B. permitted to use the "taste test" to identify any chemical for which the science book suggests using that procedure 0
   C. never permitted to use "taste" but must identify a chemical by other methods 2
   D. none of the above/does not apply

Now turn the page ...

SAFETY TEST (G) S-POLS

	Scoring scheme
6. *When working on an experiment or activity in this science class with another teacher when the regular teacher is absent students are most often*	
A. expected to follow the same safety practices set up for the class to follow but become careless and take advantage of the situation	1
B. not required to follow the safety practices set up for the class when the regular teacher is away	0
C. instructed to follow the same safety practices as when the regular teacher is in charge of the class	2
*D. none of the above/does not apply	
7. *When setting up apparatus for an experiment or activity in this science class students are most often*	
A. told or shown how to set up the apparatus but it is not checked by the teacher before they start work unless help is needed	1
B. required to have the apparatus checked by the teacher before going ahead with the activity whether or not they are shown how it should be set up	2
C. permitted to set up and use the apparatus their own way and are not required to have it checked by the teacher before starting work	0
D. none of the above/does not apply	
8. *When handling electrical or extension cords in this science class students are most often*	
A. instructed to report to the teacher any cords that are frayed or have loose plugs but continue to use them until they can be repaired or replaced	1
B. not permitted to use any cords that are frayed or have loose plugs and must report those not in good shape	2
C. permitted to use the cords without checking for safety hazards	0
D. none of the above/does not apply	
9. *When working on an extra science project or experiment in this science class students are most often*	
A. required to list the materials required and explain to the teacher what they will be doing before being told to go ahead with the work	2
B. permitted to start work on their own after giving the name of the project and/or making a list of the materials they will need	1
C. allowed to try out anything they find interesting as soon as they obtain the necessary materials	0
D. none of the above/does not apply	
10. *When discussing fire safety in this science class the teacher most often*	
A. checks at the beginning of the term to make sure students know where the emergency shower is located and how it should be operated	2
B. reminds students that there is an emergency shower in the room but never shows them how it should be operated	1
C. does not mention the emergency shower when discussing fire safety	0
D. none of the above/does not apply	

SAFETY TEST (H)

S-POLS

REMEMBER: Select the letter that describes what happens MOST OFTEN (or is <u>closest</u> to what happens MOST OFTEN) in <u>your</u> class.

If <u>NONE</u> of the A, B or C choices are close to being right, <u>OR</u> you do not think the statement relates to your class, then you should select "D".

An asterisk (*) indicates an item that applies to all science classes and MUST be answered with an A, B or C choice if at all possible.

	Scoring scheme
1. When coming into this science class to start an experiment or activity students <u>most often</u>	
A. must work in a room that is unorganized and cluttered although the laboratory tables are usually clear with sufficient space to work	1
B. find a room that is neat and well organized with all laboratory tables clear and ready for them to start work	2
C. have little space to work since the laboratory tables are often cluttered and the room unorganized	0
* D. none of the above/does not apply	
2. When explaining a new technique in this science class such as the bending or fire-polishing of hot glass (pre-lab) the teacher <u>most often</u>	
A. discusses special safety precautions and demonstrates the correct procedure but seldom checks students as they work on the activity	1
B. demonstrates the correct procedure to be used along with special safety precautions and then checks students during the period	2
C. briefly shows students what they are to do but seldom discusses special safety precautions or checks them as they work	0
D. none of the above/does not apply	
3. When coming into this science class on a lab day with an open wound or cut on hands or arms students are <u>most often</u>	
A. expected to decide for themselves whether or not they wish to have the wound covered before working in class	0
B. required to have the wound covered with either a Band-aid or dressing and/or to wear protective gloves before being given permission to work in class	2
C. given a Band-aid or dressing (or told to go to the office or school nurse to get one) only if the teacher happens to notice the wound as they are working	1
D. none of the above/does not apply	
4. When washing several items of glassware (beakers, flasks and so on) for the teacher in this science class either during or at the end of the period students are <u>most often</u>	
A. told to wear rubber gloves in addition to chemical goggles and lab aprons	2
B. required to wear chemical goggles and lab aprons but seldom or never told to wear rubber gloves	1
C. permitted to wear whatever they like OR, expected to wear protective gear only when they wish to do so	0
D. none of the above/does not apply	
5. When coming into this science class with food (or candy or gum) the teacher <u>most often</u>	
A. permits students to eat in class (or to chew gum) if it does not interfere with their work	0
B. instructs students that neither food nor candy (or gum-chewing) is permitted in class under any circumstances	2
C. will not allow eating in class but some students chew gum anyway OR, never permits gum-chewing but sometimes people eat food (or candy) while in the room	1
*D. none of the above/does not apply	

Now turn the page ...

SAFETY TEST (H) S-POLS

6. When overcrowding occurs in this science class the teacher most often

	Scoring scheme
A. allows students to find some other place in the room to work as best they can when there is not enough space at the laboratory tables	0
B. walks around the room to make sure that everyone has sufficient space in which to work at the laboratory tables and moves people around when this is necessary	2
C. instructs students to ask permission to move if they feel they need more space in which to work comfortably at the laboratory tables	1
*D. none of the above/does not apply	

7. When leaving this science room at the end of the class period students are most often

A. required to stop work when told to do so and always have plenty of time for clean-up	2
B. not permitted to clean up before they finish their work and then must use whatever time is left OR, expected to judge for themselves when to start cleaning up	0
C. told to stop work in plenty of time but some people keep working and seldom bother or have time left for clean-up	1
*D. none of the above/does not apply	

8. When studying about an eclipse of the sun in this science class or after watching the event on television or on film the teacher most often

A. discusses the dangers of using unsafe eye protection such as welding glasses or film negatives to watch an eclipse	1
B. does not talk about the dangers of watching an eclipse or suggests which is the best or safest methods to use	0
C. shows students how to make a safe home-made device that they might use to watch an eclipse and/or demonstrates a school-purchased instrument that can be used for the purpose	2
*D. none of the above/does not apply	

9. When providing blood samples for the study of blood cells in this science class the teacher will most often

A. permit students to puncture their own or each other's finger with a new disposable blade (lancet) after using alcohol to clean the finger	1
B. allow students to use an old or used blade (lancet) that has been sterilized in alcohol to puncture their own or each other's finger	0
C. puncture his/her own finger with a disposable blade (lancet) after using alcohol to clean the finger before and after puncture	2
D. none of the above/does not apply	

10. When working on an experiment or activity in this science class where open flame is needed (Bunsen burners, alcohol lamps and so on) the teacher will most often

A. permit several students to share a burner if they are working together or if there are not enough burners to go around	0
B. allow only two students to share the one burner but others can watch or record data at the same time	1
C. require that one student only work at a burner and/or permit two people to work together only if one person is recording data and not actually using the burner	2
D. none of the above/does not apply	

S A F E T Y T E S T (I)

S-POLS

REMEMBER: Select the letter that describes what happens MOST OFTEN (or is closest to what happens MOST OFTEN) in your class.

If NONE of the A, B or C choices are close to being right, OR you do not think the statement relates to your class, then you should select "D".

An asterisk (*) indicates an item that applies to all science classes and MUST be answered with an A, B or C choice if at all possible.

	Scoring scheme
1. When using chemical (reagent) bottles in this science class students most often	
A. find them labeled clearly and completely	2
B. have trouble reading or understanding the labels since they are often partially destroyed or missing	0
C. are able to read the labels easily although some of them are old and difficult to understand or use symbols in place of words	1
D. none of the above/does not apply	
2. When working with glass equipment or thermometers in this science class students are most often	
A. expected to be careful with thermometers or glassware OR, told to be careful only after a breakage occurs	0
B. instructed to handle thermometers and glassware with care but seldom checked by the teacher to make sure they are following directions	1
C. reminded and checked by the teacher as they work to make sure glassware is placed well away from the table edges and thermometers placed so that they cannot roll	2
*D. none of the above/does not apply	
3. When becoming ill from breathing a gas that is being used or prepared in this science class (before being sent to the office or school nurse if necessary) a student is most often	
A. quickly taken outside or told to go outside into the fresh air and not permitted to return to the room until it has been completely ventilated	2
B. told to go out of the room for a while and to return to class when feeling better	1
C. expected to keep on working OR, permitted to get a drink of water or go to the rest room but must then return to class immediately	0
D. none of the above/does not apply	
4. When wearing prescription lenses (glasses) or contact lenses in this science class students are most often	
A. permitted to wear contact lenses only if safety goggles are worn over them and/or to wear prescription lenses (glasses) without safety goggles	1
B. allowed to wear contact lenses or prescription lenses (glasses) and safety goggles are not required	0
C. told that contact lenses are not permitted and that safety goggles must be worn over prescription lenses (glasses)	2
D. none of the above/does not apply	
5. When noting the gas or vapor produced by a chemical reaction when working on an experiment in this science class students are most often	
A. permitted to identify the gas by sniffing and are not told to use any special technique	0
B. told to use the "wafting" technique to identify any gas used or produced in an experiment	1
C. instructed to identify a gas by sniffing gently as they use a hand to "waft" the odor toward them only when told to do so by the teacher	2
D. none of the above/does not apply	

Now turn the page ...

SAFETY TEST (I) S-POLS

	Scoring scheme
6. *When working on an experiment in this science class and the teacher is called away for a period of time students are most often*	
A. left to work on their own until the teacher returns	0
B. supervised by a student (or special laboratory assistant) who is put in charge of the class while the teacher is out of the room	1
C. left in charge of another teacher (or practice teacher) who is asked to supervise the class during the teacher's absence	2
*D. none of the above/does not apply	
7. *When inserting glass tubing or thermometer into a rubber stopper in this science class students are most often*	
A. not reminded to use a lubricant although they may have been told to do so at the start of the term (or year)	0
B. told to use stopcock grease or silicone oil only when the teacher notices that a lubricant is not being used	1
C. instructed to use a lubricant such as silicone oil or stopcock grease whenever their experiment requires this procedure	2
D. none of the above/does not apply	
8. *When working with electrical circuits (using 110-volt power source) in this science class the teacher most often*	
A. discusses with students specific safety rules related to the activity and also checks them as they work to make sure these are being followed	2
B. instructs students to set up the equipment or apparatus for the new work and safety rules are seldom if ever discussed	0
C. reminds students to follow certain safety rules related to the activity but rarely or never checks them once they start work	1
D. none of the above/does not apply	
9. *When needing help with a science experiment or activity in this science class students most often*	
A. can ask either the teacher or other people in the room whenever they need help	1
B. are expected to ask other people in the room whenever they need help and are not permitted to bother the teacher unless the problem is urgent or important	0
C. must ask the teacher when they need help OR, can ask other people in the room only when the teacher is busy and is not available for help	2
*D. none of the above/does not apply	
10. *When using open flame burners (Bunsen or alcohol lamps and so on) in this science class students are most often*	
A. instructed that the burners must not be moved under any circumstances during use	2
B. allowed to move them as they work whenever they need to do so but are expected to handle them carefully	0
C. must obtain permission from the teacher before moving them OR, must ask the teacher to move them when this is necessary	1
D. none of the above/does not apply	

SAFETY TEST
(J)

S-POLS

REMEMBER: Select the letter that describes what happens MOST OFTEN (or is closest to what happens MOST OFTEN) in your class.

If NONE of the A, B or C choices are close to being right, OR you do not think the statement relates to your class, then you should select "D".

An asterisk (*) indicates an item that applies to all science classes and MUST be answered with an A, B or C choice if at all possible.

	Scoring Scheme
1. *When requiring special equipment or materials that are stored in a high place (or places) in this science room students are most often*	
A. required to ask for special equipment or materials needed but are then sometimes told they may get them down from high storage themselves	1
B. permitted to get down from high storage any special equipment or materials needed without first asking the teacher	0
C. not allowed to get special equipment or materials down from high storage but must ask for them when they are not set out for use	2
D. none of the above/does not apply	
2. *When handling or carrying chemical (reagent) bottles in this science class students are most often*	
A. reminded to carry reagent bottles carefully but have not been told how these should be held or carried	1
B. instructed to hold or carry them by the wide part of the bottle (not by stopper or neck) supporting the base with the other hand	2
C. permitted to carry or hold them any way that is convenient	0
D. none of the above/does not apply	
3. *When feeling sick or faint while doing a dissection or working with animals in this science class (before being sent to the office or school nurse if necessary) students are most often*	
A. instructed to sit down for a while OR, sent to the rest room with another student	1
B. permitted to go to the rest room alone OR, told to get on with their work and to forget about feeling unwell	0
C. told to sit down and to bend over with head between the knees until feeling better	2
D. none of the above/does not apply	
4. *When working on experiments in this science class students are most often*	
A. told that certain kinds of open-toed shoes (such as thongs) must not be worn and that long hair must be tied back	2
B. required to have long hair tied back but nothing is said about footwear	1
C. permitted to wear long hair any way they choose and there are no rules about footwear unless school regulations require that only certain shoes be worn to class	0
*D. none of the above/does not apply	
5. *When finding small beads of mercury around this science room or when a mercury thermometer is accidentally broken students are most often*	
A. told to report it and the mercury is cleaned up when the teacher has time to take care of it	1
B. not told to report mercury found in the room and/or sometimes students collect as much as they can	0
C. required to report it immediately and the mercury is promptly and carefully collected by the teacher	2
D. none of the above/does not apply	

Now turn the page ...

SAFETY TEST (J) S-POLS

	Scoring scheme
6. *When discussing laboratory safety rules in this science class the teacher most often*	
A. reminds students at all times of the importance of a good safety record and most people work carefully throughout the term to reduce accidents	2
B. briefly mentions the importance of good safety practices but students pay little attention and seldom follow the rules set down for the class	0
C. talks about the importance of a good safety record at the beginning of the term but seldom reminds students again later and some people become careless	1
*D. none of the above/does not apply	
7. *When heating chemicals in a test tube over direct heat (Bunsen burner, alcohol lamp and so on) the contents may easily "bump" or "fly out" and students in this science class are most often*	
A. checked while working to make sure they do not look into or point a test tube toward anyone even when safety goggles are being worn	2
B. not told that a test tube should be directed away from other people during heating	0
C. reminded only when not wearing safety goggles that they should not point a test tube toward anyone	1
D. none of the above/does not apply	
8. *When setting up electrical apparatus or equipment in this science class the teacher most often*	
A. instructs students to observe certain safety rules related to the activity and then expects them to set up the equipment without supervision	1
B. allows students to set up the equipment and to start work without discussing safety factors with them	0
C. inspects each station to make sure it is correctly and safely set up before students are permitted to start work	2
D. none of the above/does not apply	
9. *When using laboratory tables for experiments in this science class students are most often*	
A. told not to put personal possessions on the tables but are never required to take anything off the tables once they are at work	1
B. not permitted to put personal possessions other than writing materials on the tables	2
C. allowed to put personal possessions or other items on the tables without anything being said about it	0
*D. none of the above/does not apply	
10. *When discussing fire safety in this science class the teacher most often*	
A. discusses the fire triangle (oxygen - fuel - heat) both when talking about fire precautions and when explaining certain chemical reactions	2
B. never mentions the fire triangle when talking about fire precautions or chemical reactions	0
C. talks about the fire triangle (oxygen - fuel - heat) only when talking about fire precautions	1
*D. none of the above/does not apply	

Appendix C

TEACHER BACKGROUND INFORMATION

Your co-operation in completing the following questionnaire will be very much appreciated:

PLEASE make your responses by circling the appropriate letter.

1. What grade level is your primary responsibility?
   a) (7 - 9) b) (9 - 12)
2. How large is your secondary (7 - 12) school system?
   a) Less than 1000 students
   b) 1000 to 3000 students
   c) More than 3000 students
3. Including this year, how many years have you taught?
   a) 1-3 b) 4-6 c) 7-10 d) 11-20 e) more than 20
4. Including this year, how many years have you taught science?
   a) 1-3 b) 4-6 c) 7-10 d) 11-20 e) more than 20
5. Which of the subject areas below are you teaching as part of your present assignment?
   a) Biology
   b) Chemistry
   c) Physics
   d) General Science
   e) Earth Science
   f) Other ______________________________(describe)
6. What is your age?
   a) 20-29 b) 30-39 c) 40-49 d) 50 or over
7. What is your sex?
   a) Male b) Female
8. Have <u>you</u> personally ever had a classroom/laboratory accident during the time you have been teaching science?
   a) Never b) Minimal c) Several minor
   d) Serious d) Minor and serious
9. Has a student(s) in your charge had a classroom-laboratory accident during the course of your science teaching career?
   a) Never b) Minimal c) Several minor
   d) Serious e) Minor and serious
10. How much safety instruction have you received (if any) to better equip you for your science teaching career?
    A. Undergraduate/graduate science laboratory courses
       a) None b) Minimal c) Adequate d) Extensive
    B. Pre-service teacher education courses
       a) None b) Minimal c) Adequate d) Extensive
    C. In-Service teacher education courses
       a) None b) Minimal c) Adequate d) Extensive
    D. Personal reading (journals or other literature) APART from A, B or C above.
       a) None b) Minimal c) Adequate d) Extensive
11. When did you LAST receive some type of instruction or workshop training relative to science education classroom safety?
    a) within the last 3 years b) 3-10 years ago
    c) more than 10 years ago d) Never
12. To what extent (percentage) is active student involvement (laboratory or "hands-on" type activities) a major part of your instructional program?
    a) 0-25% b) 25-50% c) 50-75% d) 75-100%

Appendix D

Resource References used in Preparation of Item Bank for Preliminary and Round 1 Draft of Instruments

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Appendix E

VERNE A. DUNCAN
STATE SUPERINTENDENT
OF PUBLIC INSTRUCTION

1859

STATE OF OREGON

DEPARTMENT OF EDUCATION
700 PRINGLE PARKWAY SE
SALEM, OREGON 97310
AREA CODE 503
378-3569
Toll Free: 1-800-452-7813

May 9, 1980

Dear Oregon School Administrator:

Do you want assistance in improving the science safety procedures, practices, knowledge, and attitudes about safety of your science teaching staff?

Why should this be of interest to you? If you recently perused the February 22, 1980, State Board of Education adopted STANDARDS FOR OREGON SCHOOLS you noted the expanded safety standard. STANDARD 581-22-706: EMERGENCY PLANS AND SAFETY PROGRAMS with accompanying Compliance Indicators and a Summary. This standard will effect your next STANDARDS visit report in the area of science education.

Beginning in the Fall of 1980, I will be offering a series of science safety workshops in approximately 50 geographical/demographically (science teachers 7-12) selected locations in Oregon.

Beryl Kramer, Oregon State University doctoral student, has offered to validate a set of science safety survey instruments for student and teacher that the Oregon Department of Education can use in planned science safety workshops for secondary (7-12) science instructors.

Your district has been randomly selected to help validate the student and teacher survey instruments. Beryl will hand deliver the instruments to you and your science staff. Please support her efforts. The information she gathers will be shared with me and it will be used to help in planning the proposed science safety workshops.

This is not an Oregon Department of Education survey. It will be useful in our efforts to offer a first rate science safety workshop to your school during the 1980-82 time block.

I thank you in advance for your participation in this very timely and worthwhile effort.

Cordially
Redacted for Privacy

Ray Thiess, Specialist
Science Education
378-2120

RT:lr

VERNE A. DUNCAN

STATE OF OREGON
DEPARTMENT OF EDUCATION
942 LANCASTER DRIVE NE
SALEM, OREGON 97310

December 31, 1979

Dear Colleague:

ROUND 1 of this science laboratory safety instrument development project has been completed. Now your full cooperation and participation in ROUND 2 is needed. Please take the time to help develop the set of STUDENT and TEACHER INSTRUMENTS by submitting your best professional comments and suggestions.

The ROUND 1 comments and suggestions have been studied and incorporated into ROUND 2 instruments to the extent that the Delphi process permits. The information indicates that this project can generate a useful set of STUDENT and TEACHER INSTRUMENTS. The instruments should be useful in a variety of science laboratory safety inservice programs.

You have been selected as a respondent because of your apparent awareness and interest in promoting a more safety oriented science laboratory setting for students and teachers.

Throughout my own twenty-three year professional career in science education I have found the best source of guidance and counsel in my colleagues. Once again your support and assistance is needed. Now that the item bank for the instruments has been halved from 500 to 250, you should find the critique process somewhat less overwhelming. Please see what you can contribute to this project.

Thank you in advance for lending your best professional assistance. Remember, the final products of this project will be shared with each respondent who contributes.

Your input should reach my office on or before the following date.

DEADLINE: RETURN DATE: ______________________________

Cordially,

Redacted for Privacy

Ray Thiess, Specialist
Science Education
(503) 378-2120
In Oregon Wats 1-800-452-7813 x212D

RT:lr

VERNE A. DUNCAN

STATE OF OREGON
DEPARTMENT OF EDUCATION
942 LANCASTER DRIVE NE
SALEM, OREGON 97310

September 20, 1979

Dear Colleague,

Safety education for teachers of science has long been a concern of many individuals in the profession of science instruction at all levels. In Oregon, the scene is the same. That is, there is a need for a comprehensive inservice effort for laboratory safety for all teachers of science.

The enclosed materials need your immediate attention and expert comment.

Two purposes are tied to this request that I am asking of you. First, refinement of a set of pre- and post-tests for use in the safety inservice workshops and second, partial fulfillment of requirements for the author of the material for a doctoral study at Oregon State University. By helping the doctoral candidate, you will help me and in turn you will share the product of the research for your own use in safety workshop efforts.

The timeline is near unreal as a result of a delay in printing the material to be critiqued. However, please make the efforts to help me pull this whole project off. Your assistance is very essential to the success of this project.

I have been in contact with Dr. Jack Berberich, National Institute of Occupational Safety and Health, Division of Training and Manpower Development, and he has expressed enthusiasm for this project. Safety experts in Oregon have also expressed their interest in the project.

Your support in this project is much needed. With your help, this project will be successful. The end product of this endeavor could be very useful in the effort to improve safety in the science learning environment.

Thank you for your support.

Sincerely,
Redacted for Privacy

Ray Thiess
Specialist
Science Education
(503) 378-2120
Toll Free WATS for Oregon:
1-800-452-7813

RT:mtc
Enclosure

Appendix F

Sampling Frame

TRAINING UNIT DESIGNATION	SIZE M_i	M_i	ASSIGNED RANGE
A	13	13	1- 13
B	25	38	14- 38
C	23	61	39- 61
CZ	20	81	62- 81
D	22	103	82-103
E	26	129	104-129
F	31	160	105-160
G	34	194	161-194
H	27	221	195-221
I	19	240	222-240
J	32	272	241-272
K	27	299	273-299
L	24	323	300-323
M	21	344	324-344
N	30	374	345-374
O	21	395	375-395
P	24	419	396-419
Q	15	434	420-434
R	17	451	435-451
S	28	479	452-479
T	38	517	480-517
U	27	544	518-544
V	36	580	545-580
W	31	611	581-611
X	24	635	612-635
XZ	16	651	636-651
Y/YZ	49	700	652-700
Z	21	721	701-721
AA	25	746	722-746
BB/BBZ	43	789	747-789
CC	31	820	790-820
DD	20	840	821-840
EE/FF	50	890	841-890
GG	33	923	891-923
HH	36	959	924-959
II	23	982	960-982
JJ/JJZ	36	1018	983-1018
KK	28	1046	1019-1046
LL	37	1083	1047-1083
MM	30	1113	1084-1113
NN	18	1131	1114-1131
OO	22	1153	1132-1153
PP/QQ	56	1209	1154-1209
RR	22	1231	1210-1231
SS	31	1262	1232-1262

TOTAL NUMBER OF TRAINING AREAS .... 45 as shown above

5 Areas still to be subdivided (see above)

PROPOSED NUMBER OF LECTURE/WORKSHOPS FOR STATE

.... 50

NOTE: The above does not include Portland District 1J (Multnomah County)

Procedures used in the Establishment of Training Areas in Preparation for PPS Sampling

1. From a computer print-out showing 'certified staff associated with science' in Oregon for 1977-78, the number of science teachers in each school was counted and recorded in the 1977-78 *Summary of Organization of Pupils and Staff in Oregon Public Schools* previously prepared by the Oregon Department of Education. Teachers shown as having a minor in science were assigned a *one-half* count*.

2. From information in the above Summary and the computer print-out *count*, a *Summary of Location of Science Teachers in the Oregon Public Schools 1977-78* was prepared. This was typed by county alphabetically, with each county listing commencing on a separate page. The following information was provided:

   a) District
   b) Name of school
   c) Grade levels offered by school
   d) Number of science teachers in each of four categories (high school, middle school, junior high, elementary)
   e) Total number of students in each school
   f) Total number of instructional personnel employed by each school district

3. Each school was then plotted on a map of Oregon. Colored map pins were used to designate the number of science teachers in each school as follows:

	science teachers/school
Yellow	1
Red	2
Blue	3
Green	4
Black	5
White	6
Light blue	7
Orange	8
Grey	9
Rose	10
Pink	11
Tan	12

*"½'s" were raised to show whole numbers

Elementary teachers concerned with science instruction were mapped using a single pin (green with red dot) for *each* teacher. This was generally on a "one per school" basis. For the few schools that listed more than one teacher in elementary science, a pin was used for each teacher and no attempt was made to indicate the number of teachers specific to each school by a single pin color.

4. Using *push pins* and rubber bands, areas were designated for safety training groups. The following factors were considered in delineating these units:

   a) County centers--
      towns with a substantial school population
      groupings of smaller school districts within a defined region

   b) numbers of teachers employed within a prescribed area

   c) distances and highway/freeway availability

It was generally agreed (discussion with Ray Thiess, Gene Craven and others) that a minimum of ten and maximum of thirty teachers per workshop group would be ideal. Recognizing that in some cases distance would be a factor in attendance, and also a percentage of non-interested/low-attendance teachers could be expected, preliminary divisions were made which could later be sub-divided--see item 7 below. In a few cases, two centers were equally available to a district and these were considered to have the option of alternatives.

5. Ray Thiess was consulted at this point regarding the tentative training areas that had been set up, and some changes were made in the original schema (rubber bands and push pins being readily adjusted as necessary). Changes included the formation of compatible groups of schools that traditionally worked together and the location of "key" schools within the area that contained facilities appropriate for workshops. In addition, certain areas were subdivided at this time, based on a knowledge of the local situation.

6. Taking each county in alphabetical order (as for the original *Summary of Location of Science Teachers...*, a UNIT code was assigned to each training area in the state. Symbols used were alphabetical as follows:

   A through Z)
   AA through SS) 45 training areas

   In almost every case, the original area included school districts from other counties also, and hence in many instances, a county (reached alphabetically) was found to have several school districts already assigned a unit code (in some few cases a code number based on prior alphabetical county assignment had been given to all school districts in the county).

   Many of the originally defined areas were obviously still too large and further subdivision was required.

7. Using 5 x 7 cards, Unit codes and school districts were recorded and additional information noted on cards as follows:

   County
   Location of school (town)
   Number of teachers in each high school, middle school and/or junior high
   and elementary school noted and totalled
   Suggested centers for workshop/lectures
   Name of "contacts" (possible interested persons) listed where possible

   At this time a few of the larger Training Areas were subdivided. The Unit code for the subdivision was given a 'Z' sumbol (for instance Y was divided into a Y and YZ unit area, and BB into a BB and a BBZ area, and so on). In cases where a final decision on division of an area was uncertain, the unit was tentatively divided equally with the added possibility that two workshops would be offered and a choice could be made by teachers regarding preferred attendance.

8. Each map area was checked against the information on the 5 x 7 cards, the Oregon School Directory for 1977-78 and the computer print-out of certificated staff associated with science (see item 1 above).

9. Walter Coscher, Management Services Division, Oregon Department of Education, was contacted in lieu of Jan Clemmer who was on leave. He confirmed that the only school not listed in the computer print-out was McMinnville (information lost in mail and therefore not included in print-out). The Junior High and High school in McMinnville were both contacted and a count of science teachers obtained. Walter Coscher also indicsted that the computer print-out did in fact contain every teacher in the State of Oregon associated with science and the math print-out (not available in his office at that time) would give no additional information.

10. Pins were added to the Oregon map to represent school district personnel (other than science teachers) associated with science (blue triangular pin) and IED personnel assigned to science education (red pin with yellow).

11. Each designated training area was recorded with the number of science teachers included in the area. Random sampling procedures using "probability proportional to size" would be based on a *Sampling Frame* prepared from this information.

12. Portland District 1J was treated as a separate group, and information regarding schools, school size and so on, was recorded as for other school districts and the information mapped (see items 1 to 10 above). This was done to effectively complete the information relating to science teachers in the state of Oregon and also to provide the necessary facts should District 1J be included in the listing at a later date. However, the teacher count was not included in the SAMPLING FRAME.

APPENDICES II

Appendix Table 1 T-KOLS: Round 1 Item Selection

Sect.1 Item number	COUNT				CS3 count as % of number of CS3 group selecting	Total count as % of TOTAL SELECTING
	CS3 (17)	Science Educators (5)	Safety Experts (2)	TOTAL (24)*		
1	13	5	2	20	76%	83% X
2	8	2	2	12	47	50
3	13	3	1	17	76	71 x
4	13	1	0	14	76	58 x
5	9	3	1	13	53	54
6	10	2	2	14	59	58 x
7	14	3	1	18	82	75 x
8	15	5	1	21	88	88 x
9	13	4	2	19	76	79 x
10	15	4	1	20	88	83 x
11	6	4	1	11	35	46
12	11	2	1	14	65	58 x
13	13	4	1	18	76	75 x
14	3	3	1	7	18	29
15	12	5	2	19	71	79 x
16	7	4	2	13	41	54
17	10	4	2	16	59	67 x
18	15	4	2	21	88	88 x
19	14	4	1	19	82	79 x
20	12	2	1	15	71	63 x
21	11	3	-	14	65	58 x
22	8	5	1	14	47	58 x
23	9	5	1	15	53	63 x
24	11	4	1	16	65	67 x
25	4	5	1	10	24	42
26	13	4	2	19	76	79 x
27	9	1	1	11	53	46
28	10	2	2	14	59	58 x
29	6	-	-	6	35	25
30	8	1	-	9	47	38
31	9	3	-	12	53	50
32	9	4	-	13	53	54
33	6	2	-	8	35	33
34	12	2	2	16	71	67 x
35	4	2	-	6	24	25
36	11	3	2	16	65	67 x
37	5	-	1	6	29	25
38	10	3	2	15	59	63 x
39	8	4	2	12	47	50
40	6	2	2	10	35	42
41	12	4	2	18	71	75 x
42	8	3	2	13	47	54
43	7	-	-	7	41	29
44	10	1	2	13	59	54
45	7	3	2	12	41	50
46	4	3	2	9	24	38
47	8	3	1	12	47	50
48	11	4	1	16	65	67 x
49	10	3	-	13	59	54
50	13	4	1	18	76	75 x

*( ) number of panelists selecting

(continued)

x = Selection percent >57% (included in Round 2)

Appendix Table 1 T-KOLS: Round 1 Item Selection (*continued*)

Sect.II Item number	COUNT				CS3 count as % of number of CS3 group selecting	Total count as % of TOTAL SELECTING
	CS3 (18)	Science Educators (4)	Safety Experts (2)	TOTAL (24)*		
1	13	3	1	17	72%	71% x
2	12	2	2	16	67	67 x
3	11	3	1	15	61	63 x
4	8	3	2	13	44	54
5	16	4	1	21	89	88 x
6	9	2	1	12	50	50
7	13	2	2	17	72	71 x
8	9	3	2	14	50	58
9	15	4	1	20	83	83 x
10	11	2	2	15	61	63 x
11	6	-	2	8	33	33
12	10	3	2	15	56	63 x
13	11	1	2	14	61	58
14	10	3	1	14	56	58
15	13	3	1	17	72	71 x
16	14	2	2	18	78	75 x
17	10	4	2	16	55	67 x
18	13	2	1	16	72	67 x
19	10	1	1	12	56	50
20	10	2	2	14	56	58
21	15	1	2	18	83	75 x
22	4	1	-	5	22	21
23	12	1	1	14	67	58
24	5	1	1	7	28	29
25	11	3	1	15	61	63 x
26	11	1	-	12	61	50
27	8	2	1	11	44	46
28	8	2	2	12	44	50
29	7	3	1	11	39	46
30	16	4	2	22	89	92 x
31	15	3	1	20	83	83 x
32	11	2	2	15	61	63 x
33	16	4	2	22	89	92 x
34	13	4	2	19	72	79 x
35	14	4	2	20	78	83 x
36	13	3	2	18	72	83 x
37	14	4	1	19	78	79 x
38	7	2	2	11	39	46
39	2	-	-	2	11	8
40	7	3	2	12	39	50
41	12	2	2	16	67	67 x
42	12	4	2	18	67	75 x
43	13	3	2	18	72	75 x
44	3	3	-	6	17	25
45	8	3	2	13	44	54
46	12	3	2	17	67	71 x
47	4	2	2	8	22	33
48	8	3	1	12	44	50
49	14	3	2	19	78	79 x
50	6	4	1	11	33	46

*( ) number of panelists selecting

(*continued*)

x = Selection percent >62% (included in Round 2)

Appendix Table 1 T-KOLS: Round 1 Item Selection (*continued*)

Sect. III Item number	COUNT				CS3 count as % of number of CS3 group selecting	Total count as % of TOTAL SELECTING
	CS3 (18)	Science Educators (4)	Safety Experts (2)	TOTAL (24)*		
1	16	4	1	21	89%	88% x
2	8	1	2	11	44	46
3	18	4	2	24	100	100 x
4	10	3	-	13	56	54
5	13	2	2	17	72	71 x
6	13	2	2	17	72	71 x
7	13	1	2	16	72	67 x
8	13	1	2	16	72	67 x
9	8	-	2	10	44	42
10	11	1	2	14	61	58
11	16	2	-	18	89	75 x
12	14	2	-	16	78	67 x
13	14	3	1	18	78	75 x
14	16	3	1	20	89	83 x
15	13	2	1	16	72	67 x
16	16	3	1	20	89	83 x
17	8	2	2	12	44	50
18	17	2	1	20	94	83 x
19	9	3	2	14	50	58
20	7	1	1	9	39	38
21	8	3	1	12	44	50
22	11	3	2	16	61	67 x
23	15	2	2	19	83	79 x
24	10	2	2	14	56	58
25	16	3	2	21	89	88 x
26	12	2	2	16	67	67 x
27	10	3	2	15	56	63
28	10	2	2	14	56	58
29	12	1	2	15	67	63
30	6	2	-	8	33	33
31	12	2	1	15	67	63
32	6	-	1	7	33	29
33	9	3	1	13	50	54
34	16	4	1	21	89	88 x
35	11	2	1	14	61	58
36	11	3	2	16	61	67 x
37	11	2	2	15	61	63
38	15	4	2	21	83	88 x
39	8	1	2	11	44	46
40	9	2	2	13	50	54
41	14	3	1	18	78	75 x
42	8	1	1	10	44	42
43	13	2	1	16	72	67 x
44	15	2	1	18	83	75 x
45	7	2	1	10	39	42
46	12	2	2	16	67	67 x
47	13	2	2	17	72	71 x
48	7	4	2	13	39	54
49	14	3	2	19	78	79 x
50	12	-	1	13	67	54

*( ) number of panelists selecting

x = Selection percent >66% (included in Round 2)

(*continued*)

Appendix Table 1 T-KOLS: Round 1 Item Selection (*continued*)

Sect. IV Item number	COUNT				CS3 count as % of number of CS3 group selecting	Total count as % of TOTAL SELECTING
	CS3 (18)	Science Educators (4)	Safety Experts (2)	TOTAL (24)*		
1	7	1	2	10	39	42
2	14	3	2	19	78	79 x
3	9	1	1	11	61	46
4	10	2	2	14	56	58 x
5	15	2	2	19	83	79 x
6	11	1	1	13	61	54
7	17	2	1	20	94	83 x
8	16	3	2	21	89	88 x
9	9	2	2	13	50	54
10	17	3	2	22	94	92 x
11	15	2	2	19	83	79 x
12	11	3	2	16	61	67 x
13	9	2	1	12	50	50
14	12	1	2	15	67	63 x
15	15	3	2	20	83	83 x
16	13	1	1	15	72	63 x
17	16	3	2	21	89	88 x
18	4	1	2	7	22	29
19	15	1	2	18	83	75 x
20	12	1	1	14	67	58 x
21	7	1	1	9	39	38
22	14	3	2	19	78	79 x
23	15	2	2	19	83	79 x
24	15	3	2	20	83	83 x
25	11	3	2	16	61	67 x
26	8	-	1	9	50	38
27	8	2	2	12	50	50
28	11	1	2	14	61	58 x
29	11	2	1	14	61	58 x
30	13	3	2	18	72	75 x
31	7	1	1	9	39	38
32	6	1	1	8	33	33
33	11	1	1	13	61	54
34	8	2	1	11	44	46
35	10	2	1	13	56	54
36	9	3	2	14	50	58 x
37	7	1	1	9	39	38
38	9	1	-	10	50	42
39	15	3	2	20	83	83 x
40	8	1	2	11	44	46
41	9	2	1	12	50	50
42	10	1	2	13	56	54
43	8	2	1	11	44	46
44	12	3	2	17	67	71 x
45	12	3	1	16	67	67 x
46	10	2	2	14	56	58 x
47	8	2	2	12	44	50
48	6	1	2	9	33	38
49	12	3	2	17	67	71 x
50	7	-	2	9	39	38

*( ) number of panelists selecting

x = Selection percent >57% (included in Round 2)

(*continued*)

Appendix Table 1 T-KOLS: Round 1 Item Selection (*continued*)

Sect.V Item number	COUNT				CS3 count as % of number of CS3 group selecting	Total count as % of TOTAL SELECTING
	CS3 (16)	Science Educators (4)	Safety Experts (1)	TOTAL (21)		
1	13	3	1	17	81	81 x
2	11	3	1	15	69	71 x
3	7	3	1	11	44	52
4	9	-	1	10	56	48
5	10	2	1	13	63	62 x
6	7	2	1	10	44	48
7	10	3	1	14	63	67 x
8	8	1	1	10	50	48
9	13	3	1	17	81	81 x
10	8	1	1	10	50	48
11	8	2	1	11	50	52
12	13	3	1	17	81	81 x
13	9	-	1	10	56	48
14	9	1	1	11	56	52
15	6	3	1	10	38	48
16	9	2	1	12	56	57
17	9	3	1	13	56	62 x
18	13	1	1	15	81	71 x
19	12	1	1	14	75	67 x
20	11	2	1	14	69	67 x
21	10	3	1	14	63	67 x
22	10	1	1	12	63	57
23	11	2	1	14	69	67 x
24	12	3	1	16	75	76 x
25	9	1	1	11	56	52
26	12	3	1	16	75	76 x
27	8	1	1	10	50	48
28	3	1	1	5	19	24
29	10	2	1	13	63	62 x
30	10	2	1	13	63	62 x
31	8	1	1	10	50	48
32	15	3	1	19	94	90 x
33	12	2	1	15	75	71 x
34	9	3	1	13	56	62 x
35	8	1	1	10	50	48
36	12	1	1	14	75	67 x
37	11	2	1	14	69	67 x
38	15	3	1	19	94	90 x
39	5	2	1	8	31	38
40	7	-	1	8	44	38
41	6	1	1	8	38	38
42	8	2	1	11	50	52
43	11	2	1	14	69	67 x
44	11	1	-	12	69	57
45	9	-	-	9	56	43
46	8	2	1	11	50	52
47	9	2	1	12	56	57
48	12	1	1	14	75	67 x
49	7	3	1	11	44	52
50	7	3	1	11	44	52

*( ) number of panelists selecting

x = Selection percent >61% (included in Round 2)

(*continued*)

Appendix Table 1 T-KOLS: Round 1 Item Selection (*continued*)

Sect.VI Item number	COUNT				CS3 count as % of number of CS3 group selecting	Total count as % of TOTAL selecting
	CS3 (17)	Science Educators (4)	Safety Experts (2)	TOTAL (23)*		
1	12	2	1	15	71%	65 x
2	14	4	2	20	82	87 x
3	6	3	1	10	35	43
4	15	4	1	20	88	87 x
5	10	3	2	15	59	65 x
6	8	3	1	12	47	52
7	11	2	2	15	65	65 x
8	4	2	2	8	24	35
9	13	3	1	17	76	74 x
10	11	1	2	14	65	61
11	11	3	1	15	65	65 x
12	5	1	1	7	29	30
13	15	4	2	21	88	91 x
14	11	3	1	15	65	65 x
15	15	3	2	20	88	87 x
16	14	3	2	19	82	83 x
17	12	4	1	17	71	74 x
18	13	2	2	17	76	74 x
19	13	4	2	19	76	83 x
20	16	3	1	20	94	87 x
21	9	1	1	11	53	48
22	13	2	1	16	76	70 x
23	7	3	2	12	41	52
24	7	-	2	9	41	39
25	4	2	1	7	24	30
26	16	2	2	20	94	87 x
27	5	1	2	8	29	35
28	12	2	1	15	71	65 x
29	12	3	2	17	71	74 x
30	9	2	2	13	53	57
31	15	3	1	19	88	83 x
32	8	3	2	13	47	57
33	7	1	2	10	41	43
34	12	3	1	16	71	70 x
35	9	1	2	12	53	52
36	6	1	1	8	35	35
37	7	2	2	11	41	48
38	10	1	2	13	59	57
39	13	4	2	19	76	83 x
40	10	-	1	11	59	48
41	7	1	1	9	41	39
42	4	2	1	7	24	30
43	5	3	1	9	29	39
44	10	3	2	15	59	65 x
45	11	2	2	15	65	65 x
46	11	3	1	15	65	65 x
47	12	3	1	16	71	70 x
48	8	2	1	11	47	48
49	15	1	1	17	88	74 x
50	6	3	1	10	35	43

*( ) number of panelists selecting

x = Selection percent >64% (included in Round 2)

(*continued*)

Appendix Table 1 T-KOLS: Round 1 Item Selection (*continued*)

Sect.VII Item number	COUNT				CS3 count as % of number of CS3 group selecting	Total count as % of TOTAL selecting
	CS3 (16)	Science Educators (3)	Safety Experts (2)	TOTAL (21)*		
1	9	3	2	14	56%	67% x
2	10	3	2	15	63	71 x
3	14	3	2	19	88	90 x
4	9	2	2	13	56	62 x
5	6	3	1	10	38	48
6	11	2	2	15	69	71 x
7	12	1	1	14	75	67 x
8	8	2	2	12	50	57
9	8	1	2	11	50	52
10	7	3	2	12	44	57
11	14	2	2	18	88	86 x
12	9	2	2	13	56	62 x
13	11	1	2	14	69	67 x
14	13	-	1	14	81	67 x
15	12	2	2	16	75	76 x
16	7	2	2	11	44	52
17	9	3	2	14	56	67 x
18	12	-	2	14	75	67 x
19	16	2	2	20	100	95 x
20	3	-	1	4	19	19
21	11	3	1	15	69	71 x
22	8	2	2	12	50	57
23	15	2	2	19	94	90 x
24	7	2	2	11	44	52
25	10	2	2	14	63	67 x
26	6	2	1	9	38	43
27	10	-	2	12	63	57
28	5	3	2	10	31	48
29	11	1	2	14	69	67 x
30	3	1	1	5	19	24
31	5	2	2	9	31	43
32	4	2	1	7	25	33
33	11	-	1	12	69	57
34	6	2	1	9	38	43
35	11	1	1	13	69	62 x
36	11	1	1	13	69	62 x
37	10	2	1	13	63	62 x
38	14	-	1	15	88	71 x
39	9	2	2	13	56	62 x
40	14	1	1	16	88	76 x
41	4	3	2	9	25	43
42	14	3	2	19	88	90 x
43	5	1	1	7	31	33
44	10	1	1	12	63	57
45	6	1	1	8	38	38
46	8	2	2	12	50	57
47	3	1	1	5	19	24
48	7	-	1	8	44	38
49	13	2	2	17	81	81 x
50	9	2	2	13	56	62 x

(*continued*)

*( ) number of panelists selecting

x = Selection percent >61% (included in Round 2)

Appendix Table 1 T-KOLS: Round 1 Item Selection (*continued*)

Sect.VIII Item number	COUNT				CS3 count as % of number of CS3 group selecting	Total count as % of TOTAL selecting
	CS3 (18)	Science Educators (5)	Safety Experts (3)	TOTAL (26)*		
1	8	4	2	14	44%	54%
2	14	3	2	19	78	73 x
3	11	1	2	14	61	54
4	15	3	2	20	83	77 x
5	17	3	2	22	94	85 x
6	18	5	2	25	100	96 x
7	10	5	3	18	56	69 x
8	11	5	2	18	61	69 x
9	13	3	2	18	72	69 x
10	13	4	2	19	72	73 x
11	16	4	2	22	89	85 x
12	9	3	2	14	50	54
13	16	4	2	22	89	85 x
14	5	3	2	10	31	38
15	8	3	2	13	44	50
16	9	3	2	14	50	54
17	13	2	2	17	72	65 x
18	7	2	2	11	39	42
19	12	4	2	18	67	69 x
20	17	3	2	22	94	85 x
21	11	3	2	16	61	62 x
22	9	2	2	13	50	50
23	16	3	2	21	89	81 x
24	7	1	2	10	39	38
25	4	2	2	8	22	31
26	8	2	2	12	44	46
27	10	3	2	15	56	58 x
28	7	2	3	12	39	46
29	12	3	2	17	67	65 x
30	12	2	2	16	67	62 x
31	13	2	2	17	72	65 x
32	8	1	2	11	44	42
33	13	3	2	18	72	69 x
34	7	1	2	10	39	38
35	16	2	2	20	89	77 x
36	12	2	2	16	67	62 x
37	11	2	2	15	61	58 x
38	11	2	2	15	61	58 x
39	10	3	2	15	56	58 x
40	9	3	2	14	50	54
41	10	3	2	15	56	58 x
42	9	1	3	13	50	50
43	10	1	2	13	56	50
44	12	2	2	16	67	62 x
45	12	3	2	17	67	65 x
46	3	3	2	14	50	54
47	7	3	2	12	39	46
48	9	2	2	13	50	50
49	7	2	2	11	39	42
50	16	3	3	22	89	85 x

(*continued*)

*( ) number of panelists selecting

x = Selection percent >57% (included in Round 2)

Appendix Table 1 T-KOLS: Round 1 Item Selection (*continued*)

Sect. IX Item number	COUNT				CS3 count as % of number of CS3 group selecting	Total count as % of TOTAL selecting
	CS3 (14)	Science Educators (4)	Safety Experts (1)	TOTAL (19)*		
1	9	2	-	11	64%	58% x
2	14	3	-	17	100	89 x
3	3	3	-	6	21	32
4	10	2	-	12	71	63 x
5	9	2	-	11	64	58 x
6	10	3	-	13	71	68 x
7	4	2	-	6	29	32
8	6	3	-	9	43	47
9	8	3	-	11	57	58 x
10	14	3	-	17	100	89 x
11	13	3		16	93	84 x
12	5	2	-	7	36	37
13	12	2	-	14	86	74 x
14	12	3	-	15	86	79 x
15	12	3	1	16	86	84 x
16	10	2	-	12	71	63 x
17	12	3	-	15	86	79 x
18	11	2	-	13	79	68 x
19	9	2	1	12	64	63 x
20	4	2	-	6	29	32
21	7	4	-	11	50	58 x
22	12	4	-	16	86	84 x
23	13	2	-	15	93	79 x
24	3	2	-	5	21	26
25	11	3	-	14	79	74 x
26	4	2	-	6	29	32
27	9	-	-	9	64	47
28	10	2	-	12	71	63 x
29	7	1	-	8	50	42
30	12	3	-	15	86	79 x
31	12	3	-	15	86	79 x
32	5	2	-	7	36	37
33	9	2	-	11	64	58 x
34	7	2	-	9	50	47
35	5	2	-	7	36	37
36	14	4	-	18	100	95 x
37	11	2	-	13	79	68 x
38	4	2	-	6	29	32
39	5	2	-	7	36	37
40	7	3	-	10	50	53
41	11	1	-	12	79	63 x
42	7	4	-	11	50	58 x
43	7	2	-	9	50	47
44	4	2	-	6	29	32
45	7	2	-	9	50	47
46	6	1	-	7	43	37
47	5	2	-	7	36	37
48	7	4	-	11	50	58 x
49	6	1	-	7	43	37
50	12	4	-	16	86	84 x
51	9	4	-	13	64	68 x

(*continued*)

*( ) number of panelists selecting

x = Selection percent >57% (included in Round 2)

Appendix Table 1 T-KOLS: Round 1 Item Selection (*continued*)

Sect.X Item number	COUNT				CS3 count as % of number of CS3 group selecting	Total count as % of TOTAL selecting
	CS3 (17)	Science Educators (5)	Safety Experts (1)	TOTAL (23)*		
1	16	4	1	21	94%	91% x
2	12	2	-	14	71	61
3	12	4	1	17	71	74 x
4	8	4	-	12	47	52
5	10	4	1	15	59	65 x
6	10	2	-	12	59	52
7	8	3	-	11	47	48
8	9	4	1	14	59	61
9	12	4	-	16	71	70 x
10	15	4	1	20	88	87 x
11	9	3	-	12	53	52
12	9	3	1	13	53	57
13	12	4	-	16	71	70 x
14	9	2	1	12	53	52
15	12	4	-	16	71	70 x
16	15	3	1	19	88	83 x
17	9	2	1	12	53	52
18	5	2	-	7	29	30
19	11	3	1	15	65	65 x
20	13	2	-	15	76	65 x
21	7	4	-	11	41	48
22	7	3	1	11	41	48
23	12	4	1	17	71	74 x
24	12	2	1	15	71	65 x
25	13	3	1	17	76	74 x
26	10	3	1	14	59	61
27	10	4	1	15	59	65 x
28	11	3	1	15	65	65 x
29	13	3	1	17	76	74 x
30	11	3	1	15	65	65 x
31	8	3	1	12	47	52
32	11	3	1	15	65	65 x
33	6	2	-	8	35	35
34	12	5	1	18	71	78 x
35	5	2	-	7	29	30
36	14	3	1	18	82	78 x
37	15	3	-	18	88	78 x
38	8	3	-	11	47	48
39	11	3	-	14	65	61
40	14	4	1	19	82	83 x
41	13	4	-	17	75	74 x
42	10	2	-	12	59	52
43	14	5	1	20	82	87 x
44	10	3	1	14	59	61
45	11	3	1	15	65	65 x
46	14	4	-	18	82	78 x
47	12	3	1	16	71	70 x
48	7	2	1	10	41	43
49	9	2	1	12	53	52
50	12	4	1	17	71	74 x
51	9	3	1	13	53	57

(*continued*)

*( ) number of panelists selecting

x = Selection percent >64% (included in Round 2)

Appendix Table 2 T-KOLS: Round 2 Item Selection

Section and Item number	COUNT				CS3 count as % of number of CS3 group participating	Total count as % of TOTAL SELECTING	
	CS3	Science Educators	Safety Experts	TOTAL			
Sect.I	(6)	(4)	(2)	(12)*			
1	5	3	2	10	83%	83%	x
3	4	4	2	10	67	83	x
4	3	2	2	7	50	58	x
5	3	2	1	6	50	50	
7	2	1	1	4	33	33	
8	4	4	2	10	67	83	x
9	5	3	2	10	83	83	x
10	4	3	2	9	67	75	x
12	3	-	1	4	50	33	
13	2	1	1	4	33	33	
15	4	3	1	8	67	67	x
17	3	1	1	5	50	42	
18	3	2	1	6	50	50	
19	2	3	1	6	33	50	
20	4	3	2	9	67	75	x
21	5	2	2	9	83	75	x
22	2	2	1	5	33	42	
23	2	4	-	6	33	50	
24	4	3	1	8	67	67	x
26	4	4	2	10	67	83	x
28	5	1	1	7	83	58	x
34	5	2	2	9	83	75	x
36	5	3	2	10	83	83	x
38	5	4	1	10	83	83	x
41	2	1	1	4	33	33	
48	5	-	1	6	83	50	
50	5	3	1	9	83	75	x

x = *Section I* Selection percent >57% (included in Round 3)

Sect.II	(6)	(4)	(1)	(11)*			
1	5	3	-	8	83	73	x
2	4	4	1	9	67	82	x
3	3	2	1	6	50	55	
5	3	4	1	8	50	73	x
7	5	4	1	10	83	91	x
9	3	4	-	7	50	64	x
10	3	3	-	6	50	55	
12	4	1	-	5	67	45	
15	3	2	1	6	50	55	
16	3	4	1	8	50	73	x
17	5	2	1	8	83	73	x
18	2	3	-	5	33	45	
21	4	3	1	8	67	73	x
25	-	1	1	2	-	18	
30	5	4	-	9	83	82	x
31	2	3	1	6	33	55	
32	2	4	1	7	33	64	x
33	2	4	1	7	33	64	x

*( ) number of panelists selecting

(*continued*)

Appendix Table 2 T-KOLS: Round 2 Item Selection (*continued*)

Section and Item number	COUNT				CS3 count as % of number of CS3 group participating	Total count as % of TOTAL selecting
	CS3	Science Educators	Safety Experts	TOTAL		
Sect.II - continued						
34	3	1	1	5	50%	45%
35	3	2	1	6	50	55
36	1	2	1	4	17	36
37	5	4	1	10	83	91 x
41	2	1	1	4	33	36
42	4	2	1	7	67	64 x
43	5	3	1	9	83	82 x
46	2	4	1	7	33	64 x
49	4	3	1	8	67	73 x

x = *Section II* Selection percent >63% (included in Round 3)

Sect.III	(8)	(2)	(1)	(11)*		
1	5	2	1	8	63	73 x
3	8	2	1	11	100	100 x
5	4	1	-	5	50	45
6	5	1	-	6	63	55 x
7	7	1	-	8	88	73 x
8	3	2	-	5	38	45
11	7	1	-	8	88	73 x
12	4	1	-	5	50	45
13	7	2	-	9	88	82 x
14	5	2	-	7	63	64 x
15	2	1	-	3	25	27
16	7	1	-	8	88	73 x
18	6	1	-	7	75	64 x
22	4	2	-	6	50	55 x
23	6	1	-	7	75	64 x
25	8	2	1	11	100	100 x
26	6	2	-	8	75	73 x
34	1	1	-	2	13	18
36	3	1	1	5	38	45
38	5	2	1	8	63	73 x
41	7	2	1	10	88	91 x
43	1	1	1	3	13	27
44	6	2	1	9	75	82 x
46	1	2	-	3	13	27
47	3	2	-	5	38	45
49	3	2	-	5	38	45

x = *Section III* Selection percent >54% (included in Round 3)

(*continued*)

*( ) number of panelists selecting

Appendix Table 2 T-KOLS: Round 2 Item Selection (*continued*)

Section and Item number	COUNT				CS3 count as % of number of CS3 group participating	Total count as % of TOTAL SELECTING
	CS3	Science Educators	Experts	TOTAL		
Sect.IV	(6)	(3)	(1)	(10)*		
2	3	3	-	6	50%	60% x
4	2	3	-	5	33	50
5	3	2	1	6	50	60 x
7	6	-	1	7	100	70 x
8	6	3	1	10	100	100 x
10	5	2	1	8	83	80 x
11	5	3	1	9	83	90 x
12	5	1	-	6	83	60 x
14	3	3	-	6	50	60 x
15	5	3	-	8	83	80 x
16	4	3	1	8	67	80 x
17	3	1	-	4	50	40
19	3	1	1	5	50	50
20	5	1	1	7	83	70 x
22	2	2	1	5	33	50
23	2	2	1	5	33	50
24	6	3	1	10	100	100 x
25	2	2	-	4	33	40
28	3	3	1	7	50	70 x
29	3	-	-	3	50	30
30	4	3	-	7	67	70 x
36	3	2	1	6	50	60 x
39	2	3	1	6	33	60 x
44	4	1	1	6	67	60 x
45	2	3	-	5	33	50
46	2	3	-	5	33	50
49	2	2	1	5	33	50

x = *Section IV* Selection percent >59% (included in Round 3)

Sect.V	(7)	(5)	(1)	(13)*		
1	4	2	-	6	57	46
2	2	3	-	5	29	38
5	5	4	-	9	71	69 x
7	4	4	-	8	57	62
9	6	4	-	10	86	77 x
12	6	4	-	10	86	77 x
17	5	4	1	10	71	77 x
18	7	3	-	10	100	77 x
19	5	4	-	9	71	69 x
20	3	2	-	5	43	38
21	2	4	1	7	29	54
23	5	5	1	11	71	85 x
24	6	4	1	11	86	85 x
26	7	4	1	12	100	92 x

(*continued*)

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*( ) number of panelists selecting

Appendix Table 2 T-KOLS: Round 2 Item Selection (*continued*)

Section and Item number	COUNT				CS3 count as % of number of CS3 group selecting	Total count as % of TOTAL SELECTING	
	CS3	Science Educators	Safety Experts	TOTAL			
Sect.V - continued							
29	3	4	1	8	43	62	
30	3	4	1	8	43	62	
32	5	5	1	11	71	85	x
33	5	3	1	9	71	69	x
34	4	4	1	9	57	69	x
36	7	3	1	11	100	85	x
37	2	3	1	6	29	46	
38	7	4	1	12	100	92	x
43	4	3	1	8	57	62	
48	3	3	1	7	43	54	

x = *Section V* Selection percent >68% (included in Round 3)

Sect.VI	(5)	(4)	(1)	(10)*			
1	4	4	1	9	80%	90%	x
2	5	4	1	10	100	100	x
4	5	2	1	8	100	80	x
5	1	2	-	3	20	30	
7	4	2	1	7	80	70	x
9	2	2	-	4	40	40	
11	3	2	1	6	60	60	
13	5	4	1	10	100	100	x
14	-	3	-	3	0	30	
15	4	3	1	8	80	80	x
16	5	4	1	10	100	100	x
17	3	3	-	6	60	60	
18	4	1	1	6	80	60	
19	5	2	1	8	100	80	x
20	2	3	-	5	40	50	
22	4	4	-	9	80	90	x
26	3	4	1	8	60	80	x
28	2	3	1	6	40	60	
29	4	2	1	7	80	70	x
31	5	4	1	10	100	100	x
34	1	2	1	4	20	40	
39	4	2	1	7	80	70	x
44	4	3	1	8	80	80	x
45	4	3	1	8	80	80	x
46	2	2	-	4	40	40	
47	4	4	1	9	80	90	x
49	2	3	1	6	40	60	

x = *Section VI* Selection percent >69% (included in Round 3)

(*continued*)

*( ) number of panelists selecting

Appendix Table 2 T-KOLS: Round 2 Item Selection (*continued*)

Section and Item number	COUNT				CS3 count as % of number of CS3 group selecting	TOTAL count as % of total selecting	
	CS3	Science Educators	Safety Experts	TOTAL			
Sect.VII	(7)	(4)	(1)	(12)*			
1	4	2	-	6	57%	50%	
2	2	1	-	3	29	25	
3	7	4	1	12	100	100	x
4	3	2	-	5	43	42	
6	4	1	1	6	57	50	
7	3	4	1	8	43	67	x
11	4	3	1	8	57	67	x
12	2	3	1	6	29	50	
13	4	3	1	8	57	67	x
14	5	3	1	9	71	75	x
15	4	3	1	8	57	67	x
17	2	3	-	5	29	42	
18	3	1	1	5	43	42	
19	7	3	1	11	100	92	x
21	5	2	-	7	71	58	
23	6	1	1	8	86	67	x
25	6	2	1	9	86	75	x
29	6	1	1	8	86	67	x
35	5	2	1	8	71	67	x
36	4	3	-	7	57	58	
37	6	2	1	9	86	75	x
38	4	2	1	7	57	58	
39	3	-	-	3	43	25	
40	4	3	-	7	57	58	
42	5	1	-	6	71	50	
49	5	2	1	8	71	67	x
50	5	1	1	7	71	58	

x = *Section VII* Selection percent >66% (included in Round 3)

Sect.VIII	(4)	(4)	(1)	(9)*			
2	1	2	-	3	25	33	
4	3	3	1	7	75	78	x
5	4	3	1	7	100	78	x
6	2	4	1	7	50	78	x
7	2	2	-	4	50	44	
8	-	1	1	2	-	22	
9	4	4	-	8	100	89	x
10	1	2	1	4	25	44	
11	4	4	1	9	100	100	x
13	3	3	1	7	75	78	x
17	3	3	-	6	75	67	x
19	-	2	-	2	-	22	
20	2	3	1	6	50	67	x
21	2	3	1	6	50	67	x
23	2	2	-	4	50	44	

(*continued*)

*( ) number of panelists selecting

Appendix Table 2 T-KOLS: Round 2 Item Selection (*continued*)

Section and Item number	COUNT				CS3 count as % of number of CS3 group selecting	TOTAL count as % of total selecting
	CS3	Science Educators	Safety Experts	TOTAL		
Sect. VIII	continued					
27	-	2	-	2	-	22%
29	3	1	-	4	75%	44
30	1	1	-	2	25	22
31	1	2	1	4	25	44
33	1	3	-	4	25	44
35	2	4	-	6	50	67 x
36	2	1	-	3	50	33
37	3	3	1	7	75	78 x
38	3	3	-	6	75	67 x
39	2	3	1	6	50	67 x
41	3	1	1	5	75	56
44	1	2	1	4	25	44 x
45	-	2	-	2	-	22
50	3	4	-	7	75	78 x

x = *Section VIII* Selection percent >66% (included in Round 3)

Sect. IX	(6)	(3)	-	(9)[*]		
1	3	1	-	4	50%	44%
2	5	1	-	6	83	67 x
4	1	2	-	3	17	33
5	4	3	-	7	67	78 x
6	2	1	-	3	33	33
9	2	1	-	3	33	33
10	6	3	-	9	100	100 x
11	6	3	-	9	100	100 x
13	3	3	-	6	50	67 x
14	6	2	-	8	100	89 x
15	4	-	-	4	67	44
16	4	1	-	5	67	56
17	4	2	-	6	67	67 x
18	3	1	-	4	50	44
19	3	3	-	6	50	67 x
21	3	3	-	6	50	67 x
22	2	2	-	4	33	44
23	4	2	-	6	67	67 x
25	4	2	-	6	67	67 x
28	1	2	-	3	17	33
30	4	2	-	6	67	67 x
31	6	1	-	7	100	** 78
33	-	2	-	2	-	22
36	2	2	-	4	33	44
37	3	2	-	5	50	56
41	6	2	-	8	100	89 x
42	3	-	-	3	50	33
48	2	3	-	5	33	56
50	2	3	-	5	33	56
51	4	3	-	7	67	78 x

x = *Section IX* Selection percent >66% (included in Round 3)

(*continued*)

[*] ( ) number of panelists selecting

** *omitted from selection in error*

Appendix Table 2 T-KOLS: Round 2 Item Selections (*continued*)

Section and Item number	COUNT				CS3 count as % of number of CS3 group selecting	TOTAL COUNT as % of total selecting
	CS3	Science Educators	Safety Experts	TOTAL		
Sect.X	(5)	(2)	(1)	(8)*		
1	4	2	1	7	80%	88% x
3	1	2	1	4	20	50
5	2	2	1	5	40	63 x
9	1	2	-	3	20	38
10	4	2	-	6	80	75 x
13	3	2	-	5	60	63 x
15	3	2	-	5	60	63 x
16	4	1	-	5	80	63 x
19	1	1	-	2	20	25
20	3	2	1	6	60	75 x
23	2	2	-	4	40	50
24	1	1	-	2	20	25
25	3	1	1	5	60	63 x
27	3	1	1	5	60	63 x
28	4	2	-	6	80	75 x
29	1	2	-	3	20	38
30	1	-	-	1	20	13
32	4	2	-	6	80	75 x
34	2	2	1	5	40	63 x
36	1	2	-	3	20	38
37	1	-	-	1	20	13
40	3	2	1	6	60	75 x
41	2	2	1	5	40	63 x
43	-	1	1	2	-	25
45	3	1	1	5	60	63 x
46	2	2	1	5	40	63 x
47	3	1	1	5	60	63 x
50	3	1	1	5	60	63 x

x = *Section* X Selection percent >62% (included in Round 3)

*( ) number of panelists selecting

Appendix Table 3 S-POLS: K Set Item Transfers

Section number of original Temporary K Set items	Round 2 Section and Set Number of Temporary K Set items as for Pilot Study	New Set number of Temporary K Set item for Round 3	Section number of item displaced by temporary K Set item	Fate of displaced item	Round 3 Section and Set number of Revised K Set items (Field study item bank) NOTE: K Set numbers do not necessarily reflect Sections
I					
II					
III					
IV	IV.3 (K1) IV.14 (K9)*	C4	IV.13 (was C4)	Discarded[a]	I11 (K10)[a] IV.14 (K1)
V	IV.8 (K2)	D5	V.4 (was D5)	K2	V.4 (K2)
VI	II. (K3) VI.4 (K4)	J6 H6	VI.10 (was J6) VI.1 (was H6)	K3 I6[b]	VI.10 (K3) VI.8 (K4)[b]
VII	VII.2 (K5)	F7	VII.5 (was F7)	K5	VII.5 (K5)
VIII	VIII.12 (K6)	D8	VIII.13 (was D8)	K6	VIII.13(K6)
IX	IX.9 (K7)	H9	IX.1 (was H9)	K7	IX.1 (K7)
X	X.1 (K8) X.12 (K10)*	I10	X.8 (was I10)	C10[c]	X.10 (K8)[c] X.12 (K9)

* Items constructed to bring the Temporary K set count to ten (not used in replacement)

[a] I.11--New item constructed to replace the discarded IV.13 (became K10)

[b] I.6-- Displaced VI.8 (became K4)

[c] C.10--Displaced X.10 (became K8)

Appendix Table 4 S-POLS: Rearrangement of Round 2 Items

SET	Sections									
	I	II	III	IV	V	VI	VII	VIII	IX	X
	Item number (Set)									
	1	2	3	4	5	6	7	8	9	10
A	I.10	II.5	III.9	IV.7	V.3	VI.7	VII.10	VIII.8	IX.7	X.9
B	I.5	II.7	III.2	IV.6	V.2	VI.12	VII.9	VIII.10	IX.10	X.4
C	I.2	IV.4	III.6	IV.3	V.10	VI.2	VII.4	VIII.7	IX.8	X.8
D	I.7	II.11	III.1	IV.1	IV.8	VI.11	VII.6	VIII.12	IX.4	X.5
E	I.8	II.4	III.10	IV.5	V.5	VI.5	II.8	VIII.9	II.1	X.2
F	I.1	II.12	III.5	IV.12	V.1	VI.6	VII.2	VIII.6	IX.2	X.3
G	I.3	II.10	III.4	IV.2	V.8	VI.3	VII.7	VIII.11	IX.3	X.11
H	I.6	II.9	III.8	IV.9	V.6	VI.4	VII.8	VIII.2	IX.9	X.6
I	I.9	II.2	III.7	IV.11	V.9	VI.1	VII.1	VIII.4	IX.5	X.1
J	I.4	II.6	III.3	IV.10	V.7	II.3	VII.3	VIII.5	IX.6	X.7

Appendix Table 5 T-KOLS: Preliminary Item Response Frequencies

Item number	Response	SECTION									
		I	II	III	IV	V	VI	VII	VIII	IX	X
1	Preferred	60.0%	31.1%	25.2%			31.1%				21.5%
	Less preferred	26.7	22.2	26.7			47.4				31.1
	Not acceptable	4.4	37.8	36.3			6.7				22.2
	No response	8.9	8.9	11.9			14.8				25.2
2	Pref.		29.6		19.3%		74.1			52.6%	
	Less		42.2		67.4		10.4			14.1	
	N/A		19.3		0.7		0.7			14.1	
	None		8.9		12.6		14.8			19.3	
3	Pref.	36.3		75.6				60.0%			
	Less	37.8		13.3				15.6			
	N/A	18.5		1.5				5.2			
	None	7.4		9.6				19.3			
4	Pref.	48.9					70.4		46.7%		
	Less	37.0					11.1		30.4		
	N/A	4.4					5.2		1.5		
	None	9.6					13.3		21.5		
5	Pref.		41.5		20.0	39.3%			64.4	34.8	68.9
	Less		40.7		46.7	23.7			17.0	8.9	6.7
	N/A		9.6		20.7	3.0			3.0	37.8	2.2
	None		8.1		12.6	34.1			15.6	18.5	22.2
6	Pref.			25.9					31.1		
	Less			11.9					41.5		
	N/A			50.4					14.1		
	None			11.9					13.3		
7	Pref.		78.5	47.4	14.8		64.4	50.4			
	Less		8.9	27.4	30.4		20.0	18.5			
	N/A		4.4	11.1	40.0		2.2				
	None		8.1	14.1	14.8		13.3	31.1			
8	Pref.	65.2			63.0						
	Less	23.0			18.5						
	N/A	4.4			1.5						
	None	7.4			17.0						
9	Pref.	42.2	54.1			23.0			50.4		
	Less	31.9	21.5			31.9			25.2		
	N/A	14.8	12.6			17.0			5.9		
	None	11.1	11.9			28.1			18.5		
10	Pref.	51.9			71.1					53.3	60.7
	Less	34.1			14.8					22.2	10.4
	N/A	5.2			0.7					3.7	0.7
	None	8.9			13.3					20.7	28.1
11	Pref.			33.3	34.8			26.7	74.1	43.7	
	Less			34.1	33.3			33.3	8.1	21.5	
	N/A			20.1	14.1			8.9	2.2	14.8	
	None			12.8	17.8			31.1	15.6	20.0	
12	Pref.				16.3	45.2					
	Less				60.7	17.0					
	N/A				3.7	12.6					
	None				19.3	25.2					
13	Pref			62.2			80.7	70.4	73.3	56.3	34.1
	Less			21.5			3.7	5.9	11.1	20.7	35.6
	N/A			5.9			2.2	2.2	1.5	3.0	9.6
	None			10.4			13.3	21.5	14.1	20.0	20.7

(*continued*)

Appendix Table 5 T-KOLS: Preliminary Item Response Frequencies (*continued*)

Item number	Response	SECTION									
		I	II	III	IV	V	VI	VII	VIII	IX	X
14	Preferred			68.1%	32.6%			45.9%		23.0	
	Less preferred			12.6	44.4			24.4		43.7	
	Not acceptable			1.5	7.4			5.2		11.9	
	No response			17.8	15.6			24.4		21.5	
15	Pref.	67.4%			69.6		71.1%	45.9			36.3%
	Less	13.3			13.3		12.6	24.4			32.6
	N/A	3.7			2.2		0.7	9.6			5.9
	None	15.6			14.8		15.6	20.0			25.2
16	Pref.		76.3%	60.7	57.8		73.3				54.1
	Less		11.9	20.0	20.0		5.2				17.8
	N/A		2.2	3.7	5.9		5.9				1.5
	None		9.6	15.6	16.3		15.6				26.7
17	Pref.		39.3			70.4%			66.7	52.6	
	Less		44.4			5.9			14.1	24.4	
	N/A		3.7			1.5			2.2	3.0	
	None		12.6			22.2			17.0	20.0	
18	Pref.			65.2		29.6					
	Less			14.1		34.8					
	N/A			3.0		9.6					
	None			17.8		25.9					
19	Pref.					37.0	63.7	58.5		23.7	
	Less					26.7	19.3	19.3		40.0	
	N/A					11.9	3.7	3.7		15.6	
	None					24.4	13.3	18.5		20.7	
20	Pref.	20.7			31.1				62.2		59.3
	Less	55.6			23.7				13.3		5.2
	N/A	12.6			23.0				3.7		8.9
	None	11.1			22.2				20.7		26.7
21	Pref.	51.1	21.5						52.6	17.0	
	Less	31.1	57.8						17.8	28.1	
	N/A	7.4	12.6						3.7	33.3	
	None	10.4	8.1						25.9	21.5	
22	Pref.			25.2			49.6				
	Less			25.9			35.6				
	N/A			34.8			0.7				
	None			14.1			14.1				
23	Pref.			71.9		48.1		58.5		30.4	
	Less			10.4		19.3		17.0		35.6	
	N/A			3.0		2.2		3.7		13.3	
	None			14.8		30.4		20.7		20.7	
24	Pref	25.9			63.0	57.0					
	Less	34.1			14.1	13.3					
	N/A	26.7			6.7	0.7					
	None	13.3			16.3	28.9					
25	Pref.			48.1				47.4		27.4	34.8
	Less			28.9				26.7		11.1	33.3
	N/A			8.1				5.9		40.7	11.1
	None			14.8				20.0		20.7	20.7
26	Pref	53.3		31.1		31.1	76.6				
	Less	28.1		27.4		31.1	8.9				
	N/A	3.7		25.9		11.1	1.5				
	None	14.8		15.6		26.7	13.3				

(*continued*)

Appendix Table 5 T-KOLS: Preliminary Item Response Frequencies (*continued*)

Item number	Response	SECTION									
		I	II	III	IV	V	VI	VII	VIII	IX	X
27	Preferred										18.5%
	Less preferred										42.2
	Not acceptable										16.3
	No response										23.0
28	Pref.	15.6			19.3						45.9
	Less	71.1			18.5						23.0
	N/A	0.7			38.5						8.1
	None	12.6			23.7						23.0
29	Pref.						51.1%	63.7			
	Less						30.4	13.3			
	N/A						3.7	0.7			
	None						14.8	22.2			
30	Pref.		71.9		63.0					54.1%	
	Less		7.4		15.6					17.8	
	N/A		11.1		3.8					6.7	
	None		9.6		18.5					21.5	
31	Pref.						74.8				
	Less						11.1				
	N/A						0.7				
	None						13.3				
32	Pref.		37.8			75.6					18.5
	Less		46.7			3.8					35.6
	N/A		6.7			-					23.7
	None		8.9			21.5					22.2
33	Pref.		26.7			42.2					
	Less		28.1			25.2					
	N/A		31.1			3.0					
	None		14.1			29.6					
34	Pref.	62.2				24.4					45.9
	Less	23.7				3.7					21.5
	N/A	4.4				48.1					4.4
	None	9.6				23.7					28.1
35	Pref.							60.0	43.7		
	Less							14.8	34.1		
	N/A							2.2	4.4		
	None							23.0	17.8		
36	Pref.	36.3			25.2	66.7					
	Less	36.3			29.6	7.4					
	N/A	12.6			9.6	0.7					
	None	14.8			35.6	25.2					
37	Pref.		49.6					67.4	68.1		
	Less		28.1					6.7	13.3		
	N/A		11.9					-	0.7		
	None		18.4					25.9	17.8		
38	Pref.	52.6		57.8		30.4			38.5		
	Less	31.9		17.8		34.1			6.7		
	N/A	3.7		5.9		14.8			37.8		
	None	11.9		18.5		20.7			17.0		
39	Pref.				54.1		53.3		75.6		
	Less				18.5		25.2		3.7		
	N/A				3.7		6.7		4.4		
	None				23.7		14.8		16.3		

(*continued*)

Appendix Table 5 T-KOLS: Preliminary Item Response Frequencies (*continued*)

Item number	Response	SECTION									
		I	II	III	IV	V	VI	VII	VIII	IX	X
40	Preferred Less preferred Not acceptable No response										23.0% 45.9 6.7 24.4
41	Pref. Less N/A None			50.4% 23.7 10.4 15.6						55.6% 16.3 4.4 23.7	63.0 7.4 2.2 27.4
42	Pref. Less N/A None		27.4% 39.3 11.1 22.2								
43	Pref. Less N/A None		55.6 25.2 3.7 15.6								
44	Pref. Less N/A None			63.7 17.8 3.0 15.6	45.2% 28.9 3.0 23.0		6.7 77.8 1.5 14.1		63.0 15.6 4.4 17.0		
45	Pref. Less N/A None						47.4 34.1 3.7 14.8				40.7 28.1 9.6 21.5
46	Pref. Less N/A None		33.3 26.7 27.4 12.6								20.0 54.1 6.7 19.3
47	Pref. Less N/A None						81.5 1.5 1.5 15.6				3.7 75.6 0.7 20.0
48	Pref. Less N/A None										
49	Pref Less N/A None		29.6 40.7 15.6 14.1					69.6 10.4 - 20.0			
50	Pref. Less N/A None	23.0 45.2 22.2 9.6							55.6 21.5 3.7 19.3		45.9 14.8 10.4 28.9
51	Pref. Less N/A None	68.9 15.6 5.2 10.4					73.3 11.9 1.5 13.3			23.7 50.4 3.7 22.2	
52	Pref. Less N/A None									10.4 65.9 2.2 21.5	

Appendix Table 6 S-POLS: Preliminary Item Response Frequencies

Item #	Response	Set										
		A	B	C	D	E	F	G	H	I	J	K
1	Best answer	22.9%	21.7%	52.4%	74.1%	32.9%	19.8%	48.6%	65.4%	46.0%	49.0%	9.6%
	Less preferred	7.4	16.0	27.2	9.2	33.2	43.0	18.1	17.4	20.9	32.2	76.6
	Not acceptable	5.5	44.8	4.0	9.5	9.9	16.8	14.9	4.3	8.3	7.6	5.3
2	Best answer	15.2%	20.9%	45.4%	30.8%	61.1%	26.6%	21.7%	36.3%	51.6%	42.1%	19.4%
	Less preferred	26.5	7.8	34.5	10.1	13.8	5.0	8.6	13.3	28.2	15.8	19.5
	Not acceptable	6.0	19.1	10.5	2.9	11.6	3.9	7.2	4.6	6.9	10.6	5.4
3	Best answer	56.1%	43.8%	16.6%	54.8%	17.7%	41.7%	20.3%	15.7%	18.0%	7.9%	42.8%
	Less preferred	3.6	10.9	11.6	6.4	12.9	25.7	38.3	22.3	13.3	24.9	4.4
	Not acceptable	2.5	14.1	3.1	4.2	1.7	2.7	8.1	38.4	6.9	6.3	33.6
4	Best answer	10.0%	32.6%	10.5%	20.4%	49.9%	39.8%	20.6%	6.6%	8.1%	13.3%	46.7%
	Less preferred	27.5	17.5	35.2	2.5	26.1	14.4	10.7	6.5	19.5	12.2	29.7
	Not acceptable	42.1	5.3	8.0	23.7	16.2	24.3	20.4	56.9	36.7	57.9	9.9
5	Best Answer	83.5%	21.6%	24.1%	47.7%	34.8%	8.8%	50.8%	50.1%	32.0%	57.8%	73.4%
	Less preferred	1.4	37.9	9.2	3.1	16.1	19.1	14.2	21.9	16.7	5.8	12.2
	Not acceptable	6.1	30.0	3.9	17.8	6.9	3.3	6.7	18.5	6.6	4.2	8.0
6	Best Answer	49.1%	20.4%	50.2%	3.7%	39.0%	58.9%	70.6%	30.4%	19.0%	45.7%	49.8%
	Less preferred	28.1	52.2	14.7	42.3	6.5	11.4	14.4	15.6	7.5	33.3	8.4
	Not acceptable	16.6	13.2	15.6	6.2	4.1	12.7	2.9	25.2	62.5	9.7	8.7
7	Best Answer	45.5%	19.1%	29.5%	37.9%	61.4%	34.8%	30.8%	61.6%	26.7	43.0%	10.7%
	Less preferred	31.2	35.9	32.4	29.0	3.9	8.3	36.2	24.8	7.4	11.6	19.2
	Not acceptable	8.8	15.5	7.7	5.7	23.8	8.7	19.0	6.7	15.0	10.9	13.2
8	Best Answer	20.6%	34.1%	23.2%	38.6%	26.2%	11.8%	36.1%	20.8%	32.4%	39.0%	2.6%
	Less preferred	7.3	7.2	20.4	9.7	23.3	8.5	11.5	13.2	10.2	18.7	28.1
	Not acceptable	2.9	4.6	5.0	9.4	21.2	4.7	11.0	4.1	8.4	10.0	50.8
9	Best Answer	18.2%	18.2%	9.9%	37.7%	22.6%	16.9%	23.9%	19.5%	26.3%	24.3%	14.6
	Less preferred	5.2	15.0	27.1	6.0	38.6	25.7	24.2	17.8	59.6	11.5	54.5
	Not acceptable	3.5	6.8	10.7	2.3	8.7	13.8	13.9	3.9	7.2	43.0	20.4
10	Best Answer	36.9%	29.0%	37.0%	33.8%	15.8%	11.1%	30.1%	29.6%	21.8%	22.5%	12.0%
	Less preferred	11.6	34.9	16.1	17,4	34.5	59.1	8.1	17.5	20.6	13.9	25.7
	Not acceptable	30.5	8.3	13.8	17.4	26.9	7.6	25.4	22.6	15.5	35.7	52.4

Appendix Table 7 T-KOLS: Round 3 Color-coded Item Response Frequencies (*continued*)

Section and Item number	CS$_3$ n=14				Science Educators n=3				Safety Specialists n=3				TOTAL n=20			
	G	Y	R	X	G	Y	R	X	G	Y	R	X	G	Y	R	X
Sect. III																
* 1	9	3			2	1			3				14	4		
* 3	12				3				3				18			
* 6		1	11				3				3			1	17	
7	11	1			2	1			2			1	15	2		1
* 11		2	10				3			1	1	1		3	14	1
13	11				3				2			1	16			1
14	11				2			1	2			1	15			2
* 16			11				3				2	1			16	1
18			10	1			3				3				16	1
* 22		10	2			3			1	2			1	15	2	
23			12				2	1		1	2			1	16	1
* 25	11				3				3				17			
* 26		10		1		3				3				16		1
* 38	9	2			3				3				15	2		
* 41	11				2			1	3				16			1
44	12				3				3				18			

Section and Item number	CS$_3$ n=17				Science Educators n=4				Safety Specialists n=4				TOTAL n=25			
	G	Y	R	X	G	Y	R	X	G	Y	R	X	G	Y	R	X
Sect. IV																
* 2	3	14			1	3				4			4	21		
* 5		1	16				4			1	3			2	23	
* 7		2	15				3	1	1	1	2		1	3	20	1
8	17				4				4				25			
10	17				4				4				25			
* 11	16	1			4				4				24	1		
* 12	17				4				4				25			
* 14	1	15	1			4				4			1	23	1	
15	5	8	2	2	1	3			2	2			8	13	2	2
16			17				4			1	3			1	24	
20			17				4				4				25	
24	17				4				4				25			
* 28			17				4				4				25	
* 30	17				4				3				24			
* 36	17				4				4				25			
* 39	9	1		1	1	1	1	1	3				13	2	1	1
44	17				4				4				25			

(*continued*)

Selection scheme: GREEN	- (G)	permissible and recommended
YELLOW	- (Y)	permissible with qualifications
RED	- (R)	not permissible under any circumstances
X	-	suggested discard
*	-	item included in research instrument

Appendix Table 7 T-KOLS: Round 3 Color-coded Item Response Frequencies (*continued*)

Section and Item number	CS$_3$ n=13				Science Educators n=2				Safety Specialists n=4				TOTAL n=19			
	G	Y	R	X	G	Y	R	X	G	Y	R	X	G	Y	R	X
Sect.V																
* 5			13				2				4				19	
* 9			13				2			1	3			1	18	
*12		13				2				4				19		
17			12				2				3				17	
*18			12				2			1	2			1	16	
*19		13				2				4				19		
23			13				2				4				19	
* 24			13				2				4				19	
* 26		2	11				2				4			2	17	
* 32			13				2				4				19	
33			13				2			1	3			1	18	
* 34	4	9			1	1			2	2			7	12		
* 36			13				2				4				19	
38			13				2			1	3			1	18	

Section and Item number	CS$_s$ n=9				Science Educators n=4				Safety Specialists n=2				TOTAL n=15			
	G	Y	R	X	G	Y	R	X	G	Y	R	X	G	Y	R	X
Sect.VI																
* 1			7				4				2				13	
2	7				4				2				13			
4			7				4				2				13	
* 7			6	1			4				2				12	1
13	7				4				2				13			
* 15			7				4				2				13	
16			7	1			4				2				13	1
* 19	6			1	4				2				12			1
* 22			6	1			4				2				12	1
26		1	6				4				2			1	12	
* 29	7				4				2				13			
* 31			6	1			4				2				12	1
* 39	7				4				2				13			
44	4	4			2	2				2			6	8		
* 45			6				4				2				12	
47	7				4				2				13			
*VI.51			7				4				2				13	

(*continued*)

Selection scheme:	GREEN	-	(G)	permissible and recommended
	YELLOW	-	(Y)	permissible with qualifications
	RED	-	(R)	not permissible under any circumstances
	X	-		suggested discard
	*	-		item included in research instrument

Appendix Table 7 T-KOLS: Round 3 Color-coded Item Response Frequencies (continued)

Section and Item number	CS$_3$ n=14				Science Educators n=3				Safety Specialists n=3				TOTAL n=20			
	G	Y	R	X	G	Y	R	X	G	Y	R	X	G	Y	R	X
Sect.VII																
* 3	14				3				3				20			
7			14				3				3				20	
* 11		2	12				3			1	2			3	17	
13			14				3				3				20	
14		2	12				3			1	2			3	17	
* 15	13	1			3				2	1			18	2		
* 19			14				3				3				20	
* 23			14				3				3				20	
* 25			13				2				2				17	
* 29			14				3				3				20	
* 35		1	13				3				3			1	19	
* 37			14				3				3				20	
* 49			14				3				2				19	

Section and Item number	CS$_3$ n=13				Science Educators n=3				Safety Specialists n=3				TOTAL n=19			
	G	Y	R	X	G	Y	R	X	G	Y	R	X	G	Y	R	X
Sect.VIII																
* 4			13			1	2			1	2			2	17	
* 5			13				3			1	2			1	18	
* 6	2	10		1		3				3			2	16		1
* 9		1	10	1			3				3			1	16	1
* 11	12			1	3				3				18			1
13			13				3				3				19	
17		3	9	1			3				2			3	14	1
20			13				3				3				19	
* 21			13				3				3				19	
* 35		13				3				3				19		
37			13				3				3				19	
* 38	2	11				3				3			2	17		
39			13				3				3				19	
* 44		1	12				3				3			1	18	
* 50			13				3				3				19	

(continued)

Selection scheme:		
GREEN	- (G)	permissible and recommended
YELLOW	- (Y)	permissible with qualifications
RED	- (R)	not permissible under any circumstances
X	-	suggested discard
*	-	item included in research instrument

Appendix Table 7 T-KOLS: Round 3 Color-coded Item Response Frequencies (*continued*)

Section and Item number	CS 3 n=16				Science Educators n=6				Safety Specialists n=3				TOTAL n=25			
	G	Y	R	X	G	Y	R	X	G	Y	R	X	G	Y	R	X
Sect.IX																
* 2			16			1	4	1			3			1	23	1
* 5		15		1		4	2			3				22	2	1
* 10			16				6				3				25	
* 11			16				6			1	2			1	24	
13		1	15				5	1			3			1	23	1
14		5	11			2	4			1	2			8	17	
* 17			16				5	1			3				24	1
* 19		2	14				6			1	2			3	22	
21		1	15			1	4	1			3			2	22	1
* 23		13	2	1		3	2	1		3				19	4	2
* 25		12	3	1		4	2			3				19	5	1
* 30			16				6			1	2			1	24	
41			16				6				3				25	
* 51	2	14			1	4		1		3			3	21		1
52		1	13	2			5	1			3			1	21	3

Section and Item number	CS_3 n=14				Science Educators n=3				Safety Specialists n=3				TOTAL n=20			
	G	Y	R	X	G	Y	R	X	G	Y	R	X	G	Y	R	X
Sect.X																
* 1			14				3				3				20	
5			13	1			3				3				19	1
10			13	1			3				3				19	1
* 13		14				3				3				20		
* 15			14				3				3				20	
16			14				3				3				20	
20			14				3				2				19	
* 25	12	1	1		3				3				18	1	1	
27	10	3	1		1	2				3			11	8	1	
* 28			14				3				3				20	
* 32			14				3				3				20	
* 34	14				3				3				20			
40		2	12			1	2				3			3	17	
41			11	2			3				3				17	2
* 45	14				3				3				20			
46	7	6			1	2			1				9	8		
* 47	2	12			2	1				3			4	16		
* 50	13			1	3				3				19			1

Selection scheme:
GREEN - (G) permissible and recommended
YELLOW - (Y) permissible with qualifications
RED - (R) not permissible under any circumstances
X - suggested discard
* - item included in research instrument

Appendix Table 8 T-KOLS: "Best Answer" Item Response by Delphi Panel and Oregon Teachers

Section and Statement number	"best answer" color code	DELPHI COMMITTEE			OREGON TEACHERS	
		"best answer"		"discard"	"best answer"	"no response"
		CS_3	Total	Total		
Sect. I						
1	Green	100%	100%	-	60.0 %	8.9%
3	Red	87.50	87.50	-	36.3	7.4
4	Green	100	100	4.17%	48.9	9.6
9	Red	93.75	95.83	-	42.2	11.1
10	Red	100	100	-	51.9	8.9
26	Red	100	100	-	53.3	14.8
28	Yellow	100	95.83	-	15.6	12.6
34	Green	100	100	-	62.2	9.6
36	Green	100	100	-	36.3	14.8
38	Green	100	100	25.00	52.6	11.9
Sect. II						
1	Red	100	100	-	31.1	8.9
5	Red	100	100	-	41.5	8.1
9	Green	81.82	66.67	4.17	54.1	11.9
17	Red	100	100	-	39.3	12.6
32	Red	100	100	8.33	37.8	8.9
33	Red	100	100	-	26.7	14.1
42	Red	100	95.00	4.17	27.4	22.2
43	Green	100	100	-	55.6	15.6
46	Red	100	100	8.33	33.3	12.6
49	Green	85.71	90.00	4.17	29.6	14.1
Sect. III						
1	Green	75.00	77.78	-	25.2	11.9
3	Green	100	100	-	75.6	9.6
6	Red	91.67	94.44	-	25.9	11.9
11	Red	83.33	82.35	5.00	33.3	12.8
16	Red	100	94.12	5.00	60.7	15.6
22	Yellow	83.33	83.33	-	25.2	14.1
25	Green	100	100	-	48.1	14.8
26	Yellow	100	100	5.00	31.1	15.6
38	Green	81.82	88.24	-	57.8	18.5
41	Green	100	100	5.00	50.4	15.5
Sect. IV						
2	Yellow	82.35	84.00	-	19.3	12.6
5	Red	94.12	92.00	-	20.0	12.6
7	Red	88.24	83.33	4.00	14.8	14.8
11	Green	94.12	96.00	-	34.8	17.8
12	Green	100	100	-	16.3	19.3

(*continued*)

Appendix Table 8 T-KOLS: "Best Answer" Item Response by Delphi Panel and Oregon Teachers (*continued*)

Section and Statement number	"best answer" color code	DELPHI COMMITTEE			OREGON TEACHERS	
		"best answer"		"discard"	"best answer"	"no response"
		CS_3	Total	Total		
Sect.IV:	continued					
14	yellow	88.24%	92.00%	-	32.6%	15.6%
28	red	100	100	-	19.3	23.7
30	green	100	100	-	63.0	18.5
36	green	100	100	-	25.2	35.6
39	green	90.00	81.25	4.00%	54.1	23.7
Sect.V						
5	red	100	100	-	39.3	34.1
9	red	100	94.74	-	23.0	28.1
12	yellow	100	100	-	45.2	25.2
18	red	100	94.12	-	29.6	25.9
19	yellow	100	100	-	37.0	24.4
24	red	100	100	-	57.0	28.9
26	red	84.62	89.47	-	31.1	26.7
32	red	100	100	-	75.6	21.5
34	yellow	69.23	63.16	-	24.4	23.7
36	red	100	100	-	66.7	25.2
Sect.VI						
1	red	100	100	-	31.1	14.8
7	red	100	100	6.67	64.4	13.3
15	red	100	100	-	71.1	15.6
19	green	100	100	6.67	63.7	13.3
22	red	100	100	6.67	49.6	14.1
29	green	100	100	-	51.1	14.8
31	red	100	100	6.67	74.8	13.3
39	green	100	100	-	53.3	14.8
45	red	100	100	-	47.4	14.8
51	red	100	100	-	73.3	13.3
Sect.VII						
3	green	100	100	-	60.0	19.3
11	red	85.71	85.00	-	26.7	31.1
15	green	92.86	90.00	-	45.9	20.0
19	red	100	100	-	58.5	18.5
23	red	100	100	-	58.5	20.7
25	red	100	100	-	47.4	20.0
29	red	100	100	-	63.7	22.2
35	red	92.86	95.00	-	60.0	23.0
37	red	100	100	-	67.4	25.9
49	red	100	100	-	69.6	20.0

(*continued*)

Appendix Table 8 T-KOLS: "Best Answer" Item Response by Delphi Panel and Oregon Teachers (*continued*)

Section and Statement number	"best answer" color code	DELPHI COMMITTEE			OREGON TEACHERS	
		"best answer"		"discard" Total	"best answer"	"no response"
		CS_3	Total			
Sect.VIII						
4	red	100%	89.47%	-	46.7%	21.5%
5	red	100	94.74	-	64.4	15.6
6	yellow	83.33	88.89	5.26	31.1	13.3
9	red	90.91	94.12	5.26	50.4	18.5
11	green	100	100	5.26	74.1	15.6
21	red	100	100	-	52.6	25.9
35	yellow	100	100	-	43.7	17.8
38	yellow	84.62	89.47	-	38.5	17.0
44	red	92.31	94.74	-	63.0	17.0
50	red	100	100	-	55.6	19.3
Sect.IX						
2	red	100	95.83	4.00	52.6	19.3
5	yellow	100	91.67	4.00	34.8	18.5
10	red	100	100	-	53.3	20.7
11	red	100	96.00	-	43.7	20.0
17	red	100	100	4.00	52.6	. 20.0
19	red	87.50	88.00	-	23.7	20.7
23	yellow	86.67	82.61	8.00	30.4	20.7
25	yellow	80.00	79.17	4.00	27.4	20.7
30	red	100	96.00	-	54.1	21.5
51	yellow	87.50	87.50	4.00	23.7	22.2
Sect.X						
1	red	100	100	-	21.5	25.2
13	yellow	100	100	-	34.1	20.7
15	red	100	100	-	36.3	25.2
25	green	85.71	90.00	-	34.8	20.7
28	red	100	100	-	45.9	23.0
32	red	100	100	-	18.5	22.2
34	green	100	100	-	45.9	28.1
45	green	100	100	-	40.7	21.5
47	yellow	85.71	80.00	-	3.7	20.0
50	green	100	100	5.00	45.9	28.9

* Percentage frequencies calculated as follows:

Delphi Committee: "best answer" - CS3 and Total (CS_3, Science Educators and Safety Specialists): calculated on number in each group selecting one of the three alternative responses.

"discard" - Total (CS_3, Science Educators and Safety Specialists): calculated on number of Delphi Committee members contributing to the Section. irrespective of whether they selected one of the three alternative responses, (e.g. suggested revision of item, grammatical change, approved item etc).

Oregon Teachers: "best answer" and "no response" frequencies taken from *Appendix Table 5*.