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ABSTRACT

The emphasis on laboratory activities for science students has increased. This paper describes research that sought to determine which laboratory skills and competencies are viewed by current teachers as necessary for the preservice teacher to develop. The skills and competencies survey included 145 items in three categories (general, biological science, and physical, earth, and space science). Results show that knowledge of hazardous material handling and laboratory safety skills were of greatest importance to science teachers. (WRM)

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LABORATORY SKILLS AND COMPETENCIES FOR SECONDARY SCIENCE TEACHERS

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Introduction

In recent years, the emphasis on laboratory activities for science students has increased. The *National Science Education Standards* (National Research Council, 1996) and the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) stress that students need to adopt methods of inquiry and the thinking skills similar to those used by active scientists. Implied in this directive is the assumption that the teacher has the skills to plan, prepare and carry out, laboratory activities for their students.

Science teachers may not always have the skills needed. The authors observed that, in many cases, common laboratory techniques were performed by laboratory assistants and were not performed by the undergraduate student in class. As the first year teacher enters the work force, he or she may not have adequate experience to plan and set-up laboratory activities. Thus, the focus of this research was to determine which laboratory skills and competencies are viewed by current

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teachers as necessary for the pre-service teacher. Our goal was to create a list of laboratory skills and competencies that could serve as a **minimum** standard. We believe this list could be used to improve teacher education programs.

Very little research has been done to determine what technical skills beginning teachers need. In 1970, Beisenherz noted that there was a need for a special course in laboratory skills and preparation techniques for prospective biology teachers. Students he interviewed expressed frustration that they did not have adequate skills to plan and prepare laboratories. He proposed a specific course designed to alleviate these deficiencies. Later that decade, James and Schaff (1975) administered a survey to practicing physical science teachers concerning skills needed for laboratories in chemistry, physics and physical science. From this survey, a list of general competencies was generated along with values representing need and desired instruction. James and Stallings (1977) followed with a similar study of biology laboratory competencies. Again, this survey was administered to practicing teachers. Voltmer and James (1982) surveyed college and university educators and determined the 70 most appropriate laboratory skills from a list of 85. Apparently, these studies have had little impact on teaching practices. James and Crawley (1985) reported that prospective teachers in most institutions did not receive instruction in basic laboratory skills. They describe teacher training programs at Kansas State University and the University of Texas at Austin which were designed to provide students with an opportunity to learn a prescribed list of laboratory competencies.

The authors of this study proposed to survey a range of stakeholders, including teacher educators, science content instructors in higher education institutions, pre-service teachers, and experienced teachers. We wanted to determine which specific skills are important for beginning teachers to know and be able to demonstrate prior to entering a secondary classroom as a proficient novice teacher so that diverse and effective learning experience may be safely offered in their classrooms.

Methods

Items for the survey were generated by the participants during a graduate course in science curriculum at the University of Northern Colorado. The developers included individuals with varying amounts of secondary teaching experience in chemistry, biology, earth science, space science, and physics. The initial list of competencies was generated by the authors from a combination of personal experience, interviews with selected in-service teachers and reviewing commonly used laboratory manuals.

The respondents for the first round included practicing middle and high school teachers, university faculty, and pre-service teachers. Teachers were selected based upon recommendations of the developers or colleagues. Criteria for selection were based on the likelihood of receiving a response and the teachers emphasis on laboratory activities in their courses. The majority of the middle school teachers' responses were collected from teachers participating in the UNC Institute for Chemical Education in the summer of 1997. University faculty responses were obtained during

various presentations of the survey at professional meetings in Colorado. Pre-service teachers' responses were collected from students in a science methods course at the University of Nebraska, Lincoln and at the University of Northern Colorado.

The skills and competencies survey included 145 items in three categories (general, biological science, and physical, earth, and space science). These were further divided into 11 sub-categories. Additional skills and competencies were also solicited from respondents. Participants were asked to evaluate each skill or competency using the following scale: 3- essential, 2- high priority, 1- beneficial to know, 0- not necessary to know. Arithmetic means and variance (pooled samples) were calculated. Respondents were asked to respond to the sections they personally felt qualified. This accounts for the variation in number of responses to each item.

Results

Each item was rated by a minimum of 63 respondents, some items had a total of 111 respondents. Mean scores range from a high of 2.89 to a low of 0.99. The results of the survey are presented in Tables 1-11.

Discussion

Our results show that knowledge of hazardous material handling and laboratory safety skills and competencies were of the greatest importance to pre-service teachers. This was not surprising considering the current climate of safety consciousnes within our schools. As far as the other skills and competencies are concerned there was a continuum of importance. We would suggest that any

skill with a mean of 1.5 or greater be considered essential for pre-service teachers. Skills and competencies with a mean less than 1.5 could be learned on the job.

There are several alternatives for pre-service teacher education programs to include such skills and competencies. One alternative is a specially designed techniques and methods course to address these skills. Others have suggested that these skills and competencies should be incorporated into the current curriculum of the program. Student portfolios demonstrating competency in all areas could also be utilized. If we would like to improve the quality of pre-service teacher programs these skills and competencies must be addressed.

Clearly these skills and competencies are ever-changing. Efforts should be made to include new technology and methodology as it appropriately evolves. The list of expected skills and competencies must be viewed as a dynamic rather than static target. We would encourage all educators of pre-service teachers to stay abreast of new developments within the field. For example, use of global positioning systems (GPS) was not part of our original survey. However, due to the sharp reduction in the cost of a GPS system (< $200) many schools can now afford them. Clearly pre-service science education programs should be prepared to provide pre-service teachers with the laboratory skills and competencies necessary to successfully enter the work force..

Skills are placed in rank order of importance from most to least important, based on survey responses. A space is place between what the author's interpret to be essential laboratory skills and those perceived to be non-essential laboratory skills. A mean response score of 2.0 was used for the division point.

Table 1
General Science Laboratory Skills

	Total Respondents	Mean	Variance
Proper use and safety of Bunsen and/or alcohol burners	111	2.76	0.13
Scales and balances, use, care, calibration	111	2.67	0.18
Location of common "recipes" and source books	108	2.56	0.25
General knowledge of audio visual equipment	111	2.54	0.25
Proper use of volumetric glassware, and reading a meniscus	110	2.54	0.23
Reading maps, (all type, topographic, weather, etc.)	111	2.47	0.27
Thermometers, calibration, limitations, and uses	110	2.43	0.27
Use and care of microscope including basic repairs	110	2.40	0.30
pH meters and paper, use and calibration	111	2.39	0.22
Proper dilution of solutions	110	2.26	0.27
Preparation of Molar, Normal, Percent vol/vol, mass/vol solutions	109	2.12	0.28
Proper solution filtration	104	1.85	0.29
Standard directional compass, use and care	110	1.83	0.37
Chromatography	112	1.76	0.26
Water test kits	110	1.68	0.29
Soil test kits	110	1.61	0.26
Distillation/Deionized water production	111	1.41	0.26
Proper use of a centrifuge	109	1.27	0.25
Super Glue, uses and limitations	108	1.24	0.33
Spectrophotometer operation, care and use	107	1.20	0.23
Photography, general skills	108	1.15	0.19
Spectrophotometer calibration	107	1.08	0.21

Table 2
Computer Skills

	Total Respondents	Mean	Variance
Internet skills	108	2.50	0.26

Charting, graphing, and tables with computers	108	2.43	0.25
Selection of educational programs	102	2.20	0.27
Computer integration-slaving a computer for data logging	105	1.83	0.32
Connecting two computers together	108	1.67	0.30

Table 3

Safety and Hazardous Material Handling

	Total Respondents	Mean	Variance
Proper emergency procedures	109	2.89	0.07
Proper storage of chemicals	110	2.85	0.08
Proper disposal of chemicals (including organic solvents)	110	2.83	0.08
First aid	110	2.83	0.09
Identification of known toxic substances	109	2.71	0.12
Proper disposal of sharps and broken glass	107	2.55	0.23
Proper disposal of preserved specimens	107	2.48	0.26
Goggle sanitation	109	2.30	0.27

Table 4

Chemistry Skills

	Total Respondents	Mean	Variance
pH meters, calibration, maintenance, and use	84	2.42	0.22
Selection of appropriate level of precision measuring devices	81	2.40	0.24
Filtration techniques	81	2.35	0.27
Pipeting technique	82	2.29	0.32
Conductivity testing	78	2.18	0.30
Burettes, calibration and maintenance	82	2.07	0.36
Electrodes, use and maintenance	80	1.99	0.29
Sampling protocols, liquid	82	1.94	0.27
Calorimeters, use	82	1.94	0.32
Pressure measurements	82	1.91	0.30
Spectroscope and discharge tubes, use	83	1.87	0.34
Graphing calculator, operation and use	83	1.83	0.30
Sampling protocols, gas	81	1.81	0.31
Vacuum pump, use and maintenance	81	1.75	0.29
Spectrophotometers, use and maintenance	79	1.65	0.27

Table 5
Physics Skills

	Total Respondents	Mean	Variance
Timing devices, operation	77	2.58	0.18
Selection of appropriate level of precision measuring devices	75	2.55	0.20
Power supplies, operation and use	76	2.53	0.18
Volt and ammeters, operation and use	77	2.49	0.20
Design and build simple electronic devices	77	2.45	0.26
Construction of multiple pulley systems	82	2.45	0.24
Lasers, operation and use	78	2.29	0.26
Optics bench, operation and use	73	2.18	0.24
Conductivity testing	76	2.14	0.33
Oscilloscopes, care, use, and calibration	77	2.12	0.23
Graphing calculator, operation and use	74	2.08	0.34
Spectroscope and discharge tubes, use and care	73	2.07	0.26
Calorimeters, operation and use	74	2.01	0.37
Thermal expansion device, operation and use	73	1.92	0.34
Air tracks	68	1.90	0.28
Vacuum pump, use and maintenance	74	1.88	0.36
Van De Graaf generator, operation and use	72	1.88	0.39
Signal generators, operation and use	70	1.86	0.30
Hooke's Law apparatus	68	1.84	0.40
Geiger counter, operation and calibration	75	1.80	0.34
Cloud chamber, operation and use	71	1.59	0.39
Wimshurst, operation and use	64	1.42	0.36

Table 6
Astronomy Skills

	Total Respondents	Mean	Variance
Telescope, ability to locate objects	73	2.56	0.23
Telescope, use and care	73	2.47	0.26
Astronomical charts, reading	71	2.41	0.25
Celestial globe, reading and use	69	2.16	0.31

Pendulum, operation and use	70	2.14	0.32
Spectroscope and spectrum tubes, operation and care	69	2.01	0.29
Construction of sextant from protractor	68	1.75	0.34
Inflatable planetarium, use	70	1.73	0.34
Astrolab (sextant) use	69	1.67	0.29

Table 7
Geology Skills

	Total Respondents	Mean	Variance
Mineral and rock identification, use of keys	78	2.67	0.18
Mineral test kits, assembly and use	75	2.55	0.22
Plotting latitude and longitude	75	2.52	0.28
Standard directional compass, use and care	77	2.34	0.28
Setup and operation of a stream table	77	2.05	0.29
Sorting and identification of soil types	77	2.03	0.28
Preparing a fossil sample for use	77	1.82	0.24
Seismograph, operation and tracing reading	78	1.81	0.26
Stereoscope, map reading	75	1.77	0.36
Clinometer or Brunton compass, use and care	75	1.56	0.34
Fence diagrams, reading and use	65	1.45	0.29
Tree coring, procedure and reading	75	1.40	0.19
Sterilization of owl casts (pellets)	73	1.25	0.31

Table 8
Meteorology Skills

	Total Respondents	Mean	Variance
Barometer, use and calibration	75	2.52	0.18
Rain gauge, use and calibration	74	2.43	0.26
Hydrometer, use and calibration	74	2.28	0.20
Setting up a weather station	76	2.22	0.27
Anemometer, use and calibration	74	2.20	0.40
Sling psychrometer, use and calibration	72	2.19	0.37
Calculation of wind chill, heat stress	73	2.12	0.30
Tide chart, calculations and uses	73	1.93	0.31
Cloud chamber, operation	73	1.74	0.31
Vacuum pump, operation	73	1.71	0.31
Van De Graaf Generator, use, care and basic repair	68	1.71	0.33
Wimshurst, use and care	64	1.25	0.37

Tables 9-11 summarize Life Science skills

Table 9
Genetics and Physiology

	Total Respondents	Mean	Variance
Indicators, preparation and use	63	2.51	0.25
Animal organs, procurement, storage, and disposal	66	2.35	0.31
Frog dissection	70	2.03	0.33
Synthetic blood, typing and obtaining	68	1.81	0.47
Blood typing	70	1.69	0.34
Karyotype, reading and acquisition	70	1.64	0.37
Electrophoresis, performing	71	1.63	0.32
Electrode operation, safety, and care	68	1.63	0.33
Genetic computer simulation, selection and operation	69	1.59	0.25
Sphygmomanometer operation	66	1.56	0.39

Fruit Flies, care and culture	70	1.50	0.28
PCR (Polymerized chain reaction) experimentation	68	1.47	0.40
Fermentation chambers, use and operation	69	1.41	0.37
Metabolic chambers, use and operation	72	1.32	0.35
Ability to pith properly	68	1.16	0.48

Table 10
Microbiology Skills

	Total Respondents	Mean	Variance
Specimens, care, culture, and disposal	69	2.45	0.25
Microscopes, basic repair	70	2.41	0.25
Specimens, identification	70	2.37	0.27
Acquisition of cultures	69	2.30	0.23
Media preparation	69	2.26	0.30
Plate/Tube preparation	68	2.15	0.33
Autoclave, sterilization techniques	68	2.15	0.42
Pressure cooker, sterilization techniques	67	2.09	0.39
Gram stain preparation	69	2.00	0.35
Acid fast stain preparation	67	1.64	0.46
Preparation of hay infusions	67	1.63	0.44
Flagella stain preparation	68	1.54	0.35

Table 11
Botany/Ecology/Field Biology Skills

	Total Respondents	Mean	Variance
Use of dichotomous keys (plants, trees, animals)	71	2.63	0.22
Specimen handling, including ventilation, storage, disposal	70	2.40	0.26
Specimen identification	71	2.37	0.24
Specimen collection	71	2.35	0.25
Location of local plants (elodea, seeds, etc.)	71	2.35	0.24
Animals, care and culture	70	2.31	0.28
Plants, care and culture	72	2.24	0.34
Ability to plot latitude and longitude	71	1.99	0.42
Specimen preservation	65	1.98	0.32
Greenhouse/hothouse operation (lighting, pesticides)	70	1.77	0.35
Basic vegetation measurements(% cover, point quarter)	66	1.67	0.34

Museum curation	69	0.99	0.22

Request for Participation

The authors encourage readers to provide feedback and contribute to the ongoing refinement of this competencies list through participation in the survey at <http://www.unco.edu/biology/PTEP/skills/skills.html>. Current survey results may be obtained at <http://www.unco.edu/biology/PTEP/skills/results.html>.

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