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Inclusion of Students with Disabilities in a College Chemistry Laboratory Course

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Abstract

The Center for Special Services and the Department of Physical Sciences at Auburn University at Montgomery are collaborating on a program that modifies instructional methods to fully include students with physical disabilities who use a wheelchair in the chemistry laboratory. The purpose of this project is to develop a methodology for all students with a focus on modifying classroom activities and experiments rather than requiring the student with a physical disability to adapt to the traditional curriculum. The resulting experiments are safe for students with disabilities, cost effective and leave unchanged the chemical principles being taught. Six traditional General Chemistry experiments were modified and piloted in a postsecondary chemistry laboratory. In combination with two existing experiments that did not require modification, these exercises enabled the entire first quarter of the laboratory section of the course to be adapted. All students, including two students with disabilities who used wheelchairs, performed identical modified experiments during a regular quarter. The philosophy and impact of these modifications are discussed along with the implications for increased cost-effective accessibility to laboratory settings.

The passage of the Americans with Disabilities Act (ADA) in 1990 and the Rehabilitation Act of 1973 (Section 504) have underscored the need to provide fully accessible services and training to individuals with disabilities. Postsecondary settings are continuously challenged to provide accommodations for all students seeking access to

campus programs. If the promise of federal disability legislation is to be realized, then new techniques, opportunities, solutions and mechanisms must be devised to include previously underrepresented or unserved individuals in the classroom. One area that has presented challenges because of concerns regarding safety is the chemistry laboratory. The intent of this article is to describe a process implemented at our university to increase program accessibility for students with physical disabilities by developing modifications to chemistry laboratory experiments to assure safety.

The Field of Chemistry and Students with Disabilities

Many of the attractive and growing technical careers in today's economy require the completion of at least a first year college chemistry sequence. A review of employment projections for occupations with the largest growth pattern between the years 1992-2005 shows several occupations that require postsecondary chemistry laboratory courses (U.S. Department of Commerce, 1993). These occupations are included in the broad categories of medicine, nursing, and engineering with opportunities in these fields predicted to increase by up to 80% by the year 2005. Individuals with disabilities, however, have traditionally been left out of these careertracks because of lack of access or ability to fully participate in laboratory courses (Cotler, 1986). For example, a small percentage of students with disabilities (4.3%) who are enrolled in postsecondary institutions chose the natural sciences as a course of study (U.S. Department of Education, 1993). The percentage of students with a disability enrolled in engineering and health-related fields in 1989 was 8.2% and 7.7%, respectively. One of the major reasons for the limited participation of students with disabilities in these fields may be both the real and perceived barriers inherent in traditional laboratories and chemistry experiments.

Chemistry laboratories are areas where individuals with disabilities have experienced difficulties (Crosby, 1981). Cabinetry access, equipment access, and aisle width have been identified as barriers to laboratory participation (American Association for the Advancement of Science, 1991). The use of toxic and corrosive reagents also presents danger to individuals with disabilities that inhibit dexterity and mobility. Specially designed benches with safety features are available. However, these benches can be expensive and used by only one person at a time (Larsen, Buchanan, & Torrey, 1978). Other modifications cited in the literature for individuals with varying disabilities include the purchase of special wheelchairs, assistive standing devices, special safety equipment and portable science stations (Zimmerman, 1983). Frinks and McNamara (1985) adapted a common table to accommodate wheelchairs in the physics laboratory.

The challenge to students with physical disabilities who use wheelchairs in the chemistry laboratory, however, creates a need to identify nontraditional accommodations because of the potential risk factors involved with the experimental procedures that are implemented. Individuals with paraplegia, multiple sclerosis, cerebral palsy, spina bifida, back injuries, arthritis and amputations, and other physical disabilities and mobility impairments all face barriers to fully participate in the traditional laboratory setting. The use of high temperatures and corrosive reagents in many laboratory experiments produces obvious safety hazards for all students. This is particularly true for students with limited mobility.

More importantly, perceived safety problems could inhibit enrollment by students with disabilities in chemistry laboratory courses.

Experiments designed with low risk and low cost materials can make the study of chemistry more accessible to all students, regardless of disability, at a wide variety of secondary and postsecondary institutions (Hill, 1991). In particular, inexpensive experiments utilizing locally available supplies allow an entire laboratory course to be adapted to accommodate small numbers of students with disabilities at short notice. McDaniel, Wolfe, Mahaffy and Teggin (in press) described modifications of instructional materials for a chemistry laboratory experiment to illustrate nonintrusive, cost-effective accommodations that could make chemistry laboratories accessible to individuals with physical disabilities. By developing methodology that promotes inclusion, students are provided an opportunity to explore a field of study for possible career choices in fields which they previously may have not considered to be accessible.

Adapting a College Chemistry Laboratory Course

There were several challenges that led to the creation of this project which was conducted at a medium sized, state supported university: laboratory stations could not accommodate wheelchair users, and the use of toxic and corrosive materials presented a real threat to the safety and well-being of the student with limited mobility in the event of spill or accident. To address such concerns, the authors developed an approach that modified the methods and materials used in experiments without compromising the chemical principles being taught. The exercises were performed on a common folding table which could be adjusted in height to accommodate the wheelchair user's needs. Noncorrosive materials provided the necessary safety factor in the event of an accident where a wheelchair user could not quickly move to safety.

Because of enrollment policies at the institution where the project took place, many students have not completed a laboratory course in chemistry in high school. Consequently, the first year chemistry experiments must emphasize basic procedures. This low level of sophistication is not mandated by the use of the described chemical reagents, but rather by the inexperience of the enrolled students. Principles covered in the modified experiments (see Table 1) are comparable to those illustrated by following methods in a typical laboratory text for first year chemistry. Courses specifically designed for chemistry and chemical engineering majors must include state-of-the-art laboratory procedures if enrolled students are eventually to function as professional chemists or chemical engineers. Although the described modified experiments might serve to interest a potential professional chemist with a disability in the field, it is recognized by the authors that further exposure to actual procedures and equipment employed in the workplace would be essential for such a person.

The approach used to adapt the manner in which experiments were conducted is described by McDaniel et al. (in press) who reported on the modification of the conditions involved in a college chemistry laboratory experiment to remove hazards associated with high temperatures and potentially dangerous chemical reagents. The

purpose of this initial exercise was to enable students with physical disabilities to perform similar laboratory procedures as other students enrolled in a typical first year college chemistry course. In order to facilitate adoption of the experiments by institutions with limited resources, inexpensive materials obtainable from most supermarkets were used. The experiment was performed by students in wheelchairs at a common folding table with adjustable legs within the standard laboratory setting. It was demonstrated that the experiment adequately illustrated the chemical principles involved in a standard type of procedure included in most college chemistry laboratory sequences.

Five additional experiments have been developed utilizing similar procedures. Table 1 illustrates that the six experiments cover chemical principles that are emphasized in a typical laboratory manual. Brief descriptions of the revised experimental methods are included in the Appendix. Two existing experiments from the text (Sienko, Plane, & Marcus, 1984) do not require the use of heat or corrosive materials. These exercises which involve crystal and molecular structure models have no associated safety problems.

The availability of the eight experiments has greatly decreased hazards to students and the cost of waste disposal for the entire first quarter of a general chemistry course. Because the use of a folding table is practicable with the materials and procedures employed, students with physical disabilities could be included without the need for any further special assistance.

The course, Chemistry 101 (CH101), for which these described experiments have been adopted, is required for students majoring in pharmacy, pre-engineering, and essentially all of the health-related programs awarding graduate degrees. Consequently, it could be considered the first step toward many attractive careers (McConnell, 1981).

Evaluation of Modified Experiments

During the Fall Quarter, 1993, two students with mobility impairments performed all of the procedures sitting in wheelchairs at a folding table. Thirty other students performed identical experiments standing at laboratory benches. The students with disabilities did not receive physical assistance while performing the experiments. Although these two students required slightly extended time to complete most experiments, they always produced competitive experimental reports within the three hours of time assigned for the laboratory period.

The students with disabilities made favorable comments concerning their participation in the study on an evaluation form that was administered by individuals outside of the Department of Physical Sciences. These comments included the following statements:

- I do not feel that any of the experiments exposed me to a chance of personal injury.

- Since I am majoring in Biology, this project has encouraged me greatly. In addition, the students with disabilities made valid recommendations for the modifications of procedures that had not been apparent to the two participating members.

Table 1. Principles Covered in Modified Experiments.

Present Experiment ^a	Modified Experiments ^b	Chemical Principles Involved
Density of Solids (1)	Density of Marble Chips	Weighing, measurement, graphing
Stoichiometry(9) (decomposition of KC103 at high temperatures)	Stoichiometry (decomposition of baking soda using lemon juice or citric acid at room temperature)	Equations, calculations from equations
Enthalpy (IV) (neutralization of acids)	Enthalpy (heat of solution of ammonium nitrate fertilizer)	Thermometry, Thermodynamics
Molecular Weight from Freezing Point Lowering (16) (uses molten naphthalene)	Molecular Weight from Freezing Point Lowering (salt/ice/water)	Colligative properties, molecular weight determination
Chromatographic Analysis Of Metal Ions (35) (uses strong acids and bases)	Chromatography of ink using pens, coffee filters and rubbing alcohol	Separation technology, chromatography, qualitative analysis
Acid/Base Titration (26) (uses strong acids/bases)	Acid/Base Titration (uses vinegar/washing soda)	Molarity, pH, indicators

a Number in parentheses refers to the experiment # in Experimental Chemistry (Sienko, Plane, & Marcus, 1984).

b All modified experiments use readily available inexpensive materials at close to room temperatures.

Recommendations from Faculty and Students

As a result of the project, the following recommendations for the safe inclusion of students with physical disabilities who use wheelchairs into the described laboratory chemistry program are presented. The suggested modifications are made for physical convenience and assurances for safety and do not prevent students with disabilities from developing the same qualities of observations and the calculation of numerical results similar to all other students performing the same experiments in the same laboratory section. Students with varying disabilities will continue to be provided appropriate

accommodations in the laboratory setting in addition to being able to take advantage of the revised experimental procedures.

- o The work can be performed on a simple folding table with adjustable legs. The table must be of a height that allows the arms of a wheelchair to just fit underneath, otherwise the student will not be in the correct position to perform the required manipulations without further modification.

- o Equipment, such as balances, must be placed at a convenient level for use by seated individuals. This factor must be taken into account prior to purchasing laboratory supplies. The equipment to be used must therefore be carefully selected with this criterion in mind. Although two different balances may perform exactly the same functions, it is quite possible only one will be suitable in this setting.

- o It is helpful if two students work together so they can help each other with some of the manipulations. All students in laboratory courses at this university have laboratory partners for this reason. Although two students with disabilities worked together in this study, there would be no disadvantage involved for any two students working at a folding table.

- o It is also a common practice for students to obtain chemicals and supplies for the day's experiment from a central location. It greatly expedites the procedures if the required materials are supplied on the bench for the students with disabilities.

- o It is a good idea to use large spill trays (ordinary hard plastic domestic trays will do) in order to quickly and easily contain any spills that may occur. Despite the fact that the materials themselves are noncorrosive and nontoxic, this feature reduces the chances for soiling of clothing. Even though the chemicals used in the actual experiments were nonhazardous, all students were required to perform the experiments wearing safety goggles to conform with a general laboratory regulation at our institution because hazardous materials could be present in the same room.

Summary

The proposed chemistry laboratory modifications will affect four main areas:

- o The curricular modifications for the chemistry laboratory will result in improved access for students with physical disabilities who use wheelchairs. By eliminating the barriers inherent in some experiments while not compromising the integrity of the chemical principles that are demonstrated, students with disabilities can be fully included in the laboratory setting. Students with disabilities who have concerns for personal safety will find the modified experiments risk free. The experimental modifications do not require the purchase of expensive specialized equipment such as motorized wheelchairs and laboratory benches. Installation of these specialized devices might separate the student with a disability from the class as a whole in many crowded laboratory settings. Instead, the modified experiments enhance inclusion by offering nonintrusive accommodations in

the laboratory environment and increases safety which benefits ALL students. Accommodations already in place for other specific disabilities should remain.

o Because the inclusion philosophy underlying this approach is very cost effective, schools will have the opportunity to engage in a curriculum which may not have been available due to low levels of funding. The inclusion of more individuals with physical disabilities within chemistry courses may lead to an increase in interest in this field and subsequently result in more employees with disabilities in science or health related fields.

o The development of a chemistry program which can be replicated at little expense in secondary and postsecondary institutions will provide greater exposure of nontraditional career fields to students with physical disabilities.

o The modified chemistry curriculum will be expanded to cover an entire first year of a college chemistry course. A laboratory manual will be developed by faculty and advocates for students with disabilities. An opportunity exists to set the standard for others to follow and to demonstrate a collaborative approach for others to replicate. The manual will be made available to interested parties upon request.

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APPENDIX

Descriptions of Modified Experiments

Density of marble chips

The density of commercially available marble chips is determined using a graduated cylinder. A series of measurements of the mass of a piece of marble and its volume are made. The volume is determined by displacement of water in a graduated cylinder. From these data, a graph of mass against volume is drawn, the slope of the graph giving the density of the marble chips.

Advantages over traditional experiment

This experimental procedure as described in Sienko, Plane and Marcus (1984) is safe for all students. We prefer to use marble chips instead of some of the materials suggested such as lead, or Wood's metal that contain heavy metals such as lead and cadmium which are highly toxic. The materials we use are also considerably less expensive than traditional materials.

Stoichiometry

An amount of sodium bicarbonate is weighed accurately. This material is mixed intimately with excess solid citric acid. This quantity of citric acid merely provides an excess source of acid and does not need to be known exactly. The mixture is placed in a test tube that has a lip at the mouth with a volume of about 20 ml. Between five and ten milliliters of water are inserted into a small balloon. The balloon is then attached over the lip of the neck of the test tube without wetting the mixture. On inverting the balloon, the reaction is initiated and will be complete in about one minute. The quoted amount of sodium bicarbonate produces about 150 ml. of carbon dioxide which inflates the balloon. The neck of the balloon can be tied with dental floss. The volume of gas produced is then measured in a cylindrical container of water. Water levels before and after immersion are marked. Addition of water from a graduated cylinder can now indicate the volume between the marks. Subtracting the initial amount of water placed in the balloon gives the volume of the evolved gas. A simple calculation yields the volume of carbon dioxide produced from one gram of sodium bicarbonate.

The experiment can now be repeated using a mixture of sodium bicarbonate and an inert material such as sodium chloride. From the volumes of gas produced from the mixture the students can calculate the quantity of sodium carbonate present and hence the composition of the unknown mixture. Best results are obtained if the quantities of pure sodium bicarbonate and the mixture are chosen so that each experiment produces gas volumes in the range of 120 -180 ml.

Advantages over traditional experiment

The stoichiometry experiment outlined in Sienko, Plane and Marcus (1984) uses the decomposition of potassium chlorate, a powerful oxidizing agent, with a catalyst, manganese dioxide. This procedure involves strongly heating the potassium chlorate in a test tube with the catalyst. The modified experiment provides the same instruction in the area of stoichiometry but without the use of heat and powerful oxidizing agents. Further, when heated, potassium chlorate tends to spatter, that is, small hot fragments of the material which could conceivably injure a student can fly out of the test tube during the heating process. Both sodium bicarbonate and citric acid are readily available in supermarkets and drug stores.

Enthalpy

The heat of solution of a salt in water is determined using a styrofoam coffee cup as a calorimeter. The lid, which is needed for insulation, can be made from another coffee cup by trimming it with a pair of scissors. A small hole is made in the lid to accommodate a thermometer. Ammonium nitrate, a commonly available fertilizer, is a good material to use as the unknown as it presents few disposal problems and is readily available. Students dissolve a known amount of ammonium nitrate in 100 milliliters of water of known temperature. The ammonium nitrate will lower the temperature of the water. From this change and the amount weighed out the heat of solution may be determined.

Advantages over traditional experiment

In this experiment the determination of the heat of neutralization which requires the use of both acids and bases is replaced by the determination of the heat of solution which does not require the use of any corrosive reagents. The experimental technique does not essentially change. Again, the materials in this experiment are very inexpensive and can be obtained in most supermarkets.

Determination of concentrations by freezing point lowering

A solution has a lower freezing point than a pure solvent. The depression in freezing point is proportional to the molal concentration of particles in solution. For example, a one molal sodium chloride solution would contain two moles of ions per 1000 grams of solvent. Consequently, the sodium chloride solution would produce twice the depression of a one molal solution of a nonionizing solute such as sugar.

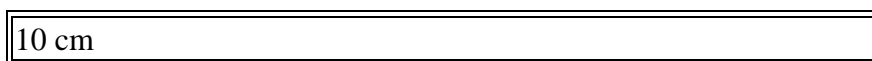
Students prepare a 1.0 molal solution of sodium chloride and determine its freezing point in an ice/salt/water bath. Students are then given a sodium chloride solution of unknown concentration. From the depression of the freezing point of this solution and the previously determined freezing point depression constant, the concentration of this unknown solution may be determined.

Advantages over traditional experiment

This experiment replaces a procedure which uses molten naphthalene as the solvent to determine the molecular weight of an inert solute such as sulfur. The naphthalene must be melted in a boiling water bath on either a bunsen burner or an electric hot plate. If a mixture of molten naphthalene and sulfur were spilled on someone, it would cause severe burns. The modified procedure is completely safe from this point of view. If the alternate solution were spilled, the student might get wet but would not be injured in any way. Further, the expensive disposal of waste naphthalene/sulfur mixtures is avoided.

Chromatography of ink

This experiment utilizes several types of pens, a coffee filter, and rubbing alcohol, which are available in supermarkets. Using a pair of scissors, students cut a rectangle with dimensions of approximately 10 cms by 3 cms from a coffee filter. A pencil line is drawn at a distance of about 2 cms from the bottom of the rectangle as illustrated below:



pencil line at 2 cm

pencil line at 3 cm

Using one of the pens a line is drawn over the original pencil line. This procedure is repeated several times and the ink is allowed to dry for a few minutes. Rubbing alcohol is placed in a 150 ml beaker so that its depth is about 1.0 cm. Then using a clamp, the filter paper is held vertically into the liquid so that the ink line never drops below the level of the liquid in the beaker. The paper is removed after the solvent has risen to within 3 cm from the top of the paper. This position is marked, the paper removed, and the resulting chromatogram allowed to dry. The procedure is repeated with a number of pens.

Inks usually consist of a mixture of colored materials with different solubilities in rubbing alcohol and different affinities for wet paper. These components are often carried upwards by the solvent at different rates. Therefore, it is common for inks with quite similar overall colors to produce very different patterns of color during the described procedure. The resulting chromatograms provide a method for the identification of the ink from a specific pen. Many important analytical procedures are based upon the same principles.

Advantages over traditional experiment

This experiment replaces an experiment which uses strong acids to analyze for several metal ions using paper chromatography. This experiment has the advantage that the students can use both the pens provided and their own pens, thus laying the bases for both analytical chemistry and forensic science.

Acid-base titration

This experiment illustrates the traditional acid-base titration using either dilute hydrochloric acid solution (used to adjust acidity in swimming pools) or vinegar as the acid. Very dilute sodium hydroxide solution or sodium carbonate solution (washing soda) is used as the other base. The experiment is performed using beakers and graduated cylinders in place of the traditional burets and pipets which are almost impossible to use from a seated position. A solution of Ex-Lax in rubbing alcohol can be used as the indicator as Ex-Lax contains phenolphthalein, a common indicator used in this reaction.

Advantages over traditional experiment

There are two modifications in this experiment that provide seated students access to this experimental procedure. The first is the removal of corrosive acid and bases and the second is the replacement of a buret with a graduated cylinder. Burets stand about one meter above bench level, thus making it very difficult to read or fill a buret from a seated position. Pipets requiring the use of a bulb type filling device are easily employed from a seated position. Assistance with filling and reading a buret would not be inappropriate because the seated student would actually determine the end point for the titration.

Authors' Notes

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Nancy McDaniel, Ed. D. is the Director of the Center for Special Services at Auburn University at Montgomery. She holds a doctorate in Rehabilitation and Special Education and has more than twenty years of experience working in the field of disabilities. Dr. McDaniel is the author many nationally recognized journal articles and coauthored several book chapters on disability issues. She is currently a co-director of a funded project for inclusion of students with disabilities in chemistry laboratories.