# The State of Middle School and High School Science Labs in the Kansas City Region

Ewing Marion Kauffman Foundation
SuccessLink®

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A report prepared by
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# Executive Summary

This report shares the findings of an audit conducted across thirty school districts in which the state of science labs was assessed. The audit was conducted by SuccessLink, with funding of the project from the Ewing Marion Kauffman Foundation. This study was conducted as part of the Kauffman Foundation's multi-year agenda to improve student achievement in mathematics, science, and technology subjects in the Greater Kansas City region.

Auditors visited 170 school buildings in thirty school districts over a five-month period during the 2006-2007 school year. They recorded observations on safety issues, science lab facilities, and equipment and materials. Auditors also conducted teacher interviews and provided online surveys to teachers and administrators in order to assess aspects of instruction, learning, and district policies. This data was then compared to standards set by the National Science Teachers Association (NSTA).[1] The results indicate that science labs in the Kansas City region do not meet national standards and that much work needs to be done to bring the school science labs up to the national standards.

# Findings

The audit identified five areas of concern and this report summarizes each area and makes recommendations for improvement. The five areas are: Safety, Facilities, Equipment and Materials, Instruction and Learning, and District Policies.

### Conclusion 1:

**The majority of science labs in the Kansas City region do not meet NSTA safety standards.**

In order to provide a safe learning environment for students, every science lab must contain basic safety equipment. During this study, auditors found missing safety equipment in more than half of the science labs.

1 Guidelines published in National Science Teachers Association. *NSTA Guide to School Science Facilities*. Biehle, James, Motz, Lamoine, and Sandra West. NSTA Press, 1999.

## Conclusion 2:

**The majority of science labs are too small, lack sufficient storage space, and are not set up in a way that effectively promotes student learning.**

More than half of labs in the Kansas City region do not have enough space to facilitate effective student learning. Labs are not currently arranged in a way that meets NSTA recommendations (see Appendix B). Short of renovations, improvements can be made by rearranging the design of labs and reducing the number of students in each science lab class. Auditors also determined that science lab storage rooms are frequently cluttered, disorganized, and dusty.

## Conclusion 3:

**Science lab equipment and materials are not used effectively or safely in many science lab classrooms.**

Auditors frequently discovered old, broken, and unused equipment in many of the observed science labs. In many cases, brand new equipment had never been opened and outdated equipment was still in use.

## Conclusion 4:

**Many teachers lead science lab classes that are larger than the recommended class size.** Compounding this challenge, many teachers are not comfortable using lab equipment or knowledgeable about how to integrate lab activities with the science curriculum.

- The recommended science lab class size is twenty-four, yet a lab size of twenty-six was the average for labs in this study.
- The NSTA recommends approximately ninety minutes for science lab learning per week. The majority of students in this study received less than one hour of science lab instruction each week.
- This audit found that collaboration is common between science teachers, and district professional development rarely addresses science labs.
- The science curriculum studied during this audit shows that science labs are rarely incorporated into the overall science curriculum. However, most teachers report that they do embed science labs in their class plans even though they are not required to do so by the district.

## Conclusion 5:

**School districts do not provide guidelines to science teachers on how to best use the science lab.**

District policies are not in place that guide building administrators and science teachers in the areas of safety, facilities, equipment, and instruction. Moreover, survey data showed a wide discrepancy between how teachers and administrators perceive district policies. Most teachers assume that there is a written vision regarding the role of science labs. In most cases, district administrators reported that this is not the case. Few teachers believed that there were district expectations about lab use, whereas most administrators claimed that there were.

## Summary

This report presents significant findings and recommends critical improvements to the quality and safety of science laboratories. In addition to implementing these recommendations, school districts must make the science laboratory experience of students a priority so that science labs are used to enhance student learning. As this audit demonstrates, schools in the Kansas City region can improve the quality of student science lab experiences while ensuring student safety. In doing so, students will better understand scientific concepts through enriching laboratory activities.

# Background

Policymakers, scientists, educators, and parents agree that high school graduates must have a working knowledge of science and technology to participate fully in the workplace, understand everyday decisions on matters ranging from health issues to energy resources, and participate as informed citizens in the civic realm. Science laboratory experiences for middle school and high school students are a fundamental, unique, and critical component for twenty-first century science education.

While the need for quality science lab instruction is clear, a recent report by the National Research Council, *America's Lab Report: Investigations in High School Science*[2] concluded:

- the quality of current laboratory experiences is poor for most students;
- the access to any type of laboratory experience is unevenly distributed;
- the students enrolled in advanced science classes spend more time in laboratory instruction than students enrolled in regular classes.

The report also concluded that most students, regardless of race or the level of science class, participate in a limited range of laboratory experiences that are not based on principles derived from recent research in science learning.

State or regional studies of science laboratories are rare. Those that exist have focused primarily on science lab safety. For example, a 2001 study by researchers at the University of Texas[3] concluded that many high school science labs in Texas were missing important safety equipment. The value of this type of safety study is obvious, but given the growing importance of science education there is a need for more comprehensive studies of science laboratory classrooms.

The National Science Teachers Association (NSTA) has developed a set of comprehensive standards related to science laboratories.[4] These standards serve as guides to best practices to ensure quality learning experiences. They include recommendations related to safety, the lab environment, and learning expectations. These standards can serve as benchmarks against which to judge science laboratories.

2 National Research Council. (2006). *America's Lab Report: Investigations in High School Science. Committee on High School Science Laboratories: Role and Vision,* S.R. Singer, M.L. Hilton, and H.A. Schweingruber, Editors. Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

3 Fuller, Edward J.; Picucci, Ali Callicoatte; Collins, James W.; Swann, Philip. *An Analysis of Laboratory Safety in Texas.* University of Texas–Austin (Spring 2001).

4 National Science Teachers Association. *NSTA Guide to School Science Facilities.* Biehle, James, Motz, Lamoine, and Sandra West. NSTA Press, 1999.

# Introduction

This report shares the findings of an audit conducted across thirty school districts in which the state of science labs was assessed. The audit was conducted by SuccessLink, with funding of the project from the Ewing Marion Kauffman Foundation. This study was conducted as part of the Kauffman Foundation's multi-year agenda to improve student achievement in mathematics, science, and technology subjects in the Greater Kansas City region.[5]

The report presents findings collected through school visits, interviews with teachers, analyses of curriculum, and surveys of teachers and administrators. The following aspects of the science laboratory experience were studied: science lab class size; facility (size, lay-out, storage); equipment (including chemicals, furniture, and water access); safety; and curriculum. Thirty school districts participated in the study.[6] Auditors visited one science lab in each middle school and high school building—170 buildings—in the participating school districts. They interviewed a science teacher in each science lab. A total of seventy-nine teachers, forty-one building administrators, and nineteen district administrators completed an online survey.[7] All survey tools are available online at *www.kauffman.org/kcsciencelabs*. The site visits, interviews, and surveys were all conducted from November 2006 to March 2007.

The following report presents the study's findings and offers a series of recommendations. In addition, this report provides a synthesis of the national standards available on middle school and high school science laboratories.

5 The Greater Kansas City area includes five counties surrounding Kansas City in Kansas and Missouri: Platte, Wyandotte, Johnson, Clay, and Jackson.

6 The participating school districts include: Archdiocese of Kansas City; Blue Springs; Blue Valley; Bonner Springs; Center; De Soto; Diocese of Kansas City–St. Joseph; Excelsior Springs; Fort Osage; Gardner Edgerton; Grain Valley, Grandview; Hickman Mills; Independence; Kansas City, Kansas; Kansas City, Missouri; Kearney; Lee's Summit; Liberty; North Kansas City; North Platte; Olathe; Park Hill; Raytown; Shawnee Mission; Smithville; Spring Hill; Turner; and West Platte.

7 The following districts (teachers and administrators) did not respond to the survey: Piper; Turner; Blue Springs; Excelsior Springs; Fort Osage; Grain Valley; Grandview; Hickman Mills; Kansas City, Missouri; Lone Jack; North Kansas City; North Platte; Raytown; and West Platte. The number or actual teacher responses was 79 (from 48 schools in 16 districts), the number of district administrator responses was 19 (from 15 districts), and the number of building administrators was 41 (from 35 schools).

# Findings

The auditors examined five characteristics of science laboratories in this study. The five areas are: Safety, Facilities, Equipment and Materials, Instruction and Learning, and District Policies. This report summarizes each area and makes recommendations for improvement.

## 1. Safety

Science experiments allow students to test hypotheses, observe how science concepts are put into practice, and interact more directly with the natural world. These experiments typically require heating sources, fumes, chemicals and other potentially dangerous variables; therefore, it is important for schools to take precautions. By limiting the number of students in a science lab, training teachers and students on how to use equipment, and using only safe combinations of materials, schools can prevent many accidents from occurring.

Auditors visited science labs in order to discover how prepared schools are for the potential dangers of science experiments. In addition, auditors investigated whether or not schools made important protective equipment available to students.

Visits to middle school science lab classrooms revealed the greatest area of concern. Auditors frequently discovered that labs are not equipped with preventive safety equipment such as safety goggles and disinfectant for safety goggles, aprons, or gloves. Many middle school science labs were also missing equipment necessary to react to an emergency, particularly fire blankets and first aid kits. Several middle school science labs did not have an eyewash station or an emergency shower. In some cases, eyewash stations and showers were present, but were not conveniently located, e.g., at one school the eyewash station was surrounded by boxes.

In the high school science labs visited, safety equipment was more clearly present. Most high school labs were equipped with adequate safety equipment for students; however, in some high school science labs auditors discovered that fume hoods did not work. Auditors also did not find posted procedures for dealing with a chemical spill in high school science labs.[8] Many science lab classrooms are also missing lockable cabinets or rooms where chemicals can be safely stored.

# 2. Facilities

A clear finding from this study is that student experiences are limited by science lab facilities. The ideal science lab provides sufficient space, a design that complements learning, and separate storage and preparation areas (see Appendix B for a NSTA illustration of a model science lab).

### Space/Design

After visiting the science labs and reviewing blueprints provided by schools, it is clear that more than 50 percent of the labs in this study need more space. Most labs fail to meet the recommended four feet of unobstructed aisle space between counters.[9] Most science labs also lack the number of sinks necessary to meet NSTA guidelines (four students per sink).

### Storage Rooms

Auditors found great variation in storage rooms. Some science labs had no separate storage space. In science labs that did have storage rooms, many were located far from the teachers' classrooms. This means that teachers must walk to the storage room in between classes, which is often not an option. In one school, the storage room for all science classes was two floors away from the science lab. The auditors concluded that the equipment in this room was rarely used because it was covered in dust.

8 It is important to have plans in place to safeguard students, school faculty and staff, the surrounding community, and the environment in the case of a spill. A procedure, including steps to be taken in case of a spill, should be developed and posted. For example, because mercury is particularly dense—one pound is only about two tablespoons—spills of mercury should only be cleaned up by trained personnel. Cleanup of spill debris, depending on the substance spilled, may be a hazardous waste subject to the Resource Conservation and Recovery Act (RCRA) regulations.

9 NSTA science lab guidelines recommend: (1) a minimum of 45-square-feet per student in a laboratory and 60-square-feet in a combined classroom/laboratory; (2) a minimum of 15-square-feet of space for each computer station as well as space for other technology; (3) two emergency exits for the laboratory as well as the preparation rooms; and (4) a ceiling height of ten feet, especially for classes of physical science and chemistry (p. 22, *NSTA Guide to School Science Facilities, 1999*).

Some science labs did have storage rooms conveniently located, but these rooms were often cluttered and dusty—suggesting that teachers overlooked boxes of kits, equipment, and other supplies. Teachers in these schools complained that they do not have enough time to clean or sort through their storage rooms. Others indicated that they were relatively new to the school and had not yet sorted through all the equipment. One middle school teacher who taught a lesson on electricity did not know until the auditors pointed it out that he had an entire box of equipment for teaching electricity.

These observations indicate that it is important for storage space to be located within close proximity of the science lab. It is also important that teachers take the time to inventory equipment in storage rooms and dispose of equipment or materials that are not needed.

# 3. Equipment and Materials

The quality of a lab experience depends in part on the equipment and materials available for student use. This audit found limited equipment and materials in the observed science labs. Auditors observed many science laboratories to contain broken and/or antiquated equipment. For example, many labs contained broken computers, and one lab contained scales and physics charts dating back to 1944. In several science labs, auditors found broken water faucets or no water access at all. Most schools also lacked the recommended one sink per four students.

### Biology Labs

Many biology labs have live animals, some of which are potentially dangerous. Some labs had large poisonous and nonpoisonous snakes present that could create a dangerous situation if these animals were to escape. It was not clear whether the science labs had appropriate procedures or were meeting standards to house, feed, and handle such animals.

## Chemistry Labs

Chemistry labs[10] typically conduct experiments in which students use chemicals. When used properly, chemical experiments can enhance chemistry lessons. If improperly used or stored, these chemicals can put students, staff, and others at risk from spills, explosions, or exposure. Every year, hundreds of thousands of dollars are spent on K–12 school incidents involving chemicals.

Fifty-six percent of the districts participating provided lists of chemicals kept at their schools. Districts and/or schools not providing chemical lists may not have current lists. The auditors received both computer software generated lists and handwritten chemical lists. All districts providing a list had chemicals on the Environmental Protection Agency's Excessive Risk List and High Risk List (see Appendix C). The risk associated with chemicals on the Excessive Risk List exceeds their utility, and those from the High Risk List should only be used for advanced level high school classes.

Proper disposal of chemical waste is a critical element in maintaining a safe science lab environment. The Material Safety Data Sheet (MSDS) provides teachers with the proper procedure for handling or working with a particular substance. When teachers were asked about the MSDS, their answers ranged from, "They are attached to the chemical" and "There is a copy of them on file" to "I don't know what you mean." At least one half of the teachers who use chemicals did not have a copy of the MSDS with the chemical but they knew where it was kept. Many high school teachers had the MSDS attached to the chemical's container. Others said that the custodian keeps the MSDSs so that he/she is prepared for fire inspections.

10 Chemistry experiments that involve chemicals typically produce waste. The waste resulting from laboratory experiments is considered hazardous and must be given special consideration in every experiment. It is the school's responsibility to determine if hazardous waste is being generated and to know what government regulations apply. For example, waste solvents must not be allowed to evaporate in fume hoods. This process is considered to be an illegal treatment of hazardous waste. Proper waste management ensures a safer school and the protection of human health and the environment. It is important to note that schools can be held legally liable for their hazardous waste and any damage it creates even after it leaves the school and is transported to a treatment, storage, or disposal facility. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund, the school can be required to contribute to the cost of cleaning any contamination resulting from the waste regardless of where the contamination occurs.

# 4. Instruction and Learning

While a quality lab experience enhances a student's understanding of complex scientific concepts, too often science lab activities are not well planned or aligned with the science curriculum. Observational and survey data gathered during this project reveal four key concerns: larger than ideal science lab class sizes, unprepared teachers, lab activities not aligned with science course curriculum, and insufficient lab time.

## Class Size

The NSTA recommends twenty-four students per science lab. Science lab class sizes varied greatly, ranging from four students to thirty-five students with the average lab class size being twenty-six (45 percent of labs had more than twenty-four students per lab). Several schools had over thirty students in one science lab class. Large class sizes limit student learning and lead to potential safety hazards.

## Teacher Preparation

Earlier in this report it was recorded that the auditors routinely observed unused equipment. This may suggest that not all teachers are confident in their ability to use available laboratory equipment. The survey administered to seventy-nine science teachers asked if they are comfortable using the following recommended NSTA equipment: microscopes, Bunsen burners, balances, thermometers, autoclaves,[11] incubators, and spectrophotometers.[12] The data reveals that teachers are comfortable with some types of equipment, but not others. For example, Missouri teachers claim to be highly skilled in the use of microscopes, Bunsen burners, balances, and thermometers, but not skilled in the use of autoclaves, incubators, and spectrophotometers.

Kansas teachers also report that they are highly skilled using microscopes, Bunsen burners, balances, and thermometers. They report "no skill" or "novice" levels for incubators, the autoclave, and spectrophotometers. These findings suggest that autoclaves, incubators, and spectrophotometers are not being used in the schools that participated in this study.

11 An apparatus in which special conditions (temperature and pressure) can be established for a variety of applications.

12 A device for measuring light as a function of color.

## Collaboration

Teacher interviews revealed that when there is more than one teacher in a building, collaboration is common. Many school districts plan biweekly after-school or late start meetings, meetings during planning periods, or informally scheduled meetings.

## Professional Development

The study's online survey and teacher interviews revealed that teachers in Missouri and Kansas participate in the following science related professional development opportunities:

- formal or informal collaboration with other science teachers;
- reading professional science journals;
- enrolling in a science-related university course.

There was a greater variance between responses when teachers in both Kansas and Missouri were asked: "Have you participated in school or district offered professional development in some way related to science in the last two years?" In Missouri, 60 percent of teachers said they had participated in professional development. In Kansas, 90 percent reported that they had gone through professional development in the past two years.

District administrators in both Missouri and Kansas indicate that their districts support the following science professional development areas:

- planning science supported instruction that meets content standards;
- implementing inquiry-based instruction[13] in science labs;
- assessing inquiry-based instruction;
- encouraging collaboration of core content areas.

These are common professional development opportunities, but do not often address the instructional strategies needed to facilitate lab activities.[14]

13 In a classroom where inquiry-based occurs, students are engaged in open-ended, student-centered, hands-on activities.

14 *NSTA Guide to School Science Facilities,* p. 17-19.

## Science Curriculum

The quality of science curriculum varied between the school districts participating in this study. Only a few districts had an outstanding curriculum that addressed the NRC recommended components;[15] however, in almost all cases, the science curriculum's written objectives were clear, focused, and aligned to state standards.

Teachers were interviewed to determine the degree to which they integrate lab activities with their science curriculum. When teachers were asked if they are required to embed science labs in their curriculum and instruction to explore science concepts in depth, they gave the following answers:

| **This school requires teachers to embed science labs to explore science concepts in depth.** | Very true | Somewhat true | Not true at all | Don't know or not applicable |
|---|---|---|---|---|
| Missouri Teachers | 28% | 48% | 16% | 8% |
| Kansas Teachers | 26% | 26% | 35% | 13% |

When asked if they regularly use science labs to enhance learning in the classroom, teachers gave the following responses:

| **I regularly use science labs to enhance learning.** | Strongly Agree | Agree | Disagree | Strongly Disagree | Don't know or not applicable |
|---|---|---|---|---|---|
| Missouri Teachers | 34% | 54% | 8% | 0% | 4% |
| Kansas Teachers | 56% | 36% | 8% | 0% | 0% |

This data indicates that many teachers do not believe that they are required to embed science labs in their curriculum. In Kansas, nearly half of teachers responded that they are not required to embed labs in the science curriculum; however, most teachers in both states report using the lab to enhance learning.

15 The National Research Council (NRC) defines science curriculum as the content of instruction and the ways in which it is structured, organized, balanced, and delivered in the classroom. The program is composed of goals, content standards, vision, and instructional materials. The curriculum must then be delivered with appropriate teaching strategies, instructional materials, and assessment.

### Lab Time

The NSTA recommends that middle and high school students have the opportunity to learn in a laboratory setting for at least ninety minutes each week.[16] Several science teachers interviewed for this study reported that they spend 50 percent of class time engaged in lab activities, but on average, most teachers spend only about forty-five to sixty minutes per week. One teacher reported using the lab only twice a month.

The following table illustrates the amount of time that students are engaged in science lab activities:

| **How much time per week does a typical student in your class(es) spend engaged in science lab activities while at school?** | Kansas Teachers | Missouri Teachers |
|---|---|---|
| None at all | 0% | 8% |
| Less than 30 minutes per week | 0% | 21% |
| 30 to 60 minutes per week | 58% | 38% |
| 1 to 2 hours per week | 21% | 29% |
| More than 2 hours per week | 21% | 4% |

A majority of teachers in both Missouri (67 percent) and Kansas (58 percent) spend less than one hour per week engaged in science lab activities.

# 5. District Policies

The school districts that participated in this study have few written science lab policies. Consequently, school building administrators decide individually how to store chemicals, maintain equipment, and arrange science lab classrooms. Although teachers follow district science curriculum, it is their responsibility to decide how lab activities can complement this curriculum.

A sample of district administrators and teachers were surveyed to determine whether or not they agree on the vision and expectations for science lab use. In general, the teachers were uncertain about whether there are written policies (they often assume that there are), and district administrators report that there are not written district policies.

16 The NSTA position statement states that "with the expectation of science instruction every day, all middle-level students should have multiple opportunities every week to explore science labs." The NSTA position statement on Laboratory Science Instruction can be found at the following website: *www.nsta.org/about/positions/laboratory.aspx*.

## Vision

When Missouri teachers were asked if their schools or districts have a vision for how science and science labs should be used:

- 29 percent responded "It isn't written down but it has been clearly shared with me and other science teachers"; and
- 29 percent responded "No, I am not aware of a vision for science and science labs, written or unwritten."

When a similar question was asked of the Missouri administrators, the respondents stated that there is not a formal written vision of how science labs should be used to improve science teaching and learning. In Kansas, 22 percent of the teachers said a formal written vision had been shared and another 22 percent said a vision was not written down but it had been shared. Thirty percent, however, said they were not aware of a vision for science and science labs either written or unwritten. Nearly all of Kansas district administrators indicated that there is no written vision for science or they do not know if there is one.

## Expectations

When Missouri teachers and district administrators were asked if teachers are expected to use science labs regularly, only 21 percent of the teachers felt they were, whereas 50 percent of the district administrators said they were. In Kansas, 63 percent of district administrators said teachers are expected to use science labs regularly, whereas only 35 percent of the teachers felt this was true.

When Missouri teachers and administrators were asked about expectations and frequency of lab use, there was some discrepancy. 54 percent of the teachers said they decide individually whether and how often they use science labs. Only 33 percent of district administrators indicated that teachers decide individually how much to use labs. In Kansas, 61 percent of the teachers reported that using labs was an individual decision while only 25 percent of district administrators believe that this is a teacher's individual decision.

# Recommendations

This study has uncovered extensive issues to be addressed in Kansas City area middle and high school science labs. The following are recommendations to address the study's findings.

## Safety

To ensure the safety of all students in science labs, it is recommended that:

- labs provide each student with goggles and disinfectant, heat resistant gloves, disposable gloves, a safety shield, and an apron;
- each lab include an eye wash station, fire blanket, fire extinguisher, and first aid kit;
- chemistry labs have working fume hoods, an emergency shower, and an acid cabinet;
- schools schedule regular maintenance to ensure that safety equipment is in working condition.

## Facilities

To improve the environment in which lab activities take place, it is recommended that:

- schools rearrange existing furniture and lab equipment to best facilitate lab instruction;
- schools follow the square footage guidelines and best practices recommended in the NSTA Guide to School Science Facilities when rebuilding or upgrading lab space;
- administrators limit the number of students in each science lab class period to meet NSTA square footage guidelines;
- teachers routinely organize storage rooms.

## Equipment and Materials

To ensure that labs contain relevant and working equipment and materials, it is recommended that:

- schools arrange to fix or replace broken equipment;
- teachers dispose of outdated equipment to allow more room for organization of equipment, materials, and supplies in current use;
- district leaders conduct a chemical inventory survey checklist at each site and create and maintain an accurate chemical list;
- schools properly dispose of chemicals on the Excessive Risk Chemicals List;[17]
- schools keep chemicals on the High-Risk Chemicals list at a minimum and use only in advanced level courses;
- district leaders develop a waste management plan.

## Instruction and Learning

To ensure that lab activities further student understanding of the science curriculum, it is recommended that:

- districts offer professional development opportunities that focus on instructional strategies in a laboratory setting;
- districts offer release time for science teachers to align lab activities with curriculum;
- districts provide science teachers with formal opportunities to collaborate;
- districts revise school improvement plans to include science lab goals;
- students receive the NSTA recommended minimum lab time.

## District Policy

To ensure that district policies support quality lab experiences, it is recommended that:

- districts develop and share science lab use expectations;
- districts revise science curriculum to include science lab guidelines;
- district administrators conduct science laboratory observations;
- districts create written vision statements for science labs and science instruction;
- districts create organized networks to share best practice information.

17 Currently the School Chemical Cleanout Campaign (SC3) is a program to help schools dispose of chemicals. To learn more about SC3, go to *www.epa.gov/sc3*

# Conclusion

Providing students with meaningful science lab experiences is a demanding task requiring teachers to have sophisticated knowledge of science content and processes, knowledge of the way students learn science, and knowledge of how to design instruction to support the multiple goals of science education. Pre-service education and in-service professional development for science teachers rarely address laboratory experiences.

This audit unveiled serious concerns in many science labs studied:

- although most of the high school science labs are equipped with adequate safety equipment for students, many middle school science labs lack basic safety equipment such as safety goggles, a fire blanket, a first aid kit, aprons, and gloves;
- at least 50 percent of the science lab classrooms need more space, especially in the middle school science labs;
- only 56 percent of the districts provided chemical lists for the audit and most teachers do not know the importance of keeping the Material Safety Data Sheets;
- many storage and preparation rooms are disorganized and the equipment inside is not used to its full potential;
- most teachers lack the knowledge necessary to use certain lab equipment;
- there is wide discrepancy between teacher and administrator perceptions about the purpose and expectations of science lab use.

This audit shows that science labs are not a high priority for many area school districts. Many teachers and district administrators have not spent the time necessary to incorporate laboratory exercises into the science curriculum in an effective way. Only when the science lab is treated as an integrated aspect of the science curriculum, and not as an add-on, can it effectively increase student learning.

The Kansas City region as a whole must work to improve science labs. This region is home to growing industries in Life Sciences and Animal Health Sciences. In order to produce the number of scientists that will be needed, middle and high schools in the region must provide rigorous and engaging science instruction.

# Appendix A

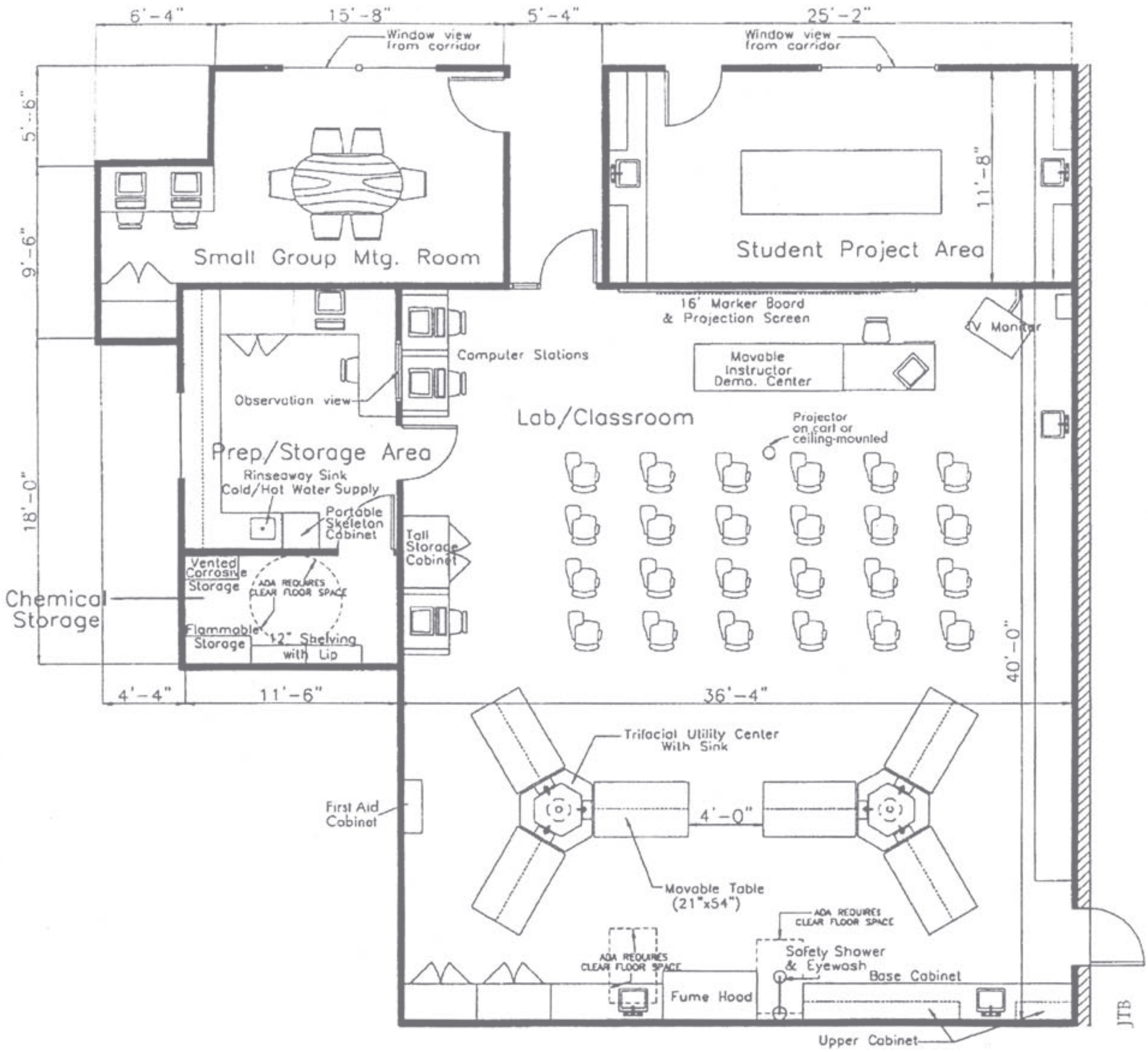
## Kansas City Metrowide Summary of Findings in Participating Labs

| Standards | Exceeds Standards | Meets Standards | Does Not Meet Standards |
|---|---|---|---|
| **Safety** | | | |
| Safety equipment in each lab should include: fire blanket, fire extinguisher, first aid kit, fume hood, eye wash, emergency shower, and acid cabinet. Protective equipment for each student includes: goggles and disinfectant apparatus, heat resistant gloves, disposable gloves, safety shield, and apron. | | | ● |
| **Facilities** | | | |
| Space/Design: NSTA guidelines: (1) a minimum of 45-square-feet per student in a laboratory and 60-square-feet in a combined classroom/laboratory; (2) a minimum of 15-square-feet of space for each computer station as well as space for other technology; (3) two emergency exits for the laboratory as well as the preparation rooms; and (4) a ceiling height of ten feet, especially for classes of physical science and chemistry. | | | ● |
| Storage: separate but adjoining storage space is available and well organized for each science lab. | | | ● |
| Water Accessibility: at least 1 sink per 4 students, 1 large sink, with swivel and high-arched faucets and deep bowls. | | | ● |
| **Equipment and Materials** | | | |
| Equipment is working and well maintained. Materials are up-to-date and enough supplies are available to match curriculum needs without unneeded excess. | | | ● |
| Chemistry Labs: a computerized chemical list is available and MSDS sheets are kept for documentation for each chemical in the lab. No excessive risk chemicals are present and high-risk chemicals are only used in advanced high school classes. | | | ● |

| Standards | Exceeds Standards | Meets Standards | Does Not Meet Standards |
|---|---|---|---|
| **Instruction and Learning** | | | |
| Class Size: a maximum of twenty-four students in each science lab class. | | | ● |
| Teacher Preparation—Collaboration: science teachers have regular opportunities to collaborate with other teachers in their school/district. | | ● | |
| Teacher Preparation—Professional Development: teachers have opportunities for professional development that specifically address instruction within the science lab. | | | ● |
| Curriculum Objectives: science curriculum objectives are clear and aligned to state standards and/or grade level expectations. | | ● | |
| Curriculum Alignment: science teachers regularly embed the science lab in the science curriculum. | | ● | |
| Lab Time: multiple opportunities (a minimum of ninety minutes) each week for laboratory experiences. | | | ● |
| **District Policies** | | | |
| Teachers and Administrators agree on district vision and expectations for lab use. | | | ● |

# Appendix B

## NSTA Model High School Science Lab/Classroom




Source: National Science Teachers Association. *NSTA Guide to School Science Facilities.* Biehle, James, Motz, Lamoine, and Sandra West, p. 50. NSTA Press, 1999.

# Appendix C

## Excessive and High-Risk Chemicals

| Excessive Risk Chemicals—Risk Exceeds Educational Utility | |
|---|---|
| **Chemical Name** | **Hazards** |
| Acetic Anhydride | Explosive potential, corrosive |
| Acetyl Chloride | Corrosive, dangerous fire risk, reacts violently with water and alcohol |
| Acrylamide | Toxic by absorption, suspected carcinogen |
| Acrylonitrile | Flammable, poison |
| Adipoyl Chloride | Corrosive, absorbs through skin, lachrymator |
| Aluminum Chloride, anhydrous | Water reactive, corrosive |
| Ammonia, gas | Corrosive lachrymator |
| Ammonium Bifluoride | Reacts with water, forms Hydrofluoric Acid |
| Ammonium Bichromate | May explode on contact with organics, suspected carcinogen |
| Ammonium Chromate | Oxidizer, poison; may explode when heated |
| Ammonium Dichromate | Reactive, may cause fire and explosion |
| Ammonium Perchlorate | Explosive, highly reactive |
| Ammonium Sulfide | Poison, Corrosive, reacts with water and acids |
| Aniline | Carcinogen, toxic, absorbs through skin |
| Aniline Hydrochloride | Poison |
| Antimony Oxide | Health and contact hazard |
| Antimony Powder | Flammable as dust, health hazard |
| Antimony Trichloride | Corrosive, emits hydrogen chloride gas if moistened |
| Arsenic compounds | Poison, carcinogen |
| Asbestos, Friable | Inhalation health hazard, carcinogen |
| Azide Compounds | Explosive in contact with metals, extremely reactive, highly toxic |
| Barium Chromate | Poison |
| Benzene | Flammable, carcinogen |
| Benzoyl Peroxide | Organic peroxide, flammable, oxidizer |
| Beryllium and its compounds | Poison. Dust is P-listed & highly toxic. Carcinogen |
| Bromine | Corrosive, oxidizer, volatile liquid |
| Cadmium compounds | Toxic heavy metal, carcinogen |
| Calcium Fluoride (Fluorspar) | Teratogen, emits toxic fumes when heated |
| Carbon Disulfide | Flammable, toxic, P-Listed, extremely hazardous |
| Carbon Tetrachloride | Toxic, carcinogen |

| Chemical Name | Hazards |
|---|---|
| Chloral Hydrate | Hypnotic drug, controlled substance |
| Chlorine | Poison gas, corrosive |
| Chlorobenzene | Explosive limits 1.8% to 9.6%, toxic, inhalation and contact hazard |
| Chloroform | Carcinogen. If old forms deadly Phosgene gas. |
| Chlorosulfonic Acid | Toxic aka Sulfuric Chlorohydrin |
| Chromic Acid | Strong oxidizer. Poison |
| Collodion | Flammable, explosive when dry. Nitrocellulose compound. |
| Cuprous Cyanide | Toxic |
| Cyanogen Bromide | Poison, strong irritant to skin and eyes |
| Cyclohexene | Flammable, peroxide former |
| Dichlorobenzene | Toxic |
| Dichloroethane | Flammable, toxic |
| Dinitro Phenol | Explosive, call "Bomb Squad" to have safely removed |
| Dinitrophenyl Hydrazine | Severe explosion and fire risk |
| Dioxane | Flammable, peroxide former |
| Ether, Anhydrous | Flammable, peroxide former |
| Ether, Ethyl | Flammable, peroxide former |
| Ether, Isopropyl | Flammable, peroxide former |
| Ethyl Ether | Flammable, peroxide former |
| Ethylene Dichloride | Toxic, contact hazard, dangerous fire risk, explosive in air 6-16% |
| Ethyl Nitrate | Explosive, call "Bomb Squad" to have safely removed |
| Ethyleneimine | Flammable, toxic, P-listed |
| Ferrous Sulfide | Spontaneously ignites with air if wet |
| Formaldehyde (Formalin) | Toxic, carcinogen, sensitizer |
| Gunpowder | Explosive |
| Hydrazine | Flammable, absorbs thru skin, carcinogen, corrosive |
| Hydriodic Acid | Corrosive, toxic |
| Hydrobromic acid | Corrosive, poison |
| Hydrofluoric acid | Corrosive, poisonous |
| Hydrogen | Flammable |
| Hydrogen Sulfide, gas | Poison, stench |
| Immersion Oil (old) | May contain 10-30% PCBs such as Arochlor 1260 |
| Isopropyl Ether | Flammable, highest-risk peroxide former |
| Lithium Aluminum Hydride | Flammable, reacts with air, water, and organics |
| Lithium Metal | Reacts with water, nitrogen in air |

| Chemical Name | Hazards |
|---|---|
| Mecaptoethanol | Flammable, corrosive, intense stench |
| Mercury compounds | Poisonous heavy metal |
| Mercury, liquid | Toxic heavy metal, carcinogen |
| Methylane Chloride | Toxic, carcinogen, narcotic |
| Methyl Ethyl Ketone | Flammable, dangerous fire risk, toxic |
| Methyl Iodide (Iodomethane) | May be a narcotic, carcinogen, Lachrymator |
| Methyl Isocyanate | Flammable, dangerous fire risk, toxic |
| Methyl Isopropyl Ketone | Toxic |
| Methyl Methacrylate | Flammable, vapor causes explosive mix with air |
| Naphthylamine, a- | Combustible, toxic, carcinogen |
| Nickel Oxide | Flammable as dust, toxic, carcinogen |
| Nicotine | Poison, P-Listed, extremely hazardous |
| Nitrilotriacetic Acid | Corrosive |
| Nitrobenzene | Highly toxic |
| Nitrocellulose | Flammable, explosives |
| Nitrogen Triodide | Explosive, call “Bomb Squad” to have safely removed |
| Nitroglycerin | Explosive, call “Bomb Squad” to have safely removed |
| Osmium Tetraoxide (Osmic Acid) | Highly toxic, P-Listed, extremely hazardous |
| Pentachlorophenol | Extremely toxic |
| Perchloric Acid | Powerful oxidizer, reactive |
| Phosphorus Pentasulfide | Water reactive, toxic, incompatible with air and moisture |
| Phosphorus Pentoxide | Oxidizer, toxic |
| Phosphorus, Red | Flammable solid |
| Phosphorus, Yellow or White | Air reactive, poison |
| Picric Acid, Trinitrophenol | Explosive when dry |
| Potassium Cyanide | Poison, P-Listed, extremely hazardous |
| Potassium Perchlorate | Powerful oxidizer, reactivity hazard |
| Potassium Sulfide | Flammable, may ignite spontaneously |
| Potassium, metal | Water reactive, peroxide former (orange fog/crystals) |
| Pyridine | Flammable, toxic, vapor forms explosive mix with air |
| Selenium | Toxic |
| Silver Oxide | Poison |
| Silver Cyanide | Extremely toxic |
| Sodium metal lump | Water reactive, ignites spontaneously in dry hot air, corrosive |
| Sodium Arsenate | Toxic, carcinogen |

| Chemical Name | Hazards |
|---|---|
| Sodium Arsenite | Toxic, carcinogen |
| Sodium Azide | Poison, explosive reaction with metals, P-Listed extremely hazardous |
| Sodium Borohydride | Flammable solid, water reactive |
| Sodium Cyanide | Poison, P-Listed, extremely hazardous |
| Sodium Flouride (Bifluoride) | Highly toxic by ingestion or inhalation; strong skin irritation |
| Sodium Fluoroacetate | Tox-X, Deadly Poison! |
| Sodium Peroxide | Water reactive, may cause fire and explosion |
| Sodium Sulfide | Fire and explosion risk |
| Strontium | Flammable, store under naphtha, reacts with water |
| Testosterone HCI | Controlled substance |
| Tetrahydrofuran | Flammable, peroxide former |
| Thioacetamide | Toxic, carcinogen, combustible |
| Thionyl Chloride | Corrosive |
| Thiourea | Carcinogen |
| Titanium Trichloride | Flammable, fire risk |
| Triethylamine | Flammable, toxic, irritant |
| Trinitrobenzene | Explosive, call "Bomb Squad" to have safely removed |
| Trintrophenol | Explosive, call "Bomb Squad" to have safely removed |
| Trinitrotoluene | Explosive, call "Bomb Squad" to have safely removed |
| Uranium/Uranyl Compounds | Radioactive |

| High-Risk Chemicals—Only Allow Very Limited Amounts in Storage Only Appropriate for Advanced-Level High School Science Classes | |
|---|---|
| **Chemical Name** | **Hazards** |
| Acetamide | Carcinogen, P-Listed, extremely hazardous |
| Ammonium Nitrate | Powerful oxidizer, reactive |
| Barium Peroxide | Fire and explosion risk with organic materials, oxidizer, toxic |
| Butyric Acid | Corrosive, intense stench |
| Cadmium Sulfide | Highly toxic, carcinogen |
| Calcium Carbide | Flammable, reaction with water |
| Chromium Trioxide | Oxidizer, poison |
| **Chemical Name** | **Hazards** |
| Ethidium Bromide | Potent Mutagen |

| Chemical Name | Hazards |
| --- | --- |
| Hexamethylenediamine | Corrosive absorbs through skin, lachrymator |
| Hexanediamine, 1-6 | Corrosive absorbs through skin, lachrymator |
| Hydrogen Peroxide, >29% | Powerful oxidizer, corrosive to skin |
| Lead Compounds | Highly toxic |
| Lead Nitrate | Toxic heavy metal, corrosive |
| Magnesium, powder | Flammable |
| Mercury Thermometers | Toxic heavy metals, corrosive |
| Phenol | Poison |
| Potassium Chlorate | Powerful Oxidizer, reactive |
| Potassium Chromate | Oxidizer, Toxic |
| Potassium Dichromate | Powerful Oxidizer, carcinogen |
| Radioactive Materials | Radioactive |
| Sebacoyl Chloride | Corrosive fumes, Lachrymator |
| Silver compounds | Toxic |
| Sodium Chlorate | Powerful oxidizer |
| Sodium Chromate | Oxidizer |
| Sodium Dichromate | Reactive, may cause fire and explosion |
| Sodium, metal, small chips | Water reactive, corrosive |
| Strontium Nitrate | Oxidizer, may explode when heated or shocked |
| Thermite | Flammable solid |
| Toluene | Flammable, dangerous fire risk, toxic |
| Wood's Metal | Poison |
| Xylene | Flammable, toxic |

Source: *www.govlink.org/hazwaste/publications/highrisktable.pdf*

# Appendix D

## Recommended Resources and Websites

- National Research Council. *America's Lab Report: Investigations in High School Science.* Committee on High School Science Laboratories: Role and Vision, S.R. Singer, M.L. Hilton, and H.A. Schweingruber, Editors. Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press, 2006.
- National Science Teachers Association. *NSTA Guide to School Science Facilities.* Biehle, James, Motz, Lamoine, and Sandra West. NSTA Press, 1999.
- NSTA Position Statement: The Integral Role of Laboratory Investigations in Science Instruction: *www.nsta.org/about/positions/laboratory.aspx*
- Fuller, Edward J.; Picucci, Ali Callicoatte; Collins, James W.; Swann, Philip. *An Analysis of Laboratory Safety in Texas.* University of Texas. Austin (Spring 2001).
- Science Safety Manual: Maryland's Public Schools: *www.mdk12.org/instruction/curriculum/science/safety/index.html*
- School Chemical Cleanout Campaign (SC3): *www.epa.gov/sc3*
- Science & Safety Consulting Services: *www.sciencesafetyconsulting.com*
- The Laboratory Safety Institute: *www.labsafety.org*