DOCUMENT RESUME

ED 081 064 EA 005 193

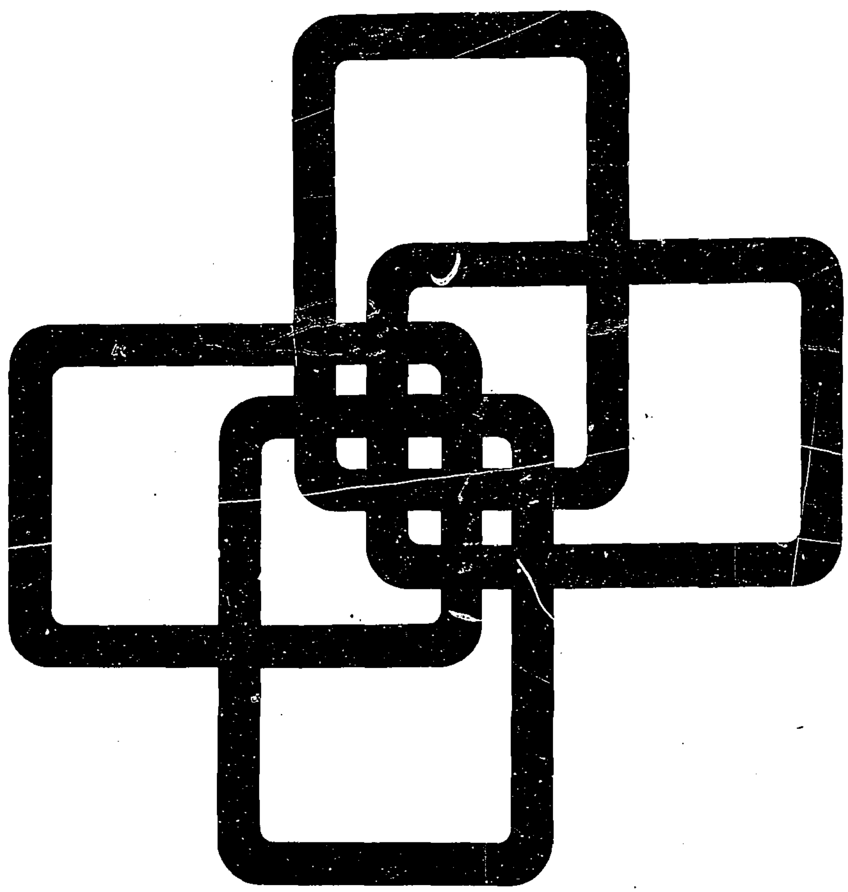
AUTHOR Woodruff, Alan P.
TITLE Career Education Facilities: A Planning Guide for Space and Station Requirements. A Report
INSTITUTION Educational Facilities Labs., Inc., New York, N.Y.
PUB DATE Apr 73
NOTE 50p.
AVAILABLE FROM Educational Facilities Laboratories, 477 Madison Avenue, New York, New York 10022 ($2.00)

EDRS PRICE MF-$0.65 HC-$3.29
DESCRIPTORS *Career Education; Flexible Faci'ities; *Laboratories; Models; Occupational Clusters; *Planning (Facilities); *School Shops; *Space Utilization; Vocational Education
IDENTIFIERS *Shared Facilities

ABSTRACT

This publication provides the educational planner and the architect with some suggestions concerning models by which they may plan new flexible-use, shared-space facilities and supports the models with guidelines for the development of facilities and educational programs for occupational education. In addition to discussing the financial advantages of space and equipment sharing by more than one program of a career or occupational education center, the publication is a comprehensive guide to planning for all the facilities likely to be encountered in career education. Each presentation of facility planning is divided into a discussion ot program and space relationships, an identification of the individual stations and areas within each of the cluster laboratories and of the relationships between these stations and the shared services of the laboratory and the cluster as a whole, and a table of space requirements for most of the individual stations required in each laboratory. These tables include the space required for each station, plus a guideline percent of stations that should be allocated to each area. (Author/MLF)

Educational Facilities Laboratories, Inc. is a nonprofit corporation established by The Ford Foundation to help schools and colleges with their physical problems by the encouragement of research and experimentation and the dissemination of knowledge regarding educational facilities.



Career Education Facilities

A planning guide for space and station requirements

Contents

First Printing April 1973
Library of Congress Catalog No. 73-76703
Copies of this publication are available at $2.00 from
EFL, 477 Madison Avenue, New York, N.Y. 10022.

Foreword

One of EFL's tasks is to advocate concepts that we believe will benefit the planners, administrators and users of schools and colleges on this continent. Recently, we have been exploring and recommending the concept of sharing facilities in order to decrease the cost per use of buildings or equipment. This sharing can take several forms, but in the context of this publication it refers to spaces and equipment that can be shared by more than one program of a center devoted to career or occupational education.

Simply stated, the concept means one sink shared by two students from different classes. In practice, it recommends that one set of machines should serve two trade groups in, say, a construction trades school. *Career Education Facilities*, however, covers more than the shared facilities; it is a comprehensive guide to planning for all the facilities likely to be encountered in career education.

This publication was written by Alan P. Woodruff, an educational planning consultant commissioned by EFL to develop his research in space and station planning into a guide of wide use to architects and educators.

EDUCATIONAL FACILITIES LABORATORIES

Introduction

In the ten years since the passage of the Vocational Education Act of 1963, tremendous changes have taken place in the programs and methods of career education. Career educators have been among the leaders in recognizing that not all learning takes place best in a group-paced, teacher-centered class or laboratory setting. Independent field study such as cooperative education and work study programs, which take the student out of the school and into the real world, have each begun to replace the traditional schoolbound class or laboratory (shop) learning environment to a significant degree.

The career development experiences provided in the laboratory have also undergone major changes. No longer do educators feel compelled to cling to shops and laboratories as surrogates for the "real world." The purpose of the school is to educate — not simply to train — and industry has responded to this new understanding by designing systems intended specifically to teach a student *how* to perform a task rather than simply providing machinery on which to perform it. In many cases these trainers may be quite unlike the machine the student will find in industry, and in such cases the newer systems must be used with not instead of traditional systems. It then becomes the problem of educators and school-program planners to determine how instructional time can most beneficially be divided between the relatively high efficiency (from a learning/time unit standpoint) teaching systems and a piece of actual machinery that is perhaps less efficient as a trainer. Unquestionably, both systems have a role to play and the ultimate selection may involve a complex set of trade-offs among program objectives.

Another common trend in occupational education is represented by the shift away from single-career programs and toward career "families" or "clusters." Such a shift has been brought about by today's rapid changes in technology that require new workers to be prepared to change careers. Thus, for instance, an electrician must now learn more than just house wiring. If his bent is toward home construction, his program may incorporate a broad base of skills in the building trades (piping, plumbing, masonry, carpentry, painting and finishing, etc.) in addition to his specialization in electrical work. On the other hand, electrical work itself may be the basis of the student's program and his courses d laboratory experiences may be designed to build a oad-based preparation for home and industrial wiring, motor/generator repair, or industrial electricity and electrical system assembly, for example. It is the obligation of the school to respond to the needs of both of these types of students. However, since it is improbable that the needs of students having diverse objectives can all be met through a single curriculum available in one laboratory, we have begun to think in terms of clusters of programs and the development of curricula which build broad skill bases within one or more laboratory clusters.

It is now recognized that the career family or cluster can provide the broader range of skills needed today. But it is apparent that we cannot afford specialized laboratories for each career program. As a result, planners have been forced to recognize that the only effective and economical way to integrate programs into multi-skill clusters is through some form of integrated, open-laboratory facility. However, the efficient design of such cluster facilities presents both the architect and the educator with major problems of program analysis and long-range program planning.

Typically, in planning the traditional one program/one laboratory school, the planner and architect fall back on a variety of standards (area per student, station, or laboratory) that could be used to calculate the space requirements for the whole laboratory. They then stock it with the standard equipment and the job is complete. But the changes in requirements brought on by the use of simulators and related systems have outdated most common space standards. Further, the planner of the multiprogram shared-spaced laboratory must plan according to an understanding of the specific functions which are required for each program separately, while giving an analysis of which stations must be planned for sharing. This approach to planning leads to two problems:

1. There are few operating examples of shared space facilities on which to base future planning.
2. There are no planning standards from which the total laboratory space may be derived.

It is the purpose of this publication to take a first step toward solving both of these problems by 1) providing the educational planner and the architect with some suggestions concerning models by which they may plan new flexible-use shared-space facilities, and 2) supporting these models with guidelines for the development of facilities and educational programs for occupational education.

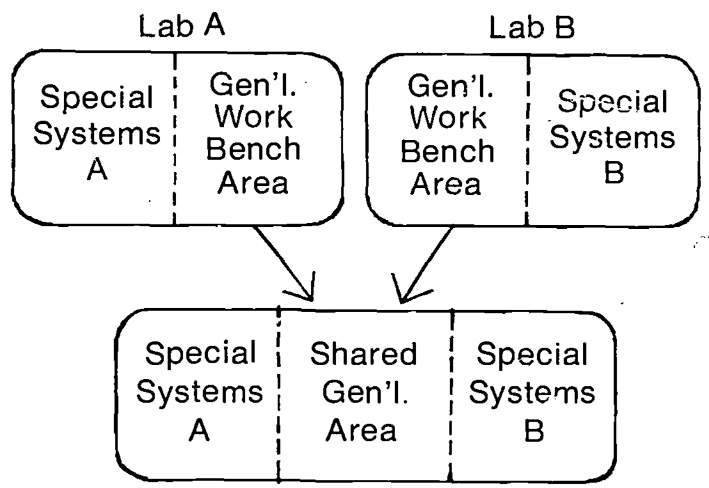


Figure 1
Example of station-sharing through overlapping laboratory facilities.

Developing Facility-Flexibility Through Space-Sharing[1]

In general there are two classes of shared-space programs that are of special interest in developing program flexibility in secondary occupational education. These two classes are station-sharing programs, and space-sharing programs.

In the present context "station-sharing" will refer to the use of one station to provide the same activity to several different instructional programs, while "space-sharing" will refer to the policy of sharing a single work area between different programs.

Station-Sharing

The development of a facility and an instructional program based on station-sharing is based on a recognition that the same basic work station can form the service core for several related programs. This may be brought about by simply locating a standard station where it is accessible to several instructional areas. Or this flexibility may be brought about by selecting or designing instructional stations which respond to the needs of more than one program and then designing the total laboratory area so that these stations can serve two or more related programs. The need to use this single station for many programs in one day or during a single period is, of course, a problem that is affected both by the flexibility of the teacher and the level of student enrollment. Here the significant issue is not the facilities planning problem *per se*, but a recognition that careful choice of shared-space facilities can offer new planning options to school administrations. The problems of individual station design are more curriculum concerns. What is a major facility-planning concern is the problem of designing so as to reflect the "clustered open shop" philosophy and the "career-family" curriculum.

The major questions to be answered are what instructional program elements lend themselves to station-sharing and how these elements can be reflected in facility relationships.

To the first of these questions there are two fundamental answers. Station-sharing options may be generally thought of as a sharing of support facilities that relate to two or more programs or a sharing of common activity or circulation space that draws together two or more programs. These relations may be translated into facilities as either:

1. Overlapping laboratories which share common services but have separate areas for specific activities or
2. Separate, specialized "mini-labs" designed around a core of shared services (similar to, but not exactly the same as, the loft-type open shop).

The first alternative is shown graphically in Figure 1. This is a model for two separate (and possibly functionally dissimilar) program areas in a single laboratory. Students from both areas share stations which support the two programs.

A simple example of this model is in the materials-testing laboratory which can be located to serve machine shop, metallurgy and civil engineering programs, or a group of metal-stock, preprocessing machines (power hacksaws, etc.), that serve the machine, welding and sheet-metal shops.

The major advantage of the "overlapping program" is that it makes the best use of systems that may be essential to, but not major components of, several programs. In an open-shop setting there is greater opportunity to meet varying program demands from year to year. Still, as in all shared-space programs, this model does not solve the problem of satisfactorily fitting students in when two or more programs are competing for the same space.

1. This chapter is modified from the paper "Occupational Education Space Flexibility Through Space Sharing," CEFP Journal, May — June 1972.

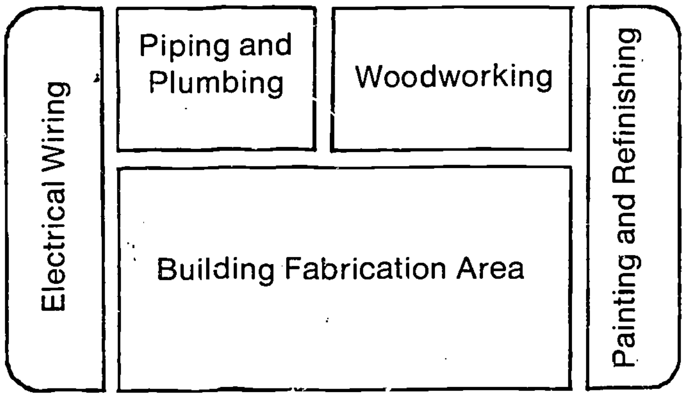
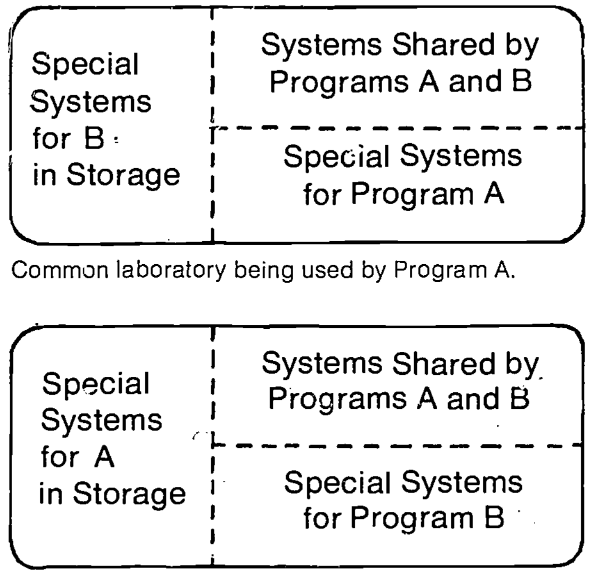


Figure 2
Building-trades cluster using a common assembly area flanked by four mini-labs.



Common laboratory being used by Program A.

Common laboratory being used by Program B.

Figure 3
Example of space-sharing based on rotational use of storage facilities by two (or more) programs.

The "mini-lab/shared core" program represents a hybrid of the cluster skill-family laboratory and the shared-space/open-space laboratory. Figure 2 shows the construction of single-purpose laboratories around a core area that has the shared stations. Since the core laboratory serves several disciplines it is the central service area for the cluster. The common area is used for a number of training programs and it may be considered an open-space shop. In one respect, this model is simply an extension of the overlapping program, but, by appropriate planning of the cluster curricula, it can lead to program unification. This is discussed further under "sequential program rotation."

The mini-lab/shared core plan provides the greatest flexibility for "clustered" facility designs since it allows for the total change of the kind of program in each mini-lab while making the most use of the shared stations. However, if the character of the cluster relationships is not carefully planned, discontinued programs can leave a lot of unused, and unusable, space. As an example, the plan in Figure 2 allows flexible enrollment in the general program but does not permit switching from plumbing to, say, welding in the satellite lab.

Space-Sharing

In addition to the sharing of instructional and support service-systems, major space savings can be made by designing for the shared use of the same physical space (but not necessarily the same facilities) for a variety of activities. There are three types of such "rotational stations":

1. Sequential program rotation,
2. Program/storage rotation,
3. Overlapping program rotation.

"Rotating" means that laboratory space may be used for various learning experiences. This principle is best illustrated by the following examples.

Rotational space-sharing in the Building Trades program is based on the analogy of the construction of a new building, which involves many skilled tradesmen working on the same space at different times. First the carpenter or concrete-form builder and foundation-construction men build the frame. They are followed by electricians, plumbers, pipefitters and sheet-metal workers, who install wiring, piping, ducts, etc. Then masons, plasterers, painters and paperhangers apply the final touches. This basic sequence of events can be copied in a shared-station plan with several trade programs cycled through one or more construction stations as the students develop the skills for each task. An example of this facility, for a Building Trades complex, might look like Figure 2.

In an education program with limited enrollment this model is an excellent way of expanding the teaching program while justifying (in terms of total space requirements) the development of courses with limited individual, but acceptably large skill-family enrollment. While large enrollments in each program in a cluster may justify the development of separate laboratories, this model makes it possible to put new activities into dead space.

The second rotational alternative is designed for the alternate use and storage of different program systems. This does not allow multiple use of facilities during a single period or day. The operation of this program is shown in Figures 3a and 3b.

Obviously, when there is extensive specialized equipment requiring large storage spaces and long laboratory conversion time this alternative is not very useful. However, where easily mobile, mounted systems are useful, this option is attractive.

The third example of rotational space-sharing is a fixed sequence of instruction in one area. This plan is exemplified by the auto-body program. In the early stages of auto-body repair students must learn such basic skills as metal pounding, shaping and shrinking, metal sanding and preparation for painting and welding and plastic filling. Only after these skills have been developed does the student begin work on a complete car. The individual skills are not related solely to auto-body repair, however. For such a program the laboratory may be more functionally related to the curriculum when viewed as having a station layout and use sequence similar to that shown in Figures 4a, 4b and 4c.

Diagnosing Opportunities for Space-Sharing

Recognizing that the foregoing has been no more than a summary of some options for making best use of facilities and making programs more flexible, the question to be asked now is how we develop spaces which can adequately serve multiple programs and allow the designer and educational planner to capitalize on these ideas.

First, we must have more information on the specific objectives of the courses being considered for the new building. Educators and researchers now have many projects underway to provide this information. But these objectives must be translated into study outlines for specific courses. The data are then analyzed to produce an instructional-station design to teach the skill. Then, we must determine which stations can be used most successfully for more than one program.

The synthesis of these ideas is a summary of the needs of this particular form of space-sharing. While these three steps should be done each time a facility is designed, they are frequently and sometimes justifiably viewed as fruitlessly time-consuming and it is often convenient to have some handy rules for general space-sharing plans. The following models are guides for such planning.

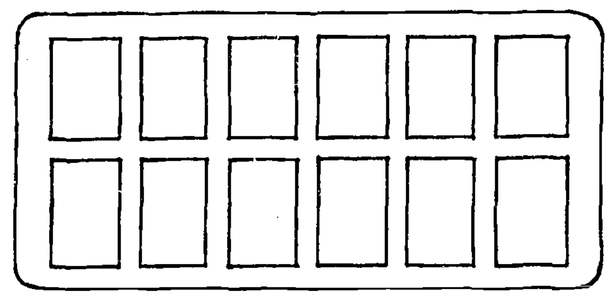
The Magnet Model — The "magnet" model is a program, in which disciplines which share, or could share, equipment, physical spaces or learning experiences are drawn together around their common feature. The plan can look like the shared station of Figure 1 or Figure 2. "Magnet" modeling is principally an approach designed to *reduce* space requirements while making teaching easier by drawing together appropriate programs and spaces.

The Spin-Off Model — A "spin-off" program uses new programs which are developed to build the facilities required for existing programs. This model provides great increases in program offerings at minimum expense. For instance, a printing program requires a darkroom for its offset camera. With only minor expansion of this space, a program in commercial photography can be established. Similarly, a small additional space in an electrical/electromechanics laboratory can provide for a program in appliance repair.

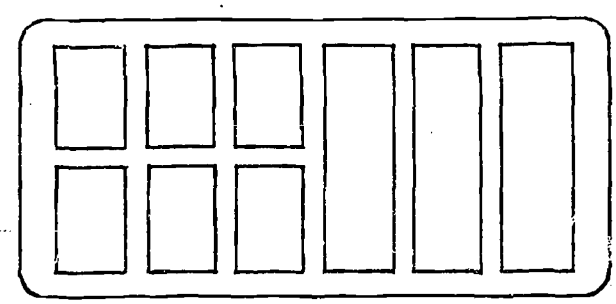
Hybrid Spin-Off/Magnet Approach — In addition to the benefits to be gained by independent use of the spin-off and magnet models it is possible to provide the facilities for a new program drawing elements from each of the old programs. For instance, an electromechanics laboratory may be combined with part of the plumbing laboratory to develop a refrigeration area, adding to the original programs and offering a third besides.

While it should be obvious that a shared-space cluster derived from the magnet logic could just have well have resulted from spin-off logic, it is important for the planner to think of and apply them separately. Thus the planner may begin with a set program of required spaces and, applying the magnet model, determine which spaces lend themselves to sharing or cluster grouping and collapse the building around these spaces. Then the planner must look at all the functional areas provided in the building and ask the question "What additional programs make use of a similar space?"

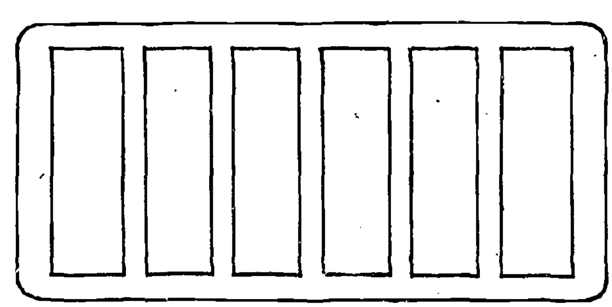
Figure 4
Example of rotational space-sharing by having multiple activities in the same program.



A. Small-scale systems or stations used early in the program.



B. Transition state when full-scale systems are introduced.



C. Final state of laboratory — all full-scale systems.

As a practical issue, the magnet model is probably more important in that it leads to space reduction for previously identified needs whereas the spin-off model leads to greater space requirements and the addition of programs not initially requested. However, the use of "spin-off" thinking still should not be overlooked because the availability of a new program at relatively low space cost may change an administrator's program priorities.

Laboratory Space-Planning Standards

The following sections are intended to guide the planner in applying the concepts of space-sharing and in deriving the total laboratory station relationships for the most general kinds of career education laboratories. For simplicity, all laboratories described in the following sections are grouped either on the basis of an opportunity to share major services or by definition (as in the "Public Services" cluster).

In instances where laboratories can be used in several clusters they have been cross-referenced to the cluster containing the major discussion. The clusters to which all laboratories have been assigned are:

A. Building Trades
B. Business, Office Occupations and Merchandising
C. Electricity and Electromechanics
D. Graphics and Communication Arts
E. Heating, Ventilation, Airconditioning and Refrigeration
F. Medical — Dental
G. Metals and Materials Fabrication
H. Public Services
I. Science and Technology
J. Vehicle Maintenance

Each of the presentations of facility planning is divided into three sections.

1. A general discussion of program and space relationships which draws together the programs in each cluster;
2. An identification of the individual stations and areas within each of the cluster laboratories and of the relationships between these stations and the shared services of the laboratory and the cluster as a whole;
3. A table of space requirements for most of the individual stations required in each laboratory.

The first section under each topic is intended as a general survey of some current ways of making optimum use of space and instructional stations. It is not intended to be an exhaustive evaluation of the opportunities and alternatives available in each cluster but rather suggests some ways of viewing the role of space and equipment in carrying out interrelated programs.

It must also be recognized that instruction will differ throughout the country, and it is unlikely that any school would want, need or be able to develop all the programs here presented.

The second section under each topic presents a summary of the function and the design characteristics that typify the programs. As in the introductory section, no attempt has been made to present a complete documentation of the architectural and/or furnishing requirements of a laboratory. These paragraphs are only intended to give the major types of spaces that should be provided in an individual laboratory.

The third section is a space-planning "shopping list" for the design of the facilities in each cluster. These tables include the space required for each station, plus a *guideline* percent of stations that should be allocated to each area. (It should be noted that the total of all area-station percentages for a given laboratory exceeds one hundred percent to account for station use which may vary from sixty to eighty percent depending on the laboratory and the different types of stations to be included.)

Once the planners have specified their objectives, they may go to these tables to "order" the spaces and configurations they need. In making their original list, however, they may wish to consult the beginning of each section to determine the best combination of spaces for their needs.[2] The number of students usually assigned to each station is also given.

2. It is most important to recognize that the spaces presented in these tables represent area per station not area per student. In many instances a single station will serve more than one student.

Interpretation and Use of Facility Space Tables

In using the data in the following sections, it will be important for the planner to bear in mind some of the general considerations that lead to their development and use. These include a recognition that: 1) providing program and space flexibility does not mean simply alloting the maximum amount of space; 2) efficient and effective space use requires advance planning based on *specific* requirements; and 3) laboratories planned for "partial" classes (over or under 20 — but especially lower numbers) must take into account the fact that the total area requirement is made up of student stations plus general support areas, and only the former vary with enrollment.

The first of these criteria reflects a growing recognition that there is both a minimum and a maximum laboratory size and plan with which a program can, from an educational viewpoint, operate efficiently. The attitude that "we can get by without a space for X, we'll just double up in space Y" no longer holds. Double-duty space makes unnecessary demands on teaching and, in the long run, constrains the growth of the program.

On the other hand, there is a maximum space that can be used efficiently. If it is not feasible or convenient to accommodate students by rescheduling groups in a shop at this maximum size, then another shop is needed — not simply a larger one.

The minimum and maximum size is dictated by the fact that efficient laboratory instruction relies on a comprehensive instructional program that may call for more stations than are required for the regulation 20 students. Unless the station requirements reflect the needs of the program the provision of too much space only adds cost without improving flexibility.

It should also be clear that it is important to list all the services to be provided in the laboratory in order to plan successfully. The space requirements for each laboratory are presented in terms of functional areas rather than single student stations. All stations require the same amount of space. Laboratories for the same basic program may differ significantly in the actual equipment and facilities required. Efficiency will be directly related to the planner's care in designing a space for all programs.

Finally, in planning any laboratory the designer must consider both the student station and "support" station requirements. Each of the facility space tables are concerned primarily with the instructional stations associated with one or more programs. In most laboratories, however, there is a basic set of support areas that must be provided regardless of the size of the class. The commitment to such service systems may or may not depend on the size of the laboratory. The problem might take the form of an equation such as the following:

Total area of laboratory = (area for basic system + area per student station) × number of students.

As an example, the woodworking shop for either a carpentry or cabinetry program must have a fixed array of power tools and the size of this area of the shop is relatively unaffected by the number of students in the class. When the class is large, additional workbenches can be set up in a nearby area. Similarly, a machine shop consists of the actual lathe presses and other machines on which students learn their skills. But this laboratory requires a set of tools, such as power hacksaws, that must be provided whether the number of students in the shop is one or twenty.

An additional allowance must be made for general circulation as well as for safety. This will be affected by the way equipment is laid out. Special considerations are noted in each space table and must be used in computing the requirements of each facility.

In each of the cluster-space tables, three basic space requirements are specified: station allowances, station circulation burden allowances, and general laboratory circulation allowances. These three types of spaces are shown in Figure 5 and are interpreted as follows:

Station Allowances: Space for the basic machine, teaching system, or workbench and the *immediate* space requirement for the student, plus (where appropriate) a minimum safety clearance. Where front and rear of front-rear-and-side access is needed the space allowance includes all related space. Usually this comes to about three feet of clearance for the student. The area defined by this value should be regarded by the architect as a building block of fixed size and shape.

Station Circulation Burden: A general circulation allowance *within that area of the laboratory containing the stations referenced.* Where safety is an obvious problem, as in the machine shop, this figure is based on a 3-ft aisle around all stations in their most common configuration. This figure is only an approximation of the ratio of general to station space in many laboratories studied and it should be considered in the light of a specific design plan.

General Circulation: A space allowance between major sub areas of the laboratory and/or an allowance for general support facilities such as a demonstration desk. Comments in the "Remarks" column have been provided where there seems to be any ambiguity. The use of these tables to compute total laboratory space requirements is shown in the following simplified example.

Manufacturing Process Laboratory: Twenty-student laboratory for machining and plastics processing (see Table 7).

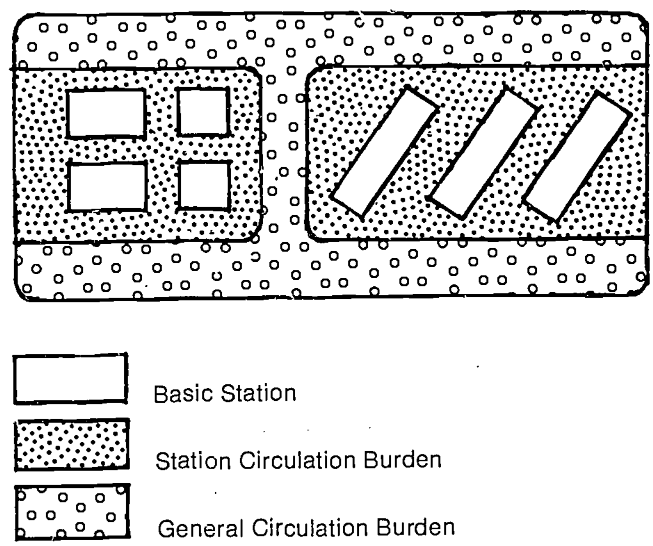


Figure 5
Pictorial representation of the three major space types defined in Tables 1 through 10.

Station		No.	Area*
Machine Shop	— Lathes	4	600
	Millers	2	200
	Grinders	2	200
	EDM	1	100
	Boring mach.	1	150
	Punch press	1	100
	Drill press	2	150
	Benches	5	300
Plastics	— Extruder	1	120
	Molder	1	120
	Vacuum former	1	50
	General plastics	—	500
General Circulation		(25%)	640
Examining Room	— Mounting		50
	Sample preparation		50
	Testing		250
Storage	— Tool		200
	Stock (metal/plastic)		300
	Stock processing		250
TOTAL			4330

uding circulation burden.

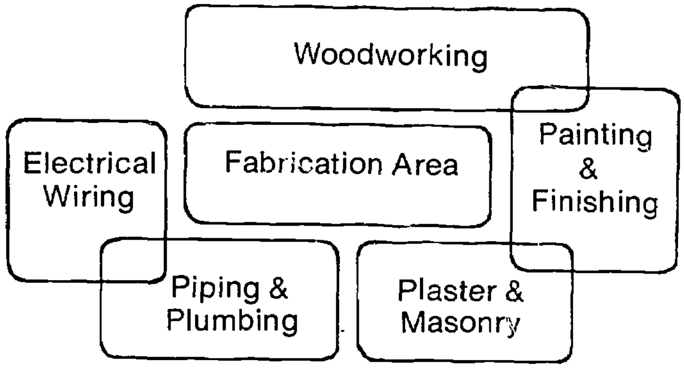


Figure 6
Example of an integrated building trades cluster.

Building Trades

Major Skill Families and Laboratory Types:

Carpentry
Construction
Piping/Plumbing
Plastering/Masonry
Flooring
Electrical Wiring
Painting and Finishing
Building Maintenance

The Building Trades cluster represents at once the most flexible and the most restrictive of the occupational education clusters. Because the career programs of this cluster are all ultimately drawn together in a common occupational setting, this cluster would appear to be a natural candidate for development as a broad career ladder program. Unfortunately, however, the craft unions — through their strict controls on the training they will accept toward apprenticeship credit and their failure to provide for parallel career development in more than one trade — have straightjacketed the learning process, preventing the development of an integrated Building Trades laboratory. However, because of commonalities in the physical learning environment there remain many opportunities for space saving through shared space.

Each of the Building Trades training programs may be viewed as a two-step learning process consisting of introductory theory or "bench-scale" study intended to develop basic skills with the tools and materials of the trade, and practical experience in a simulated real world setting in which the student begins to apply his skills. When we consider that each of the most common programs (piping/plumbing, house-wiring and construction) almost invari-ably spends a major portion of the laboratory program ...ng in or constructing frames or building sections, it ...ous that they could be shared. Unfortunately they are usually housed in separate laboratories.

Unlike most Trades and Industrial programs, in which student stations are defined by the permanence of benches and tools, the construction programs are extremely flexible and lend themselves readily to the sharing of an open loft space. There is a great gain in this practice.

The sharing of areas by many of these programs, shown schematically in Figure 6, offers two major advantages. First, there are opportunities for rotational station-sharing, and, second, students have the opportunity to gain experience in a greater variety of settings than has been feasible in the traditional laboratory.

Principal Laboratories and Laboratory Design Features

Woodworking (Carpentry-Cabinetry): In most schools the woodworking laboratory is planned either around construction carpentry or around cabinetry — a practice that exists usually because the instructor involved has a bias toward one or the other of these programs.

The woodworking laboratory can be the basis for a major spin-off model that can begin with carpentry and cabinetry and be expanded to include such programs as flooring and furniture making and, as a spin-off of furniture making, upholstery and related programs in sewing. In the opposite direction, as the program moves toward construction millwork, it functions as either a spin-off or magnet model, beginning to share its construction area with related trades such as piping and plumbing, masonry and building wiring.

The comprehensive woodworking laboratory should incorporate four primary areas: workbenches — at which both carpentry and cabinetry students will work on projects and bench-scale construction tasks; a carpentry and/or furniture project area; a building, or building section, construction area; and a general area for power tools. Additional spaces, represented in Figure 7, may be added as required.

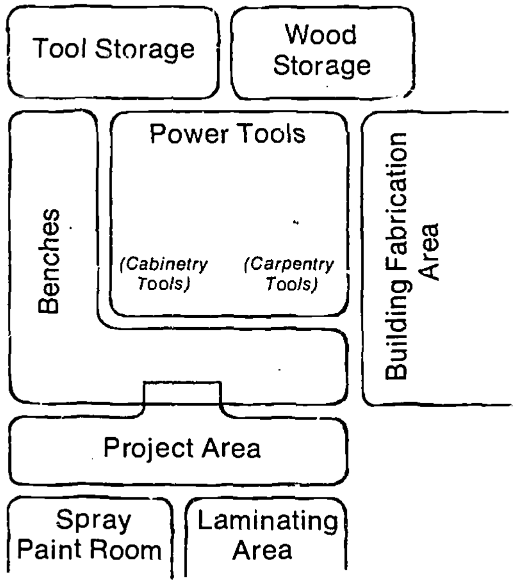


Figure 7
General relationship of program spaces in a comprehensive woodworking laboratory.

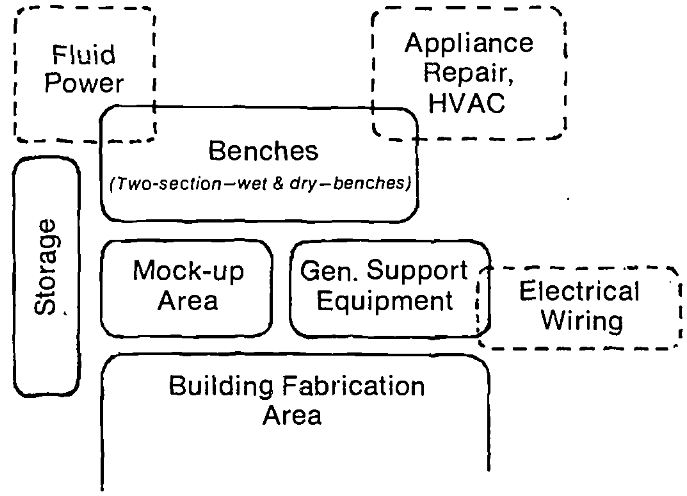


Figure 8
General relationship of program spaces in the piping & plumbing laboratory (Note the shared-station relationships — areas enclosed by dotted lines.)

Workbench stations are used primarily for developing skills in basic hand-tool manipulation, as well as small projects in cutting, fastening, and fitting of fabricated wood and plastic parts. This section of the laboratory is usually required only for cabinetry and furniture programs and has limited application to construction activities. Thus, as shown in Table 1, bench stations should be planned for every student in a cabinetry program but may be provided for a few as one fourth of the students in a construction-oriented carpentry laboratory.

At one side of the bench area, there should be an open floor area for the assembly and temporary storage of cabinetry, furniture and similar projects. This area should include, or be adjacent to, a spray-painting and drying room in which cabinetry can be finished and allowed to dry in a dustfree atmosphere.[3]

The power-machinery area will be required only to support the work of the student. Thus the size of this area, and the machinery selected, is based on the nature and scope of the program and is largely independent of the number of students in the class. For instance, a general or multipurpose laboratory may include multiple lathes, a band saw, jigsaw, jointer, drill press, thickness planer, panel saw, swing-arm saw and universal table saw. On the other hand, a laboratory with a carpentry-or furniture-making bias may place greater emphasis on lathes, jigsaws, band saws and jointers and may include additional specialty items such as a tenoner, mortiser and shaper. A construction-oriented laboratory would ignore the lathes and drill presses in favor of a more "production" oriented laboratory emphasizing heavy-duty, nonprecision saws and related units. The power-machine area should be contiguous with the construction, bench and project areas of the laboratory.

Fabrication Area: The fabrication area of the Construction Trades complex, while a required area of most carpentry programs, should be a multidiscipline indoor area (and outdoor, if feasible) in which the varied activities of all construction-related trades are integrated in a mock construction-site setting.

The area will require only a large open space — preferably with direct access to the outdoors through large double doors that can accommodate a truck, which may be required to move a prefabricated structural section. The size of this area should reflect both the size of the construction element of the woodworking program and the shared-station requirements of all programs using these facilities. A limited outdoor area immediately accessible from the fabrication area may provide for experience in foundation work, both construction and concrete. This area may also be used for large mock or real construction projects. Some form of roof over the area is recommended.

Piping and Plumbing: Student stations in the piping and plumbing laboratory should be distributed approximately equally for 1) bench stations (at which students develop basic skills in pipe and tube cutting, threading, soldering or welding, and the repair or use of such things as valves and meters); 2) simulated experiences in plumbing basic household fixtures; and 3) advanced practical experience — either on-site (through work in the fabrication area) or off-site (through cooperative or related work experience programs) — in which students study specialized problems such as pipe installations for compressed air, steam or flammable gases, drainage and sewage disposal and electrical conduiting.[4] (Figure 8)

Basic student stations in this laboratory are two-section workbenches which should be constructed so that one area may be used for wet (drained) operations (such as pressure testing) and another for dry activities (such as soldering).

If a painting and finishing program is planned, the painting room should be shared by both programs. In a comprehensive laboratory program this space may be part of the building area or planned as a separate space.

4. Plumbers work basically with systems which carry liquids. Pipefitters may work with electrical conduits, gas lines, or other applications that require knowledge of a different set of codes. The differences between these programs are reflected in curricular, rather than facility requirements.

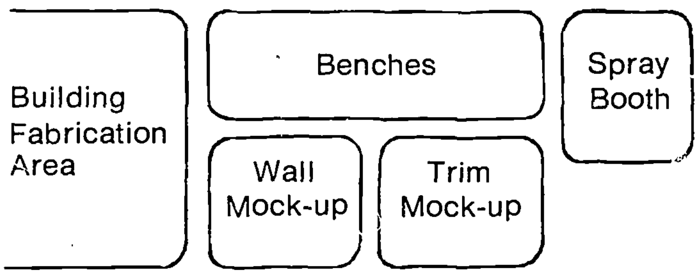


Figure 9
General relationship of program spaces in painting and finishing laboratory.

The "simulated experience" area (if it is not included in the fabrication area) should have wall and flooring mock-ups of several types (concrete block, wood frame, etc.) at which students will be able to mount and test a variety of (predominantly home) fixtures. Separate mock-ups for bathrooms (sink, toilet, tub, shower) and kitchens (sink with and without disposal unit, dishwasher, etc.) should be planned. Gas-fired waterheaters and furnaces for hot-water heating systems should also be planned for advanced study by pipefitters and plumbers. (These systems may, however, be shared with a heating and refrigeration area if such a program is planned or can be developed as a spin-off.) In addition, one portion of the piping/plumbing laboratory must be set aside for machinery such as power hacksaws, pipethreaders and pipe and conduit benders and should include one station for oxyacetylene welding. Basic welding skills should be taught in the welding laboratory. This station is intended only for operational welding activities. In an open-space laboratory the conduit-bending equipment should be located so as to be shared by the house-wiring students in the electrical program.

Painting and Finishing: This laboratory will usually be planned as an open-space facility incorporating separate areas for 1) workbench activities (for a general introduction to paint mixing and blending, etc.); 2) a series of wall mock-ups on which students will learn to paint and finish a variety of different surfaces; 3) an area containing window and door frame sections at which students will learn the skill of trim and finish painting, and 4) a spray painting booth or room.

The mock-up area of this shop will normally be composed of a series of free-standing wall sections of about 100 sq ft (set vertically) each. These mock-ups should include walls of concrete block, finished wood, unfinished wood, plaster and plasterboard. Students learn to paint on each of these surfaces and will then learn how to remove finishes such as old paint and wallpaper with torches. These wall can also be used to teach wallpaper hanging and panel installation. The window-frame section of this laboratory may also be used to teach glazing and related glass cutting skills — in which case the appropriate benches and tables must be provided. (Figure 9)

There should also be a separate spray-painting room (which may be shared with the cabinetry program of the woodworking laboratory) if required by the curriculum.

Basic Electricity and Building Wiring Laboratory: This laboratory should be planned to provide training in the understanding of basic electrical wiring skills and principles as they apply to both building wiring (for conduits, junction boxes, switches, etc.) and industrial applications (switching gear, transformers, high voltage transmission). This facility should be a general exploratory laboratory for all electrical programs. Advanced skill development areas in such programs as industrial electricity, motor/generator repair and electromechanics may then be provided in specialized areas. Thus the location of this laboratory in the building is determined by its role in the Building Trades cluster and by its role as an integral support for several advanced electricity-related career areas. (Facility requirements are discussed in the "Electricity and Electromechanics Cluster".)

Plastering/Masonry and Related Skills: Programs in masonry require no specific laboratory facilities, but may be developed in any general-trade laboratory area. They are particularly appropriate for inclusion in the Building Trades fabrication area. The availability of an adjacent outdoor area is desirable.

Plastering programs require basic wall and/or ceiling frames on which students learn finishing and repairs. Since such a program requires some new wall sections for each class, it should share (on a rotational basis) either the painting and finishing laboratory wall sections or the Construction Trades fabrication area. If such a program is to be developed in an independent laboratory, it should be based principally on wall sections similar to those in the painting and finishing laboratory.

Table 1 — Space Requirements for the Building Trades Cluster

Laboratory	Station	Unit Area	Stations per Unit Area	Circulation Burden	Allocation of Total Class Stations	Remarks
Woodworking	General Benches	11 x 11	1-4	40-60%	(Note a)	Standard four-station (each side) woodworking benches. (6 x 7 for two-station general workbenches)
	Machine Area	7 x 9 to 12 x 15	-	-	-	Choice of type and number of machines vary greatly with the objectives of the program. A "general" laboratory should be approx. 1200 sq ft.
	Project Area	40-60	1	-	(Note b)	Area requirements depend on program. Storage space should be approx. 25-35% of project area.
	Lamination Room	250+	1-4	-	-	Relates primarily to cabinetry and furniture-making areas.
	Spray-Painting Room	250±	1-4	-	-	Should be shared with Painting and Finishing area. Allowance must be made for project drying in a "clean" atmosphere.
	Building Fabrication	1000 (basic)	-	-	(Note c)	Plus 20-30 sq ft per student "assigned" to this area; 16-20 ft. ceiling is recommended.
	Gen'l Circulation	(20-30% of bench area)		-	-	
	Storage (Tools-Wood)	300 + 10 sq ft/student		-	-	Separate storage area for lumber and tools.
Piping/Plumbing	Plumbing Benches	6 x 6	1	50%	75-100%	"Wet" benches.
	Gen'l Fixture Area	500 +	5-10	-	25%	
	Building Mock-up	500 +	-	-	25%	Should be provided in Building Trades Fabrication Area if possible.
	Gen'l Circulation.	(25-50% of total)		-		Should include an allowance for a power hacksaw, power pipe threader, welding station(s), conduit bender, etc.
	Storage/Tools	150 + 5 sqft/student		-		Rack storage for pipe and bin storage for fixtures. A separate storage room for tools and general supplies.
Wiring	(See "General Electricity and Wiring" in the Electricity and Electromechanics Cluster.)					
Painting/Finishing	Gen'l Benches	6 x 6	1-2	50%	50%	Standard two-station (side by side) workbenches.
	Wall Mock-ups	10 x 12	2-4	40%	50%	
	Trim Mock-ups	6 x 6	1	50%	50%	
	Spray Painting Rm.	300 +	1-4	-		Should be shared with cabinetry project area of woodworking program.
	Spray Booths	4 x 7 to 15 x 15	1-4	-		May be used in lieu of separate room.
	Gen'l Circulation	(20% of total except spray paint rm.)				
	Storage	(10% of total)	-	-		
Masonry, etc.	Gen'l Masonry	125-150	1	-	100%	General open-space laboratory undefined by specific stations but providing for cement mixers, benches for brick cutters (adjacent outdoor area desirable).
	Wall Mock-ups	7 x 7	1-2	50%	(Included above)	
	Storage	300 +	-	-		
RELATED AREAS						
Upholstery (relates to furniture making)	Gen'l Benches	7 x 9	1-2	50%	50%	Standard two-station (opposite sides) workbench.
	Upholstering Machines	4 x 6 to 6 x 8	1	100%	75%	Laboratory should include at least: Fiber pickers, cushion fillers, button machines, and sewing machines.
	Storage	200 + 2-5 sqft/student		-		
	Gen'l Machine Area	400	-	-	25%	Drill presses, scroll saws, etc.; should be shared with woodworking laboratory.

Notes: a - 100% in cabinetry laboratory; 75% in general laboratory; 25-40% in construction laboratory.
b - Provide for 40% of students in cabinetry program; 20% in general construction laboratory.
c - 25% in general laboratory; 75% in construction laboratory.

Business, Office Occupations, Merchandising Cluster

Major Skill Families and Laboratory Types:

- *Stenography (including shorthand and court/conference stenography)*
- *Typing*
- *Accounting*
- *Business Machines*
- *Merchandising*
- *Data Processing*
- *Switchboard Operating*
- *Mail Room-Mail Clerk*
- *Tickertape/Teletype Operating*
- *Banking*
- *Retail Sales*
- *Stock/Bond Transfer*

The world of business extends far beyond the typewriter and file cabinet, and the career ladder in business-related subjects offers more options to the qualifying student than any other program. Yet we continue to think of secondary-school business education only in terms of secretarial training and distributive education. Even post-secondary programs at the community-and junior-college levels fail to meet these career needs because they emphasize the "desk jobs" (real estate and insurance sales and the like) and ignore many basic career areas.

The planning of facilities and courses in business and office skills (accounting, stenography, typing) should be based on the fact that these are major elements of programs in the trade and industrial education programs, as well as being worthwhile programs in their own right. The planning of facilities for business education should reflect not only the typing, stenographic and accounting needs of the business students but also the demand placed on these facilities by other business-related programs (court and conference stenography, medical secretarial training, etc.), and the need for students from programs as diverse as brickmasonry and textile manufacturing to learn typing and bookkeeping as part of a broad concept of career preparation.

Business education is now undergoing major changes with respect to the nature and scope of the curriculum. While, for the most part, business education laboratories do not lend themselves to the kind of space and station-sharing discussed previously, facilities for typing, stenography, and accounting provide the training for careers going far beyond the basic ones of clerk and typist. Not only are special laboratories such as medical records libraries and mock courtrooms becoming increasingly common, but the need for simulated experiences in office management is being met by using the school itself as the laboratory. Students handle secretarial, clerical, accounting and other school business needs in the "offices practices laboratory." Telephone and mail communications for the school offer still more opportunities for educational experiences at several levels, and many of these offer ideal training programs for the handicapped.

Still another direction being taken in business education is the development of advanced specialty programs such as stock and bond transaction management (built around the "back room" of a brokerage house) and banking, complete with tellers' windows and safe-deposit boxes.

Bookstores have been expanded and these student-operated stores are open all day and function as sales outlets for goods produced by students in the culinary arts and textile-production programs.

In short, the business world is now incorporated in the school in the form of laboratories.

Principal Laboratories and Laboratory Design Features

Typing/Stenographic Laboratory. With the exception of electrical outlets and, ideally, a closed-loop broadcast system for shorthand and transcription, this laboratory makes no unusual demands and may be developed in any classroom. Each student should have a desk with space for a typewriter, a dictaphone-transcriber or audio-source system and enough space for shorthand notes and other printed material.

Accounting (Bookkeeping) Laboratory. Like the typing/stenographic laboratory, the only special features required are electrical outlets for accounting machines. Many schools now provide accounting machines for students to use independently in doing problems assigned during a regular class. This approach saves space in the laboratory since there need no longer be room for lecture note-taking and machine practice in each room.

Office-Procedures Laboratory. This laboratory is intended primarily for the refinement of business skills. The area should be equipped like any modern office. Desks should have room for electric typewriters, dictation machines and private telephones. Advanced dictating and transcription systems as well as "memory" typewriters (for example, IBM's MT/ST system) should be available. There should be a large file area, an operating switchboard and a simulated mailroom.

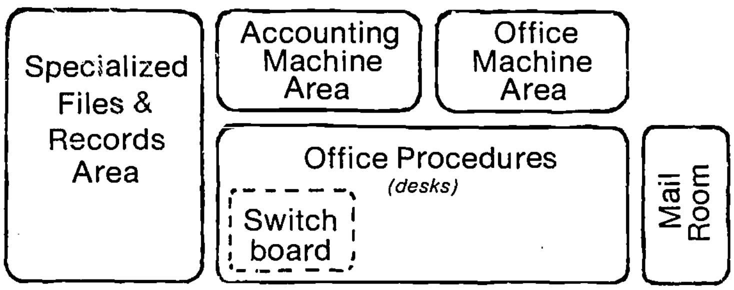


Figure 10
Suggested functional layout of a business office for advanced training.

Business-Machines Laboratory. A program in business-machine operating is rarely offered as a program in its own right. It is usually subordinate to the office practices laboratory. The following types of equipment may be considered for this area: copying machines (both dry copy and stencil), addressograph machines, franking machines and collating-and spiral-binding machines.

Business-Records Laboratory. This will be similar to the office-practices laboratory except that approximately half of the space must be devoted to files and other data storage and retrieval devices (including a computer terminal). Since some business-records libraries, particularly those of hospitals, require special types of files and other equipment, a separate place for such programs should be considered only if warranted by enrollment. It is often a good idea to plan an office suite somewhat similar to the one shown in Figure 10 as a comprehensive office procedures-accounting-office machine-business records cluster.

Data Processing. Since data processing became a recognized career in the early 1960s, the field of computer science has undergone tremendous change. Where keypunch operators and single-language programmers were once the main occupations, now only skilled computer operators and multilanguage programmers are in demand. This shift has meant less need for keypunch and related systems (card sorting, etc.) training and correspondingly greater emphasis on training for computer systems which include multiple tape and disc drives, cathode-ray tube output devices and remote terminals. Since many of the requirements (such as graphic display and remote data-processing capabilities) are common to other programs, the computer system should never be planned on the basis of data-processing career requirements alone.

The center should be developed as a cluster of related laboratory spaces for the computer, keypunches, programming, a tape-disc-and program library, possibly a remote terminal room, and any other office and storage space necessary. For the most part, the choice of computing systems determines the size of the computer room. Specific space requirements should fit each school's program and should, because computer systems are changing so rapidly, be planned with the assistance of a computer-systems specialist.

Stock Transfer Operations Laboratory. This laboratory should be equipped for mock office and "back room" operations. The office area should have standard office desks with telephone and intercom. A tickertape and, potentially, a "tote" board — both of which should be "live" systems — can be included. The "back room" needs tables, desks, extensive files and room for a lot of movement among the students.

Banking. This laboratory uses "teller" windows, including drive-in windows, a customer-service counter and work surface for each student, and an area with a bank cash register and telephone to train tellers. A counter should be maintained for the storage of records and machinery. A mock safe and safe-deposit box can be set up. (In some communities a local bank may be willing to establish a branch office in the school.)

Court/Conference Stenography. A court/conference stenography laboratory is a specialized version of the typing/stenography laboratory with the addition of recording devices used in court stenography. There is no need for a mock courtroom setting, although such an area may be considered.

Merchandising. In most schools "merchandising" is limited to the operation of a school bookstore. But sales outlets for stationery (associated with the graphics program), flowers (horticulture) and a boutique (fashion and sewing) all make for appropriate merchandising experiences and can be combined with training in the Public Services cluster.

Basic merchandising training, such as designing window and counter displays and creating advertising, should share a laboratory with programs in commercial art and design.

Table 2 — Space Requirements for the Business Cluster

Laboratory	Station	Unit Area	Stations per Unit Area	Circulation Burden	Allocation of Total Class Stations	Remarks
Typing/Stenography	Typing/Steno	3 x 5	1	100%	100%	Notes a and b.
Accounting	Calculators	3 x 5	1	100%	100%	Notes a and b.
	EAM, etc.	7 x 10	1	100%	(1)	Notes a and b.
Business Machines	Copiers, Duplicators, etc.	4 x 5 to 7 x 9	1	100%	100%	Notes a and b.
Office Procedures	Desk	6 x 7 to 7 x 10	1	100-150%	100%	Station sizes depend on the choice of desks and immediately adjacent periphery equipment. (Note a)
	Switchboard	4 x 5	1	50%	(1)	
	Mail Room	100-200	3-7	-	(1)	
Data Processing	Programming	4 x 5	1	70%	Note c	Standard classroom.
	Keypunch and Related	5 x 5	1	50%	Note c	
	Computer	-	-	-	Note c	Space requirements should be based on the specific system selected. 1200 to 1800 sq ft is usually adequate. (Additional space must be provided for an office, tape library and storage as required.)
Stock Transfer Operations	Office	6 x 7	1	75%	60%	
	"Back Room"	6 x 7	1	150%	60%	
Banking	Teller Area	4 x 7	1	150%	75%	Circulation burden applies to general "teller" and customer area.
	Office Area	6 x 7	1	100%	30%	Circulation burden includes an allowance for the safe and safe deposit box area, etc.
Merchandising	Bookstore, etc.	Varies	5-10	-	Note c	Station and space requirements should reflect an analysis of specific program objectives; however, each store should allow extensive flexibility in floor plan. 600-800 sq ft should be considered a minimum for a major merchandising laboratory.

Notes: a - Circulation burden is to be distributed to the laboratory as a whole.

b - Typing/stenography, accounting and business machines laboratories may easily be planned for as many as 40 to 50 students. For large enrollments the circulation burden may be reduced to as little as 80% of the total allocation.

c - Depends on program.

Electricity and Electromechanics

Major Skill Families and Laboratory Types:

Basic Electrical Wiring
Motor/Generator Work
Industrial Electricity
Appliance Repair
Vending-Machine Repair

Career programs in electricity and electromechanics have tended to be grouped in a single, generalized laboratory course. Today, however, the great expansion of career opportunities in both construction and industrial electricity specialties, and the growing need for mechanics in the many service industries related to motors and servomechanisms, has meant that most schools are forced to consider comprehensive programs in both areas.

While there exist many subunits into which electricity and electromechanics can be broken down, the problem of the planner is perhaps made easier if the following three-group division is adopted:

Group 1. Electrical Wiring (primarily building wiring)
Group 2. Industrial Electricity (power transmission and distribution, metering, etc.)
Group 3. Electromechanics (motor/generator; servomechanisms, etc.)

For the most part, there exists no clear dividing line between these programs and they may be viewed as a continuum of skills and specialization. Thus, from a basic laboratory in construction wiring (switches, fixtures, conduiting, junction boxes, and "house" meters and transformers) it is a small jump to the use of industrial transformers, metering panels, power supplies and switching gear. A program in basic electromechanics may begin with small-scale instruction in basic motor/generator theory and build to problems in the wiring of high voltage, multiphase industrial motor and generator installations. Basic instruction in motor theory provides the fundamental building block for education in many careers requiring knowledge of wiring and motors. This includes appliance repair (washer, dryer, vacuum cleaner, sewing machine) and advanced careers requiring these basic skills, such as office-machine maintenance. Airconditioning and refrigeration repair and furnace and ventilation system repair (all of which have motor driven fans or pumps) also demand the basic training provided in this area.

Because most of the programs that build on electromechanics are themselves "clean" laboratories, it is often reasonable to consider a shared-space laboratory in which the basic area supports a variety of related programs. Depending on program enrollment, the laboratory can be an open shop capitalizing on the shared use of specific systems (as in Figure 11), or a smaller program may be designed around the alternate use of a shared laboratory facility and storage areas (as in Figure 12). Figure 11 represents one model for an integrated electricity and electromechanics cluster. The design criteria for the subareas of this cluster are presented below.

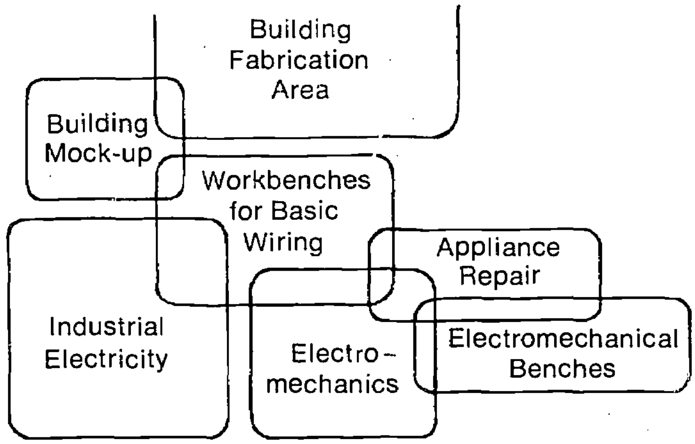


Figure 11
Example of laboratory space relationships in an integrated electricity-electromechanics cluster.

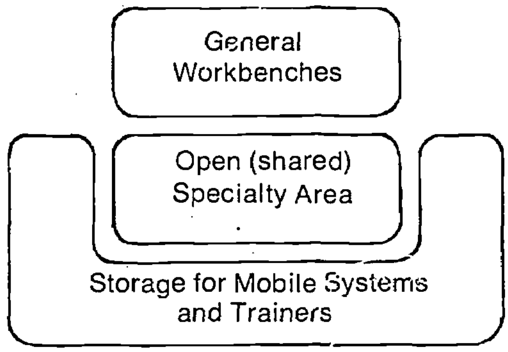


Figure 12
Facility layout for a multiprogram "rotational" laboratory in electricity and electromechanics.

Principal Laboratories and Laboratory Design Features

General Electricity and Wiring Laboratory. Three types of activity must be provided: 1) workbenches (at which students learn basic skills in soldering, wire splicing, switch and fixture wiring, basic circuit wiring, and small electric-motor wiring); 2) an industrial electricity area (in which students study advanced high voltage and multphase systems and industrial power transformers and switching gear); and 3) a mock-up building area for the development of advanced skills in building wiring. It is important to recognize in the planning of this facility that the standard shop workbenches required for heavy-duty work are not the same as those appropriate for use as electrical-power supply benches used in the classroom for this area. If this laboratory is to share services with the electromechanics program, both types of benches will probably be necessary, and in most instances must be grouped separately in the laboratory. (Figure 13)

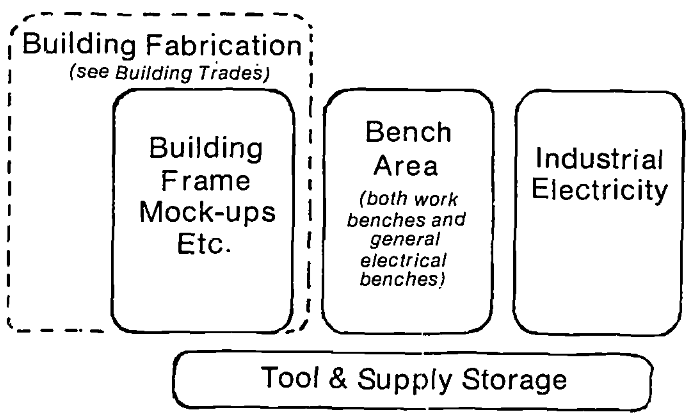


Figure 13
General relationship of program spaces in a general electricity laboratory.

The industrial electricity area is usually a flexible-use open space to accommodate a variety of large power-panel trainers (225 amp and 400 amp 3-phase), industrial metering panels and test stands for transformers. Flexibility depends on the design of the power supply and a power grid for the whole laboratory is usually necessary. Workbenches should be accessible to most stations in the laboratory.

The simulated construction-wiring area of this laboratory, if it is not to share its space and station requirements with the Building Trades fabrication area, will need a large open area containing a variety of wall, ceiling and house-section mock-ups that will be used for the installation of such components as meters, transformers, switches, fixtures, junction boxes and conduiting electrical heating units. Though not essential, it is desirable that these sections be made of a variety of materials, such as wood, concrete block and masonry. The "support" areas for this laboratory should include conduit-bending machinery and related tools. These may be shared with the piping laboratory in an open-space building laboratory.

Electromechanics Laboratory. The comprehensive electromechanics laboratory is usually planned to incorporate separate areas for benches (for the introduction of basic theory and for a variety of spin-off programs such as electromechanics assembly); a simulation area which includes a variety of "packaged" motor/generator systems (on which students are given advanced instruction in theory and begin to develop basic repair skills); and a practical area including heavy-duty workbenches and a variety of stand-mounted motors or motor/generators for students to work on. A supporting work area should provide for general machinery such as a tool grinder, drill press and armature lathe. (Figure 14)

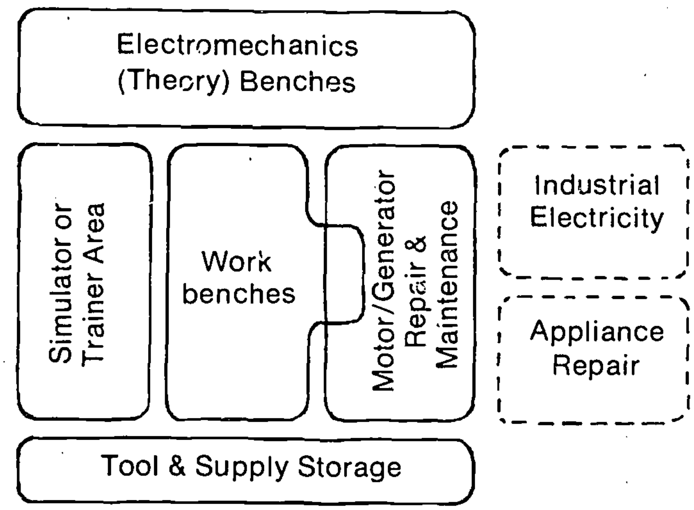


Figure 14
General relationship of spaces in motor/generator or general electromechanics laboratory.

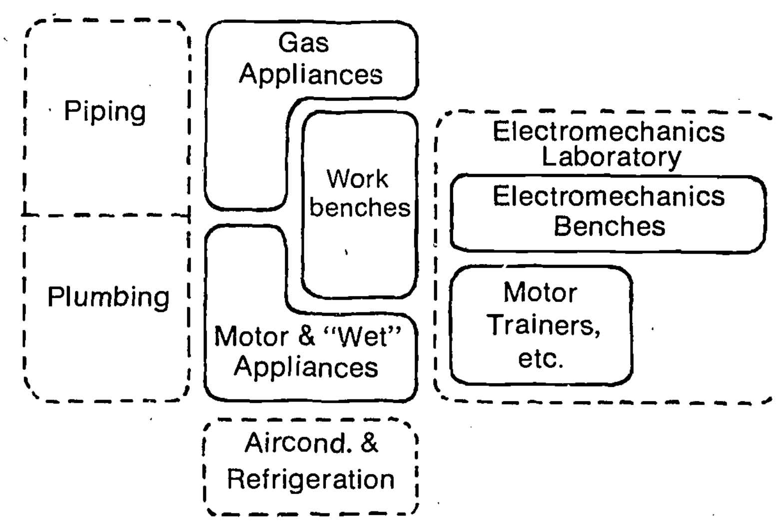


Figure 15
General relationship of spaces in an appliance and vending machine repair laboratory. Supportive teaching can be available in the piping/plumbing, electromechanics and airconditioning/refrigeration laboratories.

Appliance and Vending Machine Repair. This is essentially a large open area for washing machines, dryers, refrigerators, or vending machines. Students working in this area will also be doing motor/generator and piping and plumbing work, and these can be brought together through the open-space laboratory plan.[5] (Figure 15)

5. *Small-appliance repair, including such items as sewing machines, and small electromechanical systems repair programs, such as office machines, should use the benches provided in the electromechanics laboratory.*

Table 3 — Space Requirements for the Electricity and Electromechanics Cluster

Laboratory	Station	Unit Area	Stations per Unit Area	Circulation Burden	Allocation of Total Class Stations	Remarks
Electrical Wiring	Class Benches	9 x 9	4	25%	100%	Four-station wired electricity/electromechanics benches.
	Workbenches:					
	Wall Benches	6 x 6	1-2	50%	50%	Standard shop benches.
	Floor Benches	8 x 10	2-4	50%		
	Wiring "Carrels"	6 x 6	1-4	-	40%	Multiple carrels of different materials.
	House Frame Section	12 x 25	5-10	-	40%	
	Gen'l Circulation	(75-100% of bench area)				Includes support areas such as conduit benders (sharable with piping, etc.).
	Storage	(10-15% of total)				
Industrial Electricity	Workbenches	(See Electrical Wiring)			25%	Laboratory workbenches do not represent "assigned" student stations.
	Gen'l Industrial Elec. Systems	6+ x 6+	1-2	50%	75%	Includes high voltage transformers, metering panels, switching gear, etc.
	Industrial Elec. Test Benches	6 x 6	1-2	25%	40%	
	Gen'l Circulation	(50% of total)				
Electromechanics	Class Benches	7 x 10	1-4	25%	100%	Four-station wired electricity/electromechanics benches.
	Workbenches	5 x 6	1-2	50%	60%	
	Trainers, etc.	6 x 6	1-2	50%	60%	
	Gen'l Circulation	(25-50% of total)				Includes allowance for general support machinery.
	Storage	(10-15% of total)				
Appliance and Vending Machine Repair	Appliances	5 x 6 to 8 x 10	1-2	50%	100%	This laboratory should relate to piping/plumbing as well as to electromechanics.
	Appliance Test Consoles	4 x 5	1	-	(1)	Added to appliance area.
	Gen'l Circulation	(100-125% of total)				Includes an allowance for shared workbenches (3 x 5) in a ratio of about one for two stations.
	Storage	(5-10% of total)				

Graphics and Communication Arts

Major Skill Families and Laboratory Types:

Printing
Lithography
Photography
Bookmaking
Fashion Design
Commercial Art
Illustrating
Drafting

For the most part the programs listed above do not belong to a common family of industries or jobs. But from an educational standpoint shared laboratories provide an efficient teaching situation.

For instance, the availability of a commercial art program offers the printing student extensive opportunities to enlarge his experience by studying design and composition. Similarly, the darkroom of the printing laboratory combined with the studio facilities of the commercial art laboratory are useful to photography students. The commercial art laboratory may be used on a flexible schedule or with shared space for fashion design, merchandising displays, and interior decorating, as well as traditional studies in illustration and design. But multiple use requires careful selection of equipment and well-planned arrangement of related laboratory spaces. In general, separate areas for each program are most convenient. (Figure 16)

Principal Laboratories and Laboratory Design Features

Graphics (Printing) Laboratory. At present, there is substantial controversy over what a printing laboratory should have. Since the future of letter-press and offset printing is uncertain, it is debatable whether a laboratory should be designed for only one kind of printing. Most graphics laboratories now compromise and attempt to offer training in each.

Regardless of the decision on this question, however, the laboratory should be able to offer the total spectrum of learning experiences from typesetting to bookbinding. The fixed sequence of the actual printing process should be considered in planning the laboratory layout. Separate areas must be provided for 1) typesetting, 2) composition (layout and design), 3) offset camera and platemaking, 4) press and 5) binding operations.

Typesetting Area. While most commerical print shops now use either phototypesetting or automated typesetting systems, many of the fundamental skills of printing are best learned by the process of setting type by hand. Areas for hand and automated typesetting, flexowriters (machines for making tapes for the linotype and phototypesetting machines) and hot-type linotype are desirable.

Layout and Design Area. This area is where students lay out copy prior to initial photography (step one in making offset plate negatives) and strip and compose for offset plates. Light tables for stripping and regular tables for proofreading copy and composing and laying it out for photography are necessary.

Offset Camera and Platemaking Area. The most common type of photo-offset camera extends into a workroom through the darkroom wall. The front end of this camera does not require a light-controlled environment as this is where students set up material to be photographed. The darkroom should be big enough for up to four students to learn film loading and the use of the camera.

Offset platemaking is basically a four-step process of photographing and developing the negative of the original copy to be printed, laying out and framing (on a vacuum frame) the plate to be made, processing the plate through the plate-coating machine and final rub-up table, and finally developing the printing plate. Usually a single room provides for all these activities, plus the offset camera, but since the copy photography step is separate from the platemaking process, the camera darkroom need not necessarily be integral to this area.

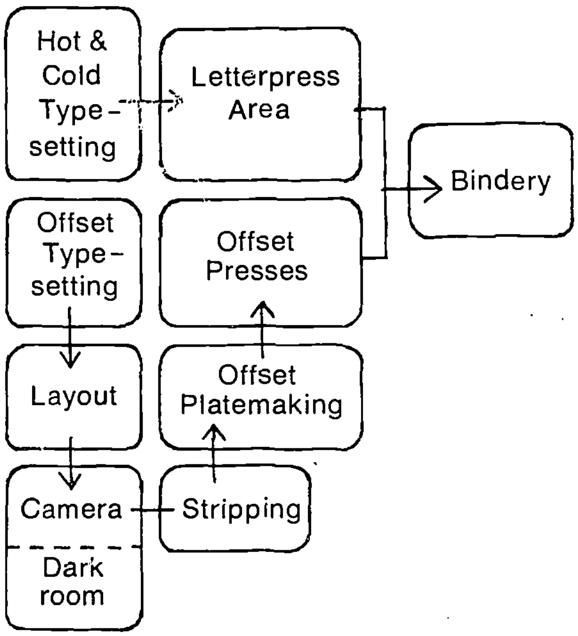


Figure 16
General relationship of spaces in a comprehensive printing laboratory (Arrows indicate flow of material in a production operation and should be reflected in the design).

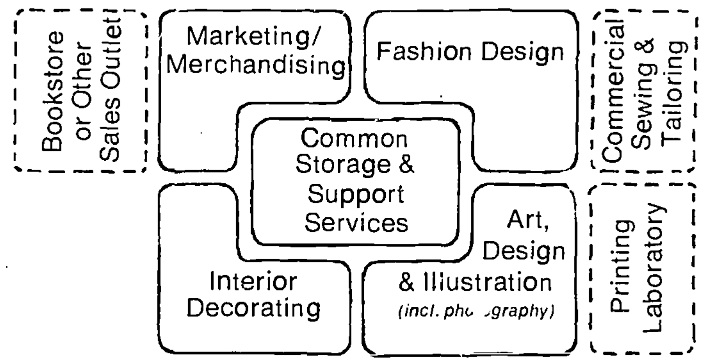


Figure 17
Hypothetical comprehensive commercial art area subdivided into specialty laboratory areas.

Printing Press Area. The press area of the graphics laboratory is defined by individual presses and related supply tables and benches. The exact size of this area depends on the size and uses of the presses chosen. Consideration must also be given to whether color processes are to be employed since this may affect the need for specialized darkroom facilities or a color stripping camera. Additional space for a power paper-cutter and general paper storage should be adjacent to both the press area and the bindery.

Bindery. The basic bindery has areas for folding, stitching, gluing, and trimming. As in the platemaking process, these operations are performed in a fixed sequence and should be so laid out. Advanced specialty book-making careers, such as those involved in leather binding and marbling, must be set up separately.

Commercial Art. In a MacLuhanesque world, commercial art is a growing area of career opportunities. Activities for which the commercial art laboratory may be the principal learning environment range from advertising design and layout, and designing window displays for marketing and merchandising to fashion design and interior decorating. The area can also double as a photography studio and a place to learn techniques of special lighting effects.

Activities in the commercial arts laboratory may be logically divided into four areas: benchwork, such as model construction; easel work, such as drawing and painting; tabletop work, for large design layouts and models, and an undefined open area to be used as the photography studio, interior design area, or general work area. Whether this facility is used as a common learning environment for textile and fashion design, interior decorating, distributive education display design or for other related programs defines the emphasis placed on individual areas and the other areas of the building to which Figure 17 should be related.

Technical Drawing. As drafting and graphics are fundamental aspects of all technical fields, students in all technically oriented programs are now expected to develop a basic competence in many phases of drafting so that they may create their own ideas and communicate them to others. The amount and kind of technical drawing required by each student is, by and large, a matter of each student's interest, aptitude, immediate program and long-range goals. A few of the many topics covered in the drafting and graphics programs and appealing to students in diverse curricula include: pictorial drawing (commercial art and design); dimensioning, threads, weld and fasteners (tool and die, machine shop); piping drawing and electrical/electronic drawing, structural drawing, architectural drawing (construction); topographic and engineering maps (civil technology); and graphs and charts (business). The technical facilities should therefore be planned to serve as both an introductory laboratory for all students to develop a basic understanding of drawing techniques in their specialties as well as a place where students can develop advanced competence as specialized draftsmen. Where the drafting program is linked to other programs (such as building construction technology) additional spaces for such activities as model construction may be desired.

Photography. The facilities of the photography cluster should serve both the graphic arts program (through provision of facilities for the photo-offset camera) and the general photography and photo-developing needs of training programs ranging from metallurgy and materials testing to police science. The area should have separate places for developing and printing black and white and color film, a separate photo print-washing and mounting area and a general photography studio

Darkroom. Three kinds of darkroom facilities will usually be required in the photography studio: one for the photo-offset camera; separate areas for film developing and color printing; and a general darkroom for black and white film printing and enlarging. All three may be included in a single darkroom or provided in separate, closely connected facilities. In either event, some provision must be made for the fact that film processing and film loading,

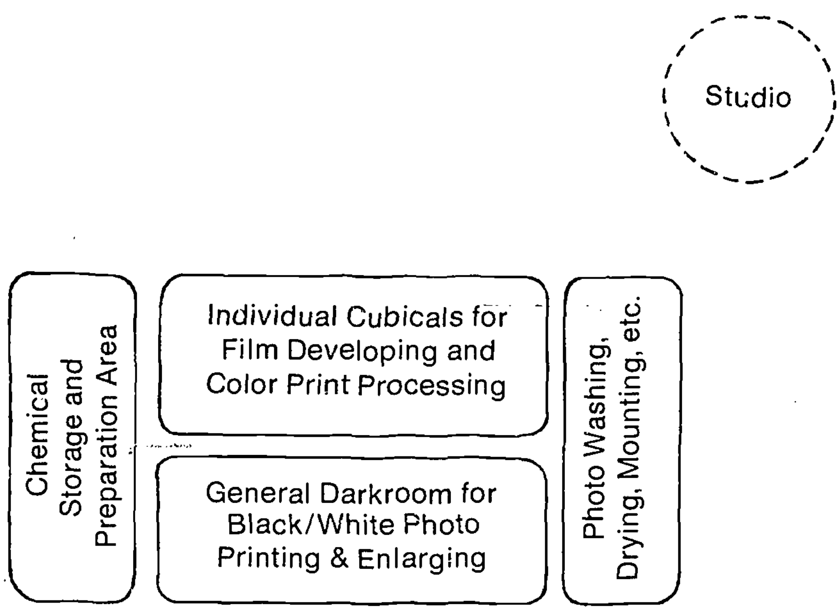


Figure 18
General relationship of spaces in a photo-processing area.

as well as color-film printing, must be done in complete darkness, while black and white film may be printed with a safelight.

Photo Washing, Drying and Mounting. Print washing, drying, and mounting should have an all-purpose room immediately adjacent to the darkroom.

Studio. A studio for the photography program may be either within a large photography complex or as an area within a related laboratory such as the commercial arts laboratory. If this is part of an extensive photography career program a specialized facility including high ceilings and flexible ceiling lighting is required.

Table 4 — Space Requirements for the Graphics and Communications Cluster

Laboratory	Station	Unit Area	Stations per Unit Area	Circulation Burden	Allocation of Total Class Stations	Remarks
Printing - Typesetting	Hand Typesetting	4 x 5	1	25%	10% +	
	Paper Tape Machine	5 x 6	1	25%	5%	
	Photo Typesetting	75-200	2-4	25%	(1)	Separate temperature and humidity controlled room may be required.
	Computer Typesetting	5 x 6	1	25%	10%	
	Linotype	7 x 10	1	10%	5%	
	Headliner	4 x 5	1	50%	(1)	
	Gen'l Circulation	(30-40% of total area)				Includes space allowance for unassigned stations such as an adman table, imposing table, proof press, etc.
- Layout and Design	Layout Tables	5 x 10	1-2	50%	10%	Standard two-station (opposite side) work tables.
	Stripping Table	5 x 6	1	50%	10%	
- Offset Camera and Plate-making	Offset Camera	250-450	2-4	-	(1)	One third to one half of this area should be provided in the darkroom.
	Darkroom	150 +	2	-	15%	Developing facilities should be provided in a darkroom or other suitably light controlled environment.
	Color Stripping Camera	14 x 18	2	-	(1)	Separate, environmentally controlled room desired.
	Platemaking-Vacuum Frame	4 x 7	1-2	50%	(1)	One station of each type is necessary and generally sufficient for even a large printing program.
	Layout Table	4 x 7	1-2	50%	(1)	
	Plate-coat. mach.	4 x 7	1-2	50%	(1)	This area should share a light controlled environment with the set-up area of the offset camera(s).
	Rub-up Table	4 x 7	1-2	50%	(1)	
	Develop. Sink	4 x 7	1-2	50%	(1)	
	Gen'l Circulation	(40-50% of total area)				
- Presses	Presses-Offset	6 x 8 to 12 x 14	1-2	50-100%	50%	
	Letterpress	6 x 8 to 12 x 18	1-2	50-100%		
	Gen'l Circulation	(50% of total area)				Includes allowance for major support spaces such as large power paper cutter, make-ready table, work tables, etc.
- Bindery	Bindery - Folding	9 x 12	1-2	25%	(1)	
	Stitching	6 x 7	1	50%	(1)	
	Gluing	7 x 8	1	50%	(1)	
	Trimming	8 x 8	1	50%	(1)	
	Gatherers	7 x 9	1	50%	(1)	
	Gen'l Circulation	(40-60% of total area)				
	Gen'l Storage (total printing)	(5-10% of total)				
Commercial Art	Benches	6 x 6	1	25%	Note a	
	Easel	4 x 6	1	25%	Note a	
	Table	6 x 6	1	25%	Note a	
	"Open"	400-700	-	-	Note a	May be used as photo "studio", merchandising display area, interior decorating area, etc.
	Storage		-	-		Storage requirements should reflect specific laboratory use and may range from 5-10% for a simple art laboratory to 50% for a rotational use laboratory shared between merchandising, interior decorating and fashion design.
	Gen'l Circulation	(50% of total exclusive of "open")				
Drafting	Basic	5 x 6	1	100%	100%	50% of circulation burden allocated to drafting area as aisle space; remainder to general laboratory.
	Advanced	6 x 8	1	100%	100%	(As above)
	Computer Graphics	5 x 6	1	-	(1)	
	Copying Room	150 + sq ft	-	-	(1)	Space allowance should provide for two types of copying machines plus storage and circulation.
Photography	Individual Cubicle	10 x 10	1-2	-	40%	Includes sink, work counter, etc. Allowance should be made for some automatic color processors and, potentially, for a motion picture film processor in one room. Light lock doors are required.
	Printing/Enlarging	4 x 6	1	-	70%	Area allowance includes prorated allowance for room circulation, sink and counter, etc. based on a facility for ten or more stations.
	Washing, Drying, etc.	250-400	-	-	(1)	This is not usually an instructional area and is, therefore, defined by equipment and not student stations.
	Chemical Storage and Prep	150-300	-	-	(1)	Space requirement varies with the size of the total program.

Notes: a - Varies with program.

Heating, Ventilation, Airconditioning and Refrigeration

Major Skill Families and Laboratory Types:

Furnace Installation and Maintenance
Refrigeration Mechanic
Airconditioner Repair and Maintenance

Career programs in heating, ventilation, airconditioning and refrigeration, that have historically been offered principally by commercial training schools, are relative newcomers to public education programs. They lend themselves to two forms of shared-space programs. Where the programs are large enough a multipurpose laboratory, as in Figure 19 is logical. Where this is not necessary, the program may be more limited, sharing existing laboratories in piping/plumbing and electromechanics.

Major Laboratory Design Considerations

Heating, Refrigeration, Airconditioning Laboratory

The heating, refrigeration and airconditioning laboratory should be integrated so that installation, assembly and maintenance of building heating and airconditioning systems (for both homes and businesses) and the repair of large and small refrigeration systems are in one place. There are usually three general areas: 1) bench stations in an introductory lecture/demonstration area; 2) basic heating, cooling and refrigeration systems and trainers; and 3) operating refrigeration systems and heating plants.

While large-scale refrigeration systems and the furnace area are semi-permanent installations, the mobility of the furnace and refrigeration trainer systems makes them appropriate for space sharing with related programs or for planning rotational use, perhaps on a semester basis, as a heating and cooling system training area.

Instructional benches should be the same as those used in the electromechanics theory laboratory. While these stations are not the same as those used as workbenches in the laboratory they are usually integrated with it to be convenient for regular use by students needing to test components. As shown in Figure 19, both these stations and the advanced areas of the total laboratory lend themselves to sharing with a variety of programs such as electromechanics (compressor and fan repair), piping and plumbing (water-cooled industrial compressors, hot-water heating systems, etc.), and sheet metal (ducting construction, etc.).

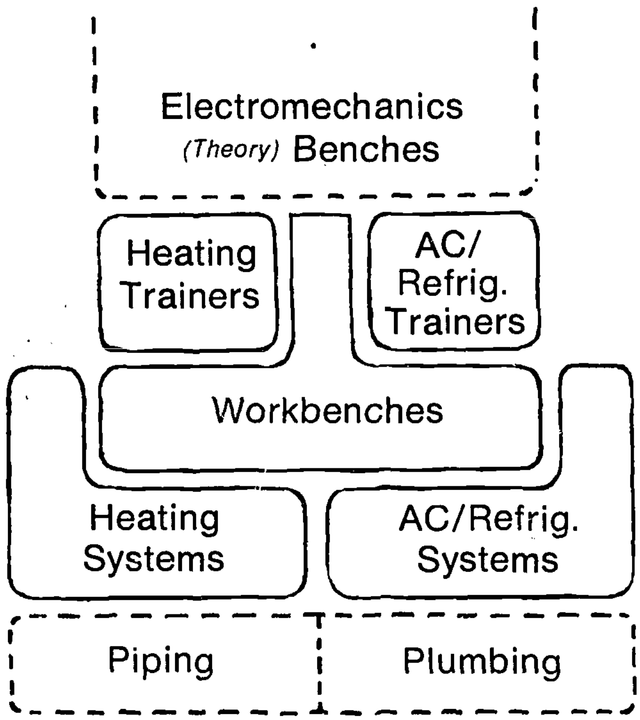


Figure 19
General relationship of spaces in an HVAC laboratory showing space and program relationships with major associated programs.

Table 5 — Space Requirements for the Heating, Ventilating and Airconditioning Cluster

Laboratory	Station	Unit Area	Stations per Unit Area	Circulation Burden	Allocation of Total Class Stations	Remarks
Airconditioning and Refrigeration	Electromechanics Benches[a]	9 x 9	1-4	25-50%	100%	Benches in the lecture-demonstration area should be "wired" benches of the type used in electromechanics. Circulation burden includes allowance for a refrigeration system demonstrator and related equipment.
	Workbenches:					
	Wall Benches	6 x 6	1-2	50%	Note b	
	Floor Benches	8 x 10	1-4	50%	Note b	
	Simulators and Trainers	6 x 8 to 8 x 10	1-2	50-100%	50-75%	Provides for a variety of stations ranging from simple refrigeration cycle systems to advanced refrigeration mock-ups.
	Appliance Area	-	-	-	-	See appliance repair in Electricity and Electromechanics Cluster.
	Cold Storage Lockers	15 x 15	1-4	50%	10-15%	
	Industrial Refrigeration and Airconditioning	12 x 12 up	1-4	100%	25-40%	Large residential or industrial building cooling system. May be forced air or chilled water system. Both electric and gas systems should be represented.
	Gen'l Circulation	(25-40% of total laboratory)				
	Tool & Supplies Storage	(5 sq ft/student)				
Heating	Electromechanics Benches (a)	9 x 9	1-4	25-50%	100%	Benches in the lecture-demonstration area should be "wired" benches of the type used in electromechanics. Circulation burden includes allowance for a heating system demonstrator and related equipment.
	Workbenches:					
	Wall Benches	6 x 6	1-2	50%	Note b	
	Floor Benches	8 x 10	1-4	50%	Note b	
	Home Furnaces	6 x 8 to 8 x 12	1-2	50%	25-50%	Both gas- and oil-fired furnaces in combination with hot water and forced air heating systems should be represented.
	Industrial Heating Plant	200-300 sq ft	4-6	50%	(1)	
	Climate Control Trainers	5 x 7 to 10 x 15	2-6	50%	50%	
	Water Heater	6 x 7	1-2	100%	10%	
	Electric Baseboard Heat	-	-	-	-	See Electricity and Electromechanics Cluster
	Gen'l Circulation	(25-40% of laboratory total)				
	Tool & Supplies Storage	(5 sq ft/student)				

Notes: a - Not included in laboratory total for purposes of circulation computation.

b - Laboratory workbenches do not represent "assigned" student stations.

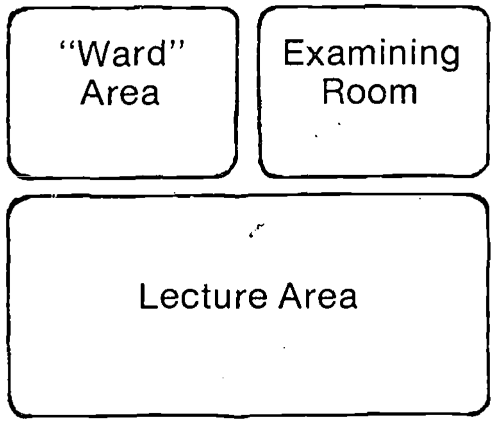


Figure 20
Typical multipurpose medical lecture-laboratory in a secondary school program.

Medical – Dental

Major Skill Families and Laboratory Types:

Medical Lab Technician
Nursing (LPN, RN, etc.)
Medical Office Assistant
Operating Room Assistant
X-Ray Technology
Dental Assistant
Dental Hygienist
Dental Lab Technician

In most career education programs, instruction at the secondary and at the post-secondary levels provides essentially the same laboratory program augmented by different levels of theoretical and academic work. The major exception to this rule is in medical, dental and other health-related occupations. Although health professions certification and occupational preparation requirements are rapidly changing (particularly with respect to lowered age requirements for some programs and restructuring the distribution of hours of instruction in the classroom and in the laboratory and clinical setting), the fixed certification requirements which now exist in most states usually restrict the opportunities to develop broad-based instructional programs at the secondary level. The following topics will consider separately the requirements of secondary and post-secondary programs.

Secondary Health Careers

Even without the opportunity for hospital or other clinical experience, there exist many kinds of worthwhile occupational education in health-related professions at the secondary-school level. Careers as hospital or home health aides, medical or dental office assistants, orderlies, and medical and dental laboratory assistants are (in most states) unlicensed careers open to the trained high school graduate. Further, the facilities required are simple and school laboratories for such programs do not usually represent a major investment.

Medical. Most medical programs at the secondary level are based on simulating either a ward room or a medical office examining room. Since both of these should be set up, and since neither requires unusual facilities, it is common for both to share a common facility with a general lecture area (as shown in Figure 20). The level of instruction at the secondary-school level does not (except in very large schools) justify separate teaching stations.

Multipurpose "Ward" Laboratory. A multipurpose medical demonstration ward should be used for lectures and practice of bedside treatment. Here nursing and nursing aide, geriatric and psychiatric aide, home health assistant and orderly training programs and patient handling techniques, including the use of wheelchairs and stretchers, are taught.

The "ward" only needs hospital beds as furniture, at least one of which should be fully equipped for demonstration of traction. Each bed should be furnished authentically and must allow sufficient space for the movement of stretchers or wheelchairs. A single "ward" does not normally need more than six beds for a class of twenty students.

Medical Office-Examining Room. The "examining room" area of a secondary-level program is usually a limited-use specialized facility in which students work in small groups to learn medical assisting and examination-room procedures. Each room should include one adjustable examination table with all auxiliary equipment and adequate space around it for students and instrument carts. For large classes more than one room, rather than an enlarged single area, is recommended.

Dental. Secondary-level dental programs are also based on a combination of lecture and practice, and again one space can serve both functions (as in Figure 21). Where medical and dental program enrollments are small (suggesting, perhaps, half-day programs) Figures 20 and 21 can be combined. The facility should be kept flexible, however, by allowing for subdivision of the general lecture space as shown in Figure 22.

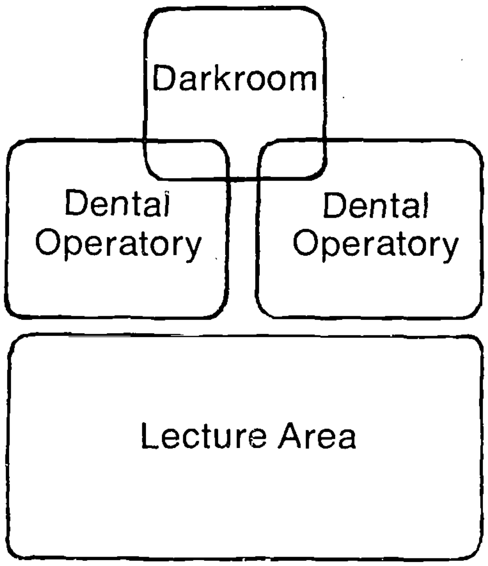


Figure 21
Typical dental office assisting laboratory.

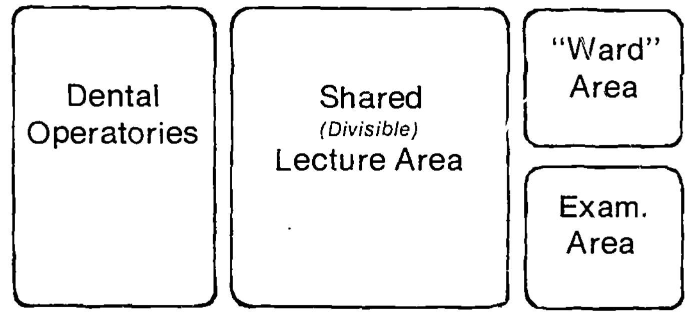


Figure 22
Multipurpose medical-dental set-up for secondary-school program.

Dental Assisting. The dental-assistant and dental-hygienist programs are usually combined in a multipurpose dental office laboratory in which students learn the basics of dental record keeping and efficient methods of dental assistance.

Laboratories designed for dental assistance should be planned around a fully operational dental set-up. In a facility combining lecture-demonstration and laboratory work one of the operatories should be a demonstration station. (A closed-circuit television system should be considered for this purpose.) One of the dental chairs should also be equipped for dental X-rays.[5]

Medical and Dental Technology Laboratories. The dental technology laboratory should provide a standard science laboratory. Each lab station should have combustible gas, compressed air, water and electricity.

Separate countertop work areas around the outside of the dental lab must be provided for plaster molding, casting, grinding and polishing. These stations are not "assigned." The size of this area depends on the scope of the program and not on the number of students in the laboratory.

Medical Technology Laboratory. The medical technology laboratory is usually intended to prepare students to perform a broad range of medical analysis tests and examinations (such as blood and urine analyses, serologies and smear examinations) and to become familiar with the operation of medical instruments and automatic diagnostic systems.

Similar to the dental lab, the medical technology lab must also be equipped with special apparatus. Additional space is needed for refrigerators, centrifuges, incubators and animal cages. These should be grouped on a counter surface convenient to the general laboratory work stations. At least one fumehooded work station should be provided.

5. This may require lead-lined walls and a lead-glass observation window. Consult state safety requirements. This room should have easy access to a darkroom in the medical sciences cluster. Each area should be a separate cubicle to create a feeling of privacy.

Post-Secondary Health Careers

Unlike secondary-level programs, post-secondary programs should offer a full curriculum in all of the programs. However, it is often overlooked in planning that up to half the students' time is spent in off-site clinical experience (required by law in most states). The result is that many facilities stand empty a significant amount of the time. This problem can be overcome by extending Figure 22 into a total medical cluster, such as that shown in Figure 23, which provides specialized laboratories around a shared class area.

Nursing. Facility requirements are similar to ward and examining rooms in the secondary programs.

Operating Room. An operating room is a limited-use facility in which students work in small groups (of operating room technicians, inhalation therapists, and nurses, for example) to learn general operating-room procedures.

This laboratory should include one operating table with all auxiliary equipment (i.e., surgical lights, inhalation gas system, etc.) and room for tools, tool trays, sponge racks and other necessary equipment. There is no need for sterile control, ventilation, or other hospital operating room controls since the set-up is merely to teach students about the general environment. A "scrub area" should be equipped with a surgical scrub sink and glove dispenser.

Occupational and Physical Therapy. Normally this combines the requirements of both programs in a single shared-space laboratory. The physical therapy part of this laboratory must be planned on the basis of the specific curriculum requirements. It should be equipped with such items as wall pulleys, mechanical lifts, step and ramp areas and parallel bars. Low exercise tables may also be required. A central open space should be available for the use of walkers and wheelchairs.

The occupational therapy area should be equipped with workbenches and tables at which students learn to help patients redevelop manual skills and to use artificial limbs in various occupations.

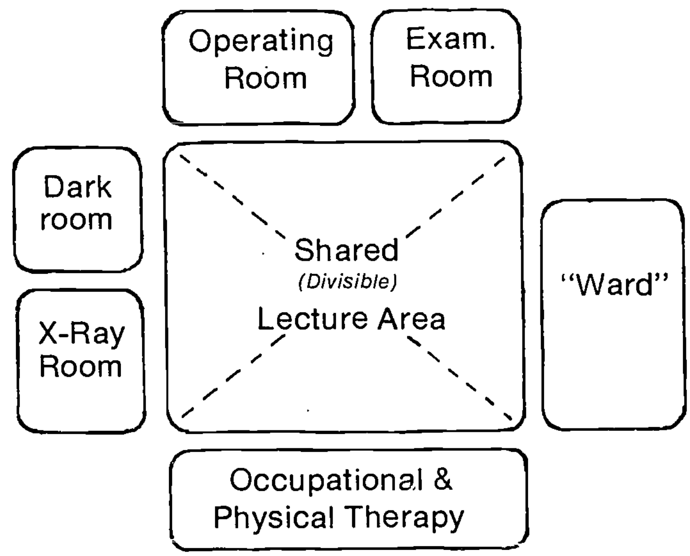


Figure 23
Flexible multipurpose medical layout for a post-secondary school program.

Whirlpool or other aquatic therapy training facilities are usually not provided at the school as this is available in clinical work.

X-Ray Laboratory. An X-Ray laboratory should include a standard radiographic fluoroscope, a horizontal X-ray table, and several X-ray viewing screens. There should be space on both sides of the unit for students to watch patient set-up procedures. The lead-shielded control panel must be sufficient for both students and instructor. Lead shielding of walls may be required to comply with state medical safety standards.

Dental Assistant Program. The facilities are similar to the secondary-school program.

Dental Hygiene. The materials and layout need not duplicate the dental office setting but may, instead, simply include a dental chair and circulation space around the chair. Note, however, that this is a practice laboratory, not simply a demonstration station as in the dental-assistance program. There must be at least one chair for every two students.

Table 6 — Space Requirements for the Medical-Dental Cluster

Laboratory	Station	Unit Area	Stations per Unit Area	Circulation Burden	Allocation of Total Class Stations	Remarks
Medical	Ward Beds[a]	8 x 10	2-4	60%	Note c	Maximum of six to eight beds.
	Examining Room[a]	15 x 15	4-6	-	(1)	Usually planned as an alcove off, or sub-area of, the classroom.
	Operating Room[a]	15 x 15	10	-	(1)	Principally a Demonstration Facility - usually planned as an alcove off, or sub-area of, classroom.
	X-ray Room[a]	15 x 15	10	-	(1)	Principally a Demonstration Facility - usually planned as an alcove off, or sub-area of, classroom.
	Darkroom[a]	10 x 10	4-6	-	(1)	Should provide equipment for both automatic and manual X-ray processing.
	Occupational and Physical Therapy[a]	-	-	-	Note c	Space requirements defined by scope of program; approx. 100-140 sq ft/student.
	Med. Tech. Lab[a, b]	4 x 5	1	150%+	100%	
	Med. Records Library	(See Business Records Laboratory)			-	
	Classroom	(Approximately 25-30 sq ft per station inclusive)			100%	Required as a support area for ward, examining, operating and X-ray areas.
Dental	Dental Operating[a]	12 x 12	1-2	-	Note c	Unit area represents an alcove or similar space including allowance for all related counter space, etc.
	Hygienics Chair[a]	7 x 7	1-2	150%	50%	General circulation allowance represents room burden including common counter space, support storage, etc.
	Dental Tech. Lab[a, b]	4 x 5	1	150%+	100%	Circulation burden includes allowance for general counter support systems using a 30" counter around the room.
	Classroom	(Approximately 25-30 sq ft per station inclusive)			100%	Required as a support area for dental operatories and hygienics areas.
	Demonstration Chair	9 x 9	-	-	(1)	Demonstration chair assumed to be in classroom; no special circulation allowance is required.

Notes: a - Liberal cabinet storage allowance should be made in each laboratory.
b - Storage rooms should be planned at 10-20% of the laboratory total.
c - Depends on requirements of program.

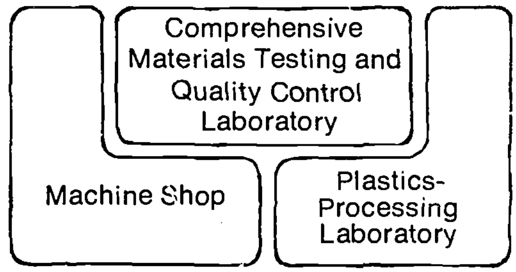


Figure 24
Basic spaces in a general manufacturing laboratory.

Metals and Materials Fabrication Processes

Major Skill Families and Laboratory Types:

- *Welding*
- *Machine Tool*
- *Sheet Metal*
- *Plastics*
- *Materials Testing (Quality Control)*
- *Manufacturing Processes*
- *Heat Treating*
- *Foundry*

Educational programs in metals and materials fabrication processes have undergone a number of major changes and these have brought about a significant restructuring of programs. Part of this change is due to the growth of plastics and related processing technologies as a major form of manufacturing. Another change stems from increased mechanization in manufacturing processes and the associated decline in the number of jobs. Still another factor is the growing importance of careers in materials technology and quality control. The result of these changes has been a trend toward consolidation of programs through restructuring of curricula, facilities, or both. Consolidation has been possible by collapsing programs and it has been encouraged by the drastically reduced opportunities in many metal-related trades that have forced schools either to consolidate or discontinue many programs. Common approaches to consolidation are exemplified in the following programs:

Manufacturing Process: This laboratory usually reflects a program which responds to the needs of a broad-based machine-oriented industry and generally combines experiences in machine tool processes (lathes, millers) with plastic manufacturing processes (blow molding, extrusion). The tool program is usually augmented by broad experience opportunities in materials testing and quality control practices. In an automated society the student must know how to *operate* a variety of machines (rather than developing a high level of craftsmanship on one machine type) in order to have increased career mobility. The emphasis of the facility and equipment plan is therefore on automated systems, and instruction is concerned primarily with machine set-up and operation rather than on developing skill in manual operations. (Figure 24)

Metals and Machine Trades: This is a consolidated metals program, usually combining facilities to teach skills in welding, machine-tool operation and sheet metal. While such a program may include advanced specialization in any of the three metal processing skills, the combined planning of facilities for metal-processing programs offers many advantages in terms of individual program flexibility and opportunities for space sharing that would not be found in traditionally defined separate programs and facilities. Such a combined facility also reflects the relation of metals-processing skills to other programs and may be used to support them rather than as a self-contained program. (Figure 25)

Metals Processing: This is a somewhat broader interpretation of the "metals and machine trades" program in that it includes activities such as metallurgy, heat treating, sample preparation, materials testing (precision measurement, quality control) and potentially even foundry operations under the general umbrella of metals processing. In some cases, these programs may even be offered in the absence of the more "product-oriented" experiences such as welding and machine shop work.

While superficially very similar, these programs are different in the materials they require. For instance, the type of lathes required in a general manufacturing laboratory (where the objective may be to teach only basic skills

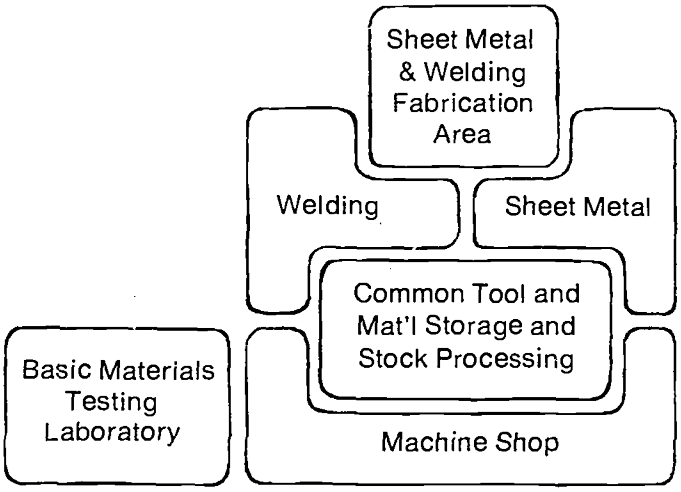


Figure 25
General program space requirements in a metals and machine trades cluster.

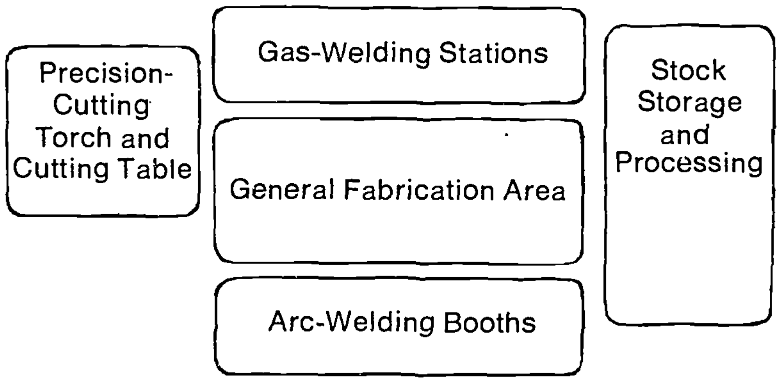


Figure 26
General relationship of program spaces in a typical welding laboratory.

of lathe operation) may be significantly different from those in a full machine shop where it is important to teach the principles of lathe operation all the way from hand operations through numerical control systems. These differences are reflected in both the numbers and size of the systems, and in the physical relationships of the systems to one another.

Combination laboratories also offer an opportunity for significant space reductions by providing for the sharing of stock storage and preprocessing machine (e.g., power hacksaws) areas. While separate single program laboratories may be warranted in some schools, the general trend is toward a clustering of programs according to either the "manufacturing processes" or "metals and machine trades" models.

Principal Laboratories and Laboratory Design Features

Machine Shop. The general machine shop should be equipped with lathes (in multiple sizes and accounting for approximately forty percent of the laboratory stations), presses, grinders, and milling machines (in roughly equal numbers) and at least one boring and one electronic discharge machine. Very advanced laboratories will soon begin including ultrasonic and pulsed laser machinery for which provisions should be made in initial planning. At least one of each of the major systems should be numerically controlled. Benches are not assigned but should be provided in sufficient numbers to be convenient to most machines. The number of benches is thus dependent on the laboratory layout. The machinery area of this laboratory should be easily accessible to the materials testing room.

A general support area should be provided to prepare large stock for machinery operations. The stock-processing area should include power hacksaws, oxyacetylene cutting torches for sheet steel and pipes, drill presses, and large power saws for cutting sheet metal, rod and bar stock. This area is not intended to be part of the classroom area.

Welding. The welding laboratory has separate areas for each type of welding and a common materials preparation and fabrication area (usually shared with the sheet-metal area in the shared-space laboratory). Gas-welding stations and arc-welding booths, usually provided in equal numbers, are or should be planned around a common fabrication area. This area either abuts on or includes a special area for a cutting table and precision-cutting torch assembly. (Note: For safety reasons the layout of this laboratory should allow the instructor to see the work surface in front of all students from any point in the laboratory.

Stock storage and stock preprocessing equipment should be adjacent. (Figure 26)

Plastics. The plastics laboratory should be planned as a three-part laboratory incorporating large plastics-production machinery (molders, extruders, formers) bench-top systems (laminating machines and small vacuum formers, for example) and a general bench area in which to develop a variety of plastic pour-molding operations.

Blow molders, injection molders, and extruders represent standard equipment in the plastics laboratory, although vacuum formers and poured plastics operations are gaining in importance. Tables or benches are not required except, as in the machine shop, for other activities.

Sheet Metal: The sheet-metal part of this laboratory should be planned to incorporate functionally separate areas for bench operations, fabrication projects and general sheet-metal processing machinery. Layout and fabrication benches for each of the students should be provided. Four-station benches (two to a side on a rectangle rather than one to a side on a square) are usually preferred as this shape is best for most small and medium-sized assembly activities.

The fabrication area should be planned as a general construction space where students can construct large projects such as prefabricated duct systems. This area should be convenient to the general machine area and the fabrication bench area. Where a heating and ventilation program is planned the sheet-metal laboratory should be nearby.

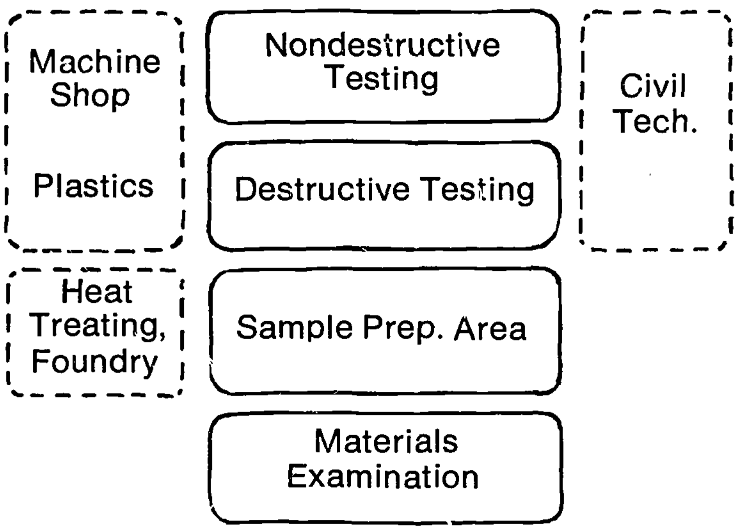


Figure 27
General program space requirements of a comprehensive materials-testing laboratory. Dotted lines indicate laboratories commonly requiring direct access to the area indicated.

The planning of this area must take into account the fact that sheet-metal handling is difficult and hazardous, so careful attention must be given to the position of machines to allow for safe movement of large stock between the machines, benches and fabrication area.

Heat Treating (and Metallurgy) Laboratory. Through the proper choice of equipment, the heat-treating laboratory may be a subsidiary of the machine shop or an independent program in heat treating, metallurgy, or ceramics technology. Since most advanced furnaces and quenches would be appropriate for any of these programs, the planning problem is primarily one of determining the range of equipment. At a minimum, the comprehensive heat treating/metallurgy/ceramics laboratory should include a gas-fired crucible furnace, an induction furnace and an electric-arc furnace, plus several oil quenches and salt baths.

If this laboratory is to be used for a metallurgy program, some consideration should also be given to the selection of ovens, furnaces and other forming machines suitable for processing ceramics and for developing courses in powered-metal processing.

Workbench space is not needed in this laboratory, but several tables or desks for holding in-process components will be required. These should be near the processing areas, but should be placed so as not to interfere with work around each station.

Foundry: A foundry laboratory should be composed of separate areas for sand testing and mold making and a subdivided area for melting, molding and pouring. The sand-testing and mold-making area should have stations for each of the basic mold making functions, including a core maker, core oven, core blower, shake-out box, green sandbox and molding bench. The melting area should include gas, electric-arc and induction furnaces of at least 20 to 50 pounds capacity. Benches and work tables in this laboratory are required only for other functions.

Materials Testing: This laboratory can be a subsidiary to the study of metallurgy, plastics, machine shop, and instrumentation or be a training facility in its own right. The services provided should lie in four functional areas: 1) destructive testing (compression, tensile, bend testing); 2) nondestructive testing (ranging from magna-fluxing and hardness testing to industrial X-ray equipment); 3) a sample preparation area (cutting, mounting, polishing); and 4) an area sample examination and microscopic analysis of grain structure. Where warranted by other programs offered in the school or by local need, this laboratory may be combined with the civil technology and/or metals (specifically machine shop) programs or developed as a quality-control laboratory representing a spin-off from its more common parent program

Table 7 — Space Requirements for the Metals Cluster

Laboratory	Station	Unit Area	Stations per Unit Area	Circulation Burden	Allocation of Total Class Stations	Remarks
Welding	Gas	4 x 6	1	50-100%	60%	Approximately four feet of bench per station.
	Arc (Booth)	5 x 5	1	50%	60%	Individual welding booths; circulation burden includes area requirement for transformer.
	Torch Cutting Table	10 x 10	1-3	25-50%	(1)	
	Gen'l Circulation and Support	(100-250% of total)				Includes allowance for power hacksaw, cutting torch(es), fabrication area, etc., and related equipment.
	Storage	(5-10% of total)				
Sheet Metal	Brakes, Shears, Rolls, etc.	6 x 8 to 14 x 14	-	-	-	Basic sheet metal machinery area will be 1000-1500 sq ft.
	Sheet Metal Benches	12 x 12	2-4	100%	75-100%	
	Fabrication Area	1000 sq ft basic area plus 15-20 sq ft per student over 20.			-	
	Gen'l Circulation	(20-40% of station total)				Includes allowance for unassigned support stations such as pedestal grinders, buffers, drill presses, welding booth (if not shared with welding program), etc.
	Storage	(5-10% of total)				
Machine Shop	Lathes, Presses, Millers, Screw Machine, Grinders	8 x 8 to 9 x 11	1	40-70%	Note a	The circulation burden includes general safety circulation requirements. Note: Add 50-75% to station allowance for N/C systems.
	Benches	5 x 6	-	100%	25-50%	Unassigned stations—should be convenient for use by most major machines.
	Gen'l Circulation	(40-60% of station total)				Includes allowance for unassigned support stations such as pedestal grinders, buffers, drill presses, welding booth (if not shared with welding program), etc.
	Storage	(5-10% of total)				
Plastics	Extruder	8 x 10	2-4	40-60%	(1-2)	Includes allowance for workbench as required.
	Molder	8 x 10	2-4	40-60%	(1-2)	Includes allowance for workbench as required.
	Vacuum Former	4 x 6	2-4	40-60%	(1-2)	Includes allowance for workbench as required.
	Rotary Molder	4 x 6	1	50%	(1)	
	Gen'l Plastics	750-1000	10 +	-	25-50%	Flexible open area; may include workbenches.
	Gen'l Circulation	(150-250% of total - excluding Gen'l Plastics)				Includes allowance for a dicer, mill, and mixer; not usually identified as a student station.
	Storage	(10% of total)				
Heat Treating (Metallurgy)	Ovens and Furnaces	5 x 7 to 8 x 8	-	100-150%	See Remarks	Heat-treating laboratories are not defined by stations per se as a design criteria. Rather, a basic service capability representing at least one gas, electric, and induction furnace and at least one oil and salt bath represent a minimum facility to serve 10 to 20 students. (Note: These standards apply only to "production" systems and not to bench-mounted systems which require only a single bench station.)
	Quenches	4 x 6	-	100%		
Foundry	Crucibles	5 x 7 to 9 x 9	-	100%	(2-4)	
	Molding Bench	4 x 5	1	-	50%	
	Sand Box	100	-	-	-	
	Green Sand Box	100	-	-	-	
	Sandmolding	4 x 8	1-2	50%	-	
	Gen'l Circulation	(150-200% of total)				Includes demonstration area and unspecified storage (sand, castings, etc.) area and non-instructional stations such as core oven, core blower, shake-out box, sand blaster, etc.
Materials Testing	Sample Preparation	3 x 5	1	100%	Note b	
	Non-destructive Testing	3 x 6 to 8 x 10	1	100%	Note b	Hardness testing, magnaflux equipment, metallurgical X-ray machines, etc.
	Destructive Testing	7 x 10	1	100%	Note b	Tensile/compression testing machines, etc.
	Microscopic Exam.	4 x 5	1	100%	Note b	Bench or table stations.

Notes: a - Lathes, 40%; Millers, 20%; Grinders, 20%; Electronic Discharge Machine, (1); Borers, 10%; Screw Machines, (1); Drill Presses, 10-15%; Punch Presses, 5-10%.

b - Varies with requirements of program.

Public Services

Major Skills or Occupational Specialties

Culinary Arts and Food Service Management
Cosmetology
Barbering
Commercial Sewing
Child Care
Laundry/Dry Cleaning
Hotel/Motel-Management-Housekeeping
Commercial Sewing and Tailoring

Unlike the trade and industry programs laboratories in the public services must generally be designed around the specific needs of only one program and there is little possibility of space sharing. This is not, however, to imply that there are few variables to be considered in the facility design.

Since many of the public service careers lend themselves to planning as both functioning "public invited" laboratories in the school and as off-site cooperative educational experience, the planner has the opportunity to design anything from a bare minimum facility (which will merely prepare the student to enter the real world setting) to a real commercial operation in the school. While such factors as state and local labor laws, local work opportunities, and the availability (and cost) of space in the school must all be considered in the planning of such programs, the end product is usually a combination of both on-site facilities and cooperative programs. However, it is usually appropriate to design the facility as though it were to be complete at the school site.

As schools attempt to become more a part of the community they serve and to provide a service that will draw the community to the school, these services become commercially oriented and are often clustered into a "Commercial Mall." In some cases the mall, is limited to the facilities in Figure 28, but in other cases, the school offers other services such as stenography (business cluster), printing (graphic cluster) and the like, which may be available elsewhere in the school.

Principal Laboratories and Laboratory Design Features

Barbering and Cosmetology. Until recently, barbering was rarely offered as a career program in the public schools. However, the growing number of salons for men has created a sudden need for expanded programs in hair styling and cosmetology for men.

Cosmetology, and barbering when it is combined with cosmetology, is usually planned as a two-phase program including 1) a general introductory and basic skill development program offered in a "Laboratory" setting and 2) an advanced course and a customer relations laboratory in a working beauty salon or barber shop. The laboratory is commonly planned as a complex with separate areas for basic and advanced laboratories.

Since salons for men and women are customarily operated independently, laboratories for both the principles of cosmetology and the business of operating a beauty salon are usually required. Since the effective practice at advanced levels requires the participation of real customers—both the public and other students—they should be in the Commercial Mall or other suitably central location. The major subdivisions of the cosmetology program include the following:

Office/Waiting Area. An attractively decorated lobby, office and waiting area is needed if this facility is to be used by the public.

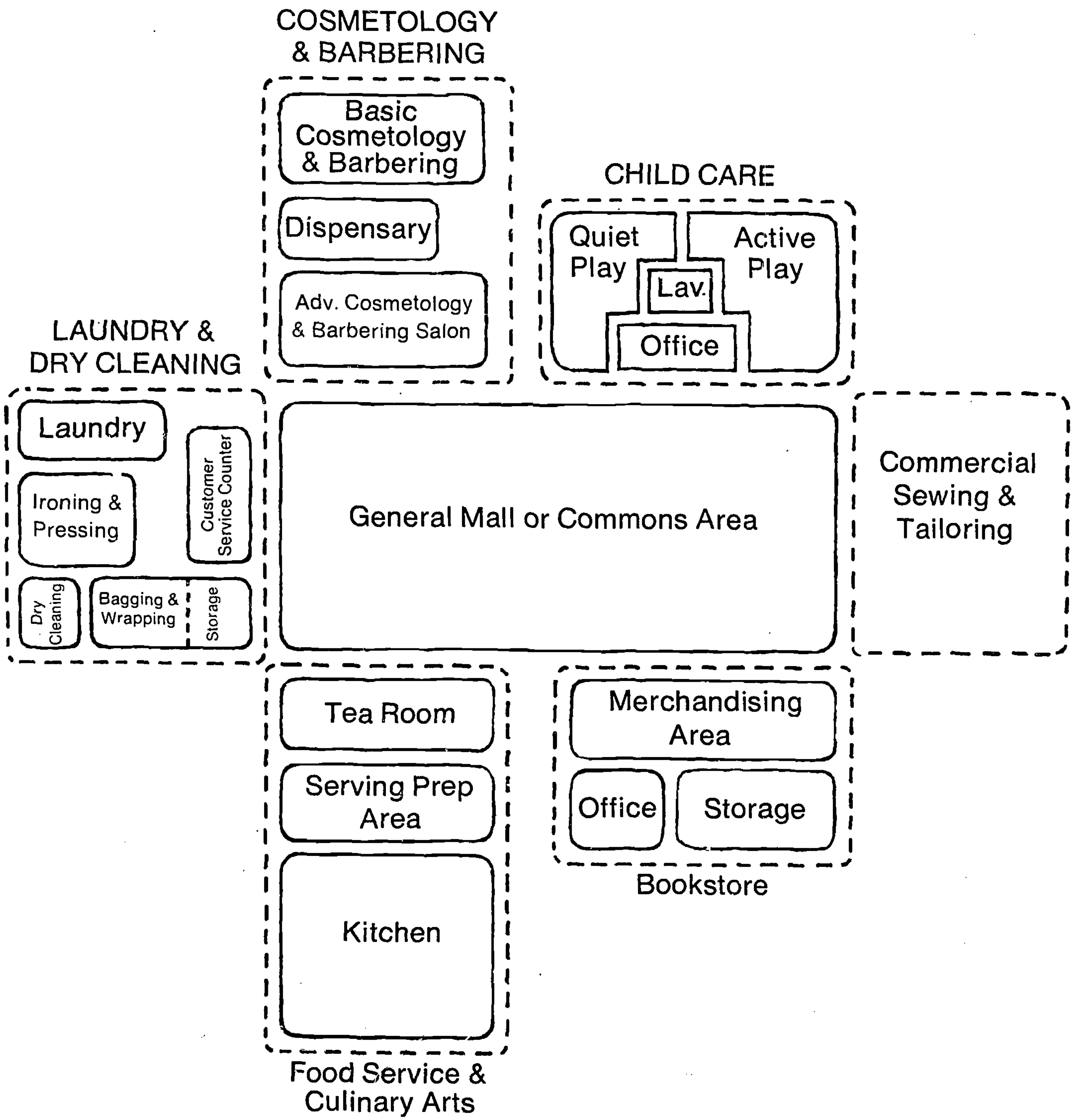


Figure 28
A hypothetical "commercial mall" showing major laboratories and the program space requirements and relationships of each.

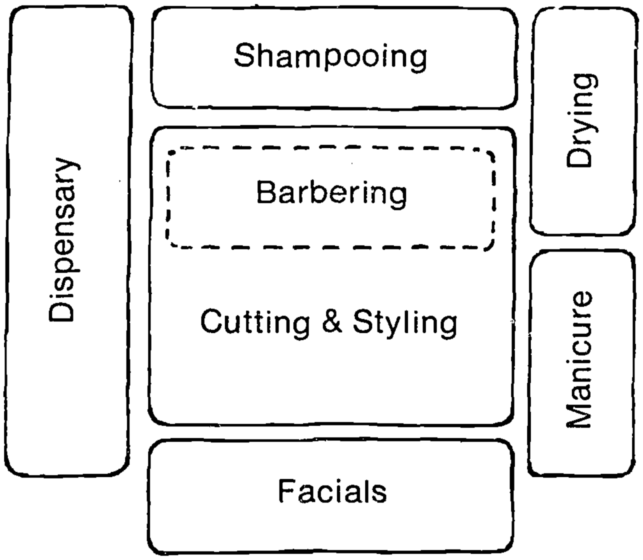


Figure 29
Basic program space requirements and suggested space relationships in a cosmetology laboratory.

Hair and Facial Treatment Laboratory. The main laboratory will need four different areas, for facials, shampooing, hair drying and hair styling, as shown in Figure 29. This area of the laboratory is the core of most cosmetology programs and should therefore be given careful planning consideration. State laws vary in their requirements for shampooing, drying, cutting and styling. This can have an important effect on the cost of the total facility (i.e., fully equipped individual stations increase the total laboratory cost fifteen to twenty-five percent).

Shampoo Preparation and Dispensary Area. A storage and support area, it is usually used as a student station where students learn to prepare solutions used throughout the cosmetology program.

Model Beauty Salon. The model beauty salon is used for advanced students to perfect their skills in hair and facial treatment and to learn the skills of operating and managing a salon. It should be fully equipped for "commercial" salon operation and management, with space built-in dresserettes, shampoo bowls, and a sanitary cabinet for towels and other supplies. This facility should be functionally integrated with the main "Hair and Facial Laboratory" but should be a physically independent area convenient for public access.

Child Care and Development. Students majoring in this program follow a sequence of classes and laboratory experiences designed to increase their understanding of the development of young children, and their care and education. Child care majors usually get specialized training in the field through working with children in an operating on-site day care center. Since the day care center will be the "laboratory," this program may be considered principally an on-the-job training experience. Other areas of study in- de human relations, nutrition, management practices of ursery school, health safety and care of children, use of iterials, speech, music and art — all of which can be taught in related school laboratories.

Nursery Area. The central nursery area is a single large room that allows play areas for several groups of children of different ages. This space should be acoustically divisible into separate areas for active and quiet play (or nap). Two connected classrooms are usually adequate for this purpose.

The nursery should be located near a playground which does not have direct access from parking lots or traffic areas.

Outdoor Play Area. The playground, part of which should be sheltered, should have swings, slides, a jungle gym, a sandbox and sufficient unobstructed running room for games.

Commercial Sewing and Tailoring. A program in commercial sewing and tailoring can be an independent program or a hybrid program building on (and contributing to) such programs as fashion design, upholstery and laundry and dry cleaning. Space requirements in this laboratory are based on a mix (in roughly equal proportion) of cutting tables, sewing machines and ironing tables (or steam presses if this facility is to contain the laundry and dry cleaning program as well). Rather than defining separate areas for each of these functions, the laboratory layout should reflect the fact that there is regular student movement among all stations.

Laundry and Dry Cleaning. The laboratory for laundry and dry cleaning has fixed requirements that provide only minimum flexibility in the number of physical relationships. At best, the facility is subdivided for washing and dry cleaning; pressing (separate equipment stations for pants, coats, silks, and general pressing); packaging; sewing and tailoring; and counter operations. Introductory study in the theory and use of solvents should be programmed into the school's general science facilities.

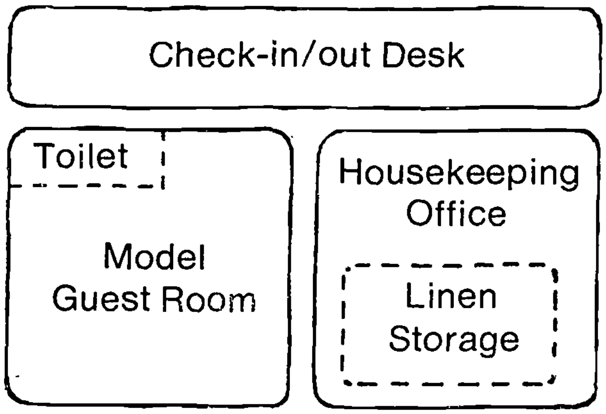


Figure 30
Program space requirements in the hotel/motel career area.

Culinary Arts and Food Service. Increasingly, the traditional cooking class has been broadened to include careers in such specialties as baking and bakery management, gourmet cooking, and programs for waiters and waitresses and short-order cooks. In some states these programs may be provided through a quasi-cooperative education or on-the-job program, using the school's own kitchen and cafeteria. Other schools have culinary arts complexes ranging from complete commercial kitchens to on-site restaurant and banquet facilities and snack bars for short-order service. The more modest programs, however, are content with a kitchen and small "tearoom" designed basically to serve the school's students and faculty. The size of both the tearoom and kitchen are effected by such major variables as 1) whether the staff, the public and students all be served, and whether separate banquet rooms are desired; and 2) should the kitchen give special emphasis to meat cutting (supermarket), baking, package or fast-frozen food preparation, etc. The requirements for support facilities, such as frozen-food lockers, will also depend on both the number of meals to be served and legal concerns (where federally subsidized food programs are in effect) regarding the mixing of "culinary arts" foods and institutional food.

Hotel/Motel Occupations. Career programs in hotel/motel maintenance and administration may be planned either as separate careers and laboratories or combined as a comprehensive laboratory with separate learning stations.

Hotel/Motel Housekeeping. The hotel/motel housekeeping laboratory should be a modern hotel room — bathroom, sound system, thermostat — and should provide for all services that must be performed in cleaning and preparing a guestroom. There should be a "housekeeping office" including a linen and cleaning supplies storage area and records area.

Hotel/Motel "Management". This is a check-in/check-out counter. There should be a registration area, cashier station, mail and key repository and general office area.

Table 8 — Space Requirements for the Public Services Cluster

Laboratory	Station	Unit Area	Stations per Unit Area	Circulation Burden	Allocation of Total Class Stations	Remarks
Cosmetology	Shampooing	5 x 7	1	25%	25%	
	Drying	4 x 5	-	25%	Unassigned	Drying stations may be non-instructional support stations provided in 1:1 ratio with shampoo stations.
	Facial	5 x 7	1	25%	20%	
	Styling	4 x 5	1	See Circ.	100%	
	Manicuring	5 x 5	1	-	(1)	
	Dispensary	250-400	1-4	-	(1)	
	Gen'l Circulation	(40-60% of total)				
	Office/waiting	200-300	1-2	1	(1)	
Barbering	Barber Chair	7 x 10	1	20-40%	100%	
	Storage	100 +	-	-		
Child Care	Active Play	-	-	-	70%	Space requirements vary widely with the scope of the program and must reflect both curriculum goals and the intended role of the facility as a neighborhood child care or day care center. 1000 sq ft of both indoor and outdoor space represents minimums for a basic, comprehensive program.
	Quiet Play/Nap	-	-	-	50%	
	Outdoor	-	-	-	-	
	Office	150	-	-	-	
Commercial Sewing/Tailoring	Pattern Tables	11 x 11	1-4	25%	35%	
	Sewing Machine	4 x 5	1	40%	70%	
	Ironing Board	5 x 6	1	25%	15%	
	Mannikins	6 x 6	1-2	25%	-	
	Storage	250 +				
Laundry & Dry Cleaning	Washer	25-40	-	25% +	(2-3)	Unassigned station.
	Dry Cleaner	30-50	-	25% +	(2-3)	Unassigned station.
	Dryer	30-50	-	25% +	(2-3)	Unassigned station.
	Ironing	12 x 18	1-2	-	20%	Includes standard ironing table and sheet mangle.
	Pants Press	15 x 15	1-3	-	30%	Includes legging press, topping press and utility press.
	Coat/Dress Press	12 x 12	1-2	-	20%	Includes steam/air form and utility press.
	Silk Unit	15 x 15	1-3	-	30%	Includes steever, puff irons, hot head offset press.
	Spotting Table	7 x 6	1	25%	10%	
	Bagging/Wrapping	12 x 16	1-4	-	20%	Includes basic slick rail storage.
	Service Counter	300-600	2-4	-	-	Includes marking bin, general storage area, counter, etc.
	Gen'l Circulation	(40-60% of total)				
Culinary Arts	Kitchen - Meat	200-400	2-4 (a)	-	20%	Preparation area only.
	Vegetable	200-400	2-4 (a)	-	20%	Preparation area only.
	Dessert	200-400	2-4 (a)	-	20%	Preparation area only.
	Salad	150-300	2-4 (b)	-	20%	Preparation area only.
	Bakery	300-600	3-6 (c)	-	40%	Preparation area only.
	Gen'l Cooking	500-800	-	-	-	
	Food Storage	(10-30% of kitchen - divided between cold storage (30%), frozen storage (30%), dry food (40%).				
	Tea Room	(11-16 sq ft per planned seat)			As Required	
	Short Order	(100 sq ft per station, two-station min.)			As Required	
Hotel-Motel	Guest Room	15 x 25	3-6	25%	50%	Two-room mock-ups should occupy one laboratory.
	Bathroom	8 x 10	1-2	-	-	
	Linen Room	15 x 20	3-6	-	25%	Includes "housekeeping office," linen and cleaner storage, etc.
	Desk	10 x 15	3-5	50-75%	50%	

Notes: (a, b, c) These figures do not necessarily *imply* "per station" equivalents of a) 100 sq ft, b) 75 sq ft, or c) 100 sq ft.

Science and Technology

Major Skills or *Occupational Programs*

Civil Technology
Electronics
Instrumentation
Horticulture/Forestry
Chemical Lab Technology
Medical Lab Technology
Production Process Technology
Crime Lab Technology

The rapid expansion of all phases of science and technology has meant that more and more of our population will be earning a living in a career requiring an understanding of, and a minimal ability to deal with, systems whose function is based on or controlled by a machine or scientific apparatus. Occupational education programs, particularly those whose express purpose is to serve specific local industrial needs, are increasingly being called upon to develop advanced "technology"-based programs.

As a general class, the technology programs tend to be more consumer-oriented than industry-oriented. That is local industry often has specific demands and programs are tailored to produce graduates for a specific employer whose needs may differ drastically from a "standard" curriculum. Thus, for instance, the foods processing program in Battle Creek, Michigan, would be cereal-oriented, while a program of the same title in Florida might be concerned only with frozen-juice processing. For the most part, there is no such thing as a "general" laboratory in programs in this class.

There are, however, many technology programs which have a broad enough scope to justify consideration of a "general" laboratory format within which local requirements or unusual characteristics can be accommodated. While not intended to be an exhaustive list, the laboratories presented here have the virtues of broad generalized employment opportunities plus major features for convenient development as "spin-offs" of commonly existing programs.

Major Laboratory Design Considerations

Civil Technology Laboratory. The civil technology program is usually based on separate classes of laboratory experience in 1) surveying and field study (which is supported on-site by the school's drafting facilities) and 2) soils and construction-materials testing (which are usually developed as an extension of the materials-testing laboratory). The only major additions that must be made to offer a basic program in civil technology are mixing and curing facilities for concrete, a test facility for asphalt, and a soils-testing area.

Electronics. Most schools make an unnecessary distinction between the facilities and programs for basic and advanced electronics and in doing so artificially limit laboratory and program flexibility. In fact, most basic and advanced study in electronics requires only standard electronics benches, and the only difference between the two is in the specialized equipment, such as television-repair trainers and computer logic systems, for advanced work. However, since most electronics programs now use "packaged" benches that have a variety of power sources and most basic meters built into the requirements of the over-all program should be considered in bench selection — particularly with respect to the usable work surface. Benches to be used for television repair require up to fifty percent more area per station than a standard bench.

Many electronics programs are also beginning to emphasize the production aspects of the electronics industry by incorporating educational programs in electronics assembly and printed-circuit production. Printed-circuit facilities are essentially darkrooms incorporating acid-etching tanks and a variety of similar specialized processing equipment. While the importance of this production will undoubtedly grow, it is unlikely that it will become an independent program.

Production Process Technology. (Note: Since, as indicated earlier, production process technologies tend to have a strong local flavor, the following comments are intended to be generally applicable to all production process technologies, whether chemical, plastics, sanitation, food or paper.) For the most part, laboratories in process technology are defined exclusively by the hardware requirements of the intended curriculum. In most instances, this means the program will use "real" machinery and equipment — mostly because the relatively limited demands for such programs have not spurred development of mock-ups and similar teaching systems such as are available in other programs. However, since the equipment in these facilities often makes unusual utility requirements (water, steam, electricity, compressed air, and special ventilation for fire protection), it is important to be clear about the objectives of the program, and the equipment required, early in the planning process.

Chemical Laboratory Technology and Medical Laboratory Technology. Chemical and medical laboratory technology programs may be regarded as a generic classification for a broad range of technical careers ranging from bacteriology to chemical-process quality control. The basic facilities of these laboratories are usually the same as those for the general science laboratories and differ only in the specialized equipment required. As a result, such laboratories may readily be fitted into existing science facilities.

Crime Laboratory. The crime laboratory should include instruments and technology for the study of ballistics, fingerprinting, and police chemical laboratory analysis. Space in this laboratory should be allowed for pistol and rifle ballistics test stands, a fingerprinting area, and several chemical and blood technology analyses and related areas. Most chemical analysis study can be construed with the regular chemical and medical labs. Lecture/demonstration stations for this laboratory should be provided as tables that can double as work stations for plaster casting and fingerprint analysis, for example.

Instrumentation Technology. This is a broad title intended, generally, to reflect the common requirements of process measurement and control systems as they relate to any production process. Since such skills are independent of the product being made, this laboratory usually contains a roughly equal distribution of single-station process or control simulators and one or more multiprocess simulators incorporating pneumatic and electronic pressure, temperature, and flow measuring and recording devices as well as multiple servomechanism controllers.

Analog computers (either pneumatic or electronic) may be incorporated for advanced study. Specialized study of instrument circuitry and mechanical measuring systems may be gained in the electronics-and materials-testing laboratory.

Horticulture/Forestry. Under this general classification there exists a broad range of career opportunities ranging from nursery management to landscaping and from golf course to forest management. These programs, all of which are growing rapidly, can make use of a single greenhouse and the school's grounds.

The greenhouse, if it is to be used by students in a wide range of programs, should be appropriate for growing anything from azaleas to pine seedlings. There should be at least two (more if many programs are planned) sections to allow for different thermal and humidity environments for different types of plants. As this room will also be used in the study of botany, it should be planned to be convenient to the science laboratory.

Table 9 — Space Requirements for the Science and Technology Cluster

Laboratory	Station	Unit Area	Stations per Unit Area	Circulation Burden	Allocation of Total Class Stations	Remarks
Gen'l Sci. Laboratory	Laboratory Bench	4 x 5	1	100-150%	100%	Circulation allowance allocated throughout laboratory.
Technologies (chemical, medical lab technologies, etc.)	Laboratory Bench	4 x 5	1	100-150%	100%	Three feet of general service counter (two feet or deeper) per station.
	Counter	-	-	-		Varies with program requirements; common storage facilities should serve multiple laboratories.
	Storage	(20-35% of laboratory)				
Civil Technology	Flexible Open Space	(80-150 sq ft per station)			100%	Flexible open space preferred. Requirements vary principally with the degree to which major testing equipment may be shared. See "Materials Testing" in Table 7.
Electronics and Related	Electronics	4 x 5	1	50-60%	Note a	
	Radio-TV	4 x 5	1	50-60%	Note a	
	Printed Circuitry	200-400	3-6	-	Note a	Light controlled room.
	Elec. Assembly	3 x 5	1	50-60%	Note a	
	Support Area	(0-40% of laboratory)				Provision for large systems such as transmitters, computer components, etc.
	Gen'l Circulation	(40-60)				
	Storage	(10-15% of each laboratory)				
Crime Lab Technology	Ballistics Stand	6 x 15	1-2	25%	(1)	
	Gen'l Bench	4 x 5	1	50%	100%	For activities ranging from fingerprinting to plaster casting, microscopic ballistics study and chemical analysis.
Production Process Tech. (foods processing, chemical production, etc.)	Varies with program and local needs. Laboratory should reflect a specific program rather than a general one.					
Instrumentation (fluidics, pneumatics, etc.)	Trainers	4 x 5 to 20 x 20	1-2 to 8-12	50% +	100%	Trainer/simulators may be bench-top trainers for single monitoring and/or controller systems to large process simulators incorporating multiple flow and energy transfer processes and control systems.
	Workbenches	6 x 10	2-4	50%	-	
Horticulture	Greenhouse	20 x 30	10	-	100%	Multiple 20 x 30 areas should be planned to provide different controlled growing environments.
	Florist Shop	20 x 30	4-6	-	20%	Includes general display area, refrigerators, etc.

Notes: a - Depends on program.

Vehicle Maintenance

Major Skill Families and Laboratory Types:

Auto Mechanics
Small Engine Repair
Diesel Mechanics
Auto Body
Air Frame
Aviation Mechanics

Unquestionably, careers in vehicle maintenance will continue to be a major element in most occupational programs. Teaching of engine mechanics has, more than any other program, capitalized on recent trends towards the development of career ladder curricula and development of sequential learning experiences based on the use of increasingly more complex studies and materials.

The use of electronic ignition systems and computerized engine diagnostic systems has meant that many elements of the curriculum (and the facilities associated with it) will soon require major revision. Similarly, the potential for the electric or steam-driven vehicle has meant that electricians and plumbers may become the auto mechanics of the future — and such changes must be planned for in a building that will certainly still exist when such systems become realities.

All these influences have contributed to a trend away from programs and facilities designed around the use of cars as the sole educational system and have led to the planning of more flexible-use spaces for freestanding engines, transmission, chassis assemblies and hydraulic systems — whether they are for automobiles, airplanes, or snowmobiles. Similarly, carrels for audiovisual programs or small-system mock-ups have become common for teaching operation theory and repair principles of carburetors, fuel pumps, electrical systems, and the like. In fact, the car can realistically be relegated to a minor status, potentially occupying only twenty to thirty percent of total teaching time and facility space.

But this reflects more than a simple redistribution of instructional time in the automotive program. More and more, other kinds of engine mechanics, such as lawnmowers, outboard motors, motorcycles, diesel mechanics and aircraft engine repair have made inroads into the traditional auto mechanics shop. The trend has had significant consequences in the architectural requirements for vehicle maintenance programs. Particularly where the use of a car on a lift has been required less, much of the architectural burden of the high-ceiling facility has been removed. Similary, the use of simulators and freestanding systems such as transmissions and chassis assemblies, have drastically altered the need for costly walls that meet the fire code. This shift has led to an increase in space use efficiency (as reflected in a major reduction in the "area per station" requirements, in Table 10) and program flexibility. The planning of a mechanics laboratory on this basis also provides greater flexiblity in the kinds of specialties that can be developed. (Figure 31)

Principal Laboratories and Laboratory Design Features

Mechanics Simulator, Trainer & Mock-up Areas. In new mechanics programs the mechanics simulator, trainer, and mock-up areas of the laboratory should represent as much as seventy percent of the student stations and are intended to provide experience in all the *basic* principles and skills required to tune-up and repair automobile and diesel engines, those for trains and reciprocating aircraft engines.

Initial comprehension of these mechanical skills does not require experience on the actual vehicle and is, in fact, better learned in a classroom situation. Separate spaces in the shop area may be provided for engine tune-up and overhaul, transmission repair, chassis-suspension-brake system repair, and automotive electrical and accessory systems. (Note: None of the spaces for these activities *requires* a garage facility (high ceiling, etc.) and it may therefore be a single-story area opening off the auto-bay area. The extra space above the laboratory areas can be used for

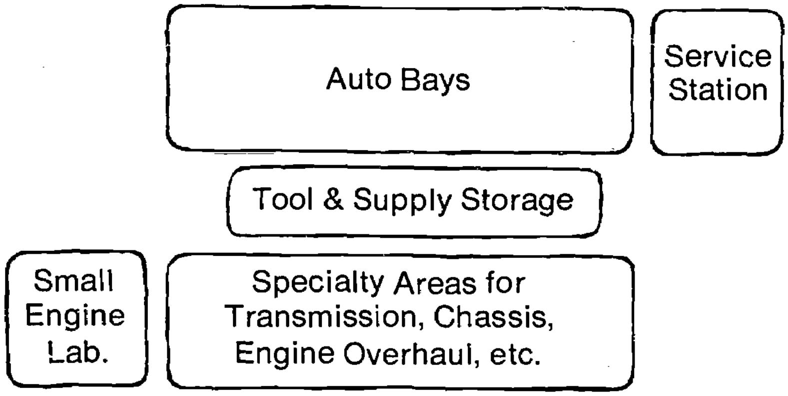


Figure 31
Program space requirements in the auto and engine mechanics cluster.

storage, or for such equipment as driver-training simulators.)

An *engine tune-up and test laboratory* is provided to to teach students the basic skills of engine timing and tune-up, carburetor and fuel-system repair, and other minor mechanical repair operations. Operating mock-ups of free-standing six-and eight-cylinder gasoline and diesel engines should be supplied. If provision is to be made for an automotive technology program, this area of the laboratory should also provide for one or more fully instrumented engine/transmission dynamometers. This laboratory can be a multiprogram area with alternate use and storage of automotive, diesel and aircraft engines.

The *engine overhaul* work stations should consist of heavy-duty metal benches and an adjoining area where engines may be mounted while in use. Engine stands should be movable to allow for the location of a different engine at each station during alternate laboratory periods. Overhaul and repair require some specialized equipment (such as presses and grinders) and there should be access to a milling machine and cylinder-boring machine — this accounts for the large circulation burden provided in Table 10. (An area for temporary storage should be provided off to the side.)

The *transmission area* should be designed to lead students to develop the ability to repair automatic transmissions, fluid couplings, torque converters and hydromatics; to develop an understanding of gear ratios and planetary systems, clutches, control mechanisms, electrical and vacuum mechanisms; and to learn about fluids, seals, bearings and hydraulic valves. This area should consist of several automatic and manual transmissions mounted on stands, plus one or more complete chassis and drive-train(engine, transmission, differential, rear axle) systems. If a fully equipped chassis section is needed it can be shared with the adjoining chassis-steering-suspension area. Each student *station in this shop* will need a heavy-duty metal transmission workbench furnished with compressed air and an electrical outlet.

The *chassis-steering-suspension* area is used to teach the principles of, and repair skills for, manual and powersteering mechanisms, brake-and suspension-system adjustment and wheel alignment, caster and camber adjustment. There should be one or more full chassis front-end assemblies. A workbench near each chassis is needed for tools and parts and an audiovisual teaching system. In addition, carrels or other suitably structured individual system mock-ups of wheel-brake-spring-shock absorber assemblies for the initial study of these systems may be useful.

Small Engine Repair. As an option under the engine mechanics and automotive service program, the small-engine mechanics program is a specialty leading to careers in the maintenance of outboard motors, motorcycles, lawn mowers, snowmobiles, etc.

The small-engine repair shop requires only heavy-duty benches arranged to allow for a cart-mounted gasoline generator, motorcycle, outboard motor or whatever next to it.

Vehicle Garage. The garage "bay" should be a study area planned only for training in those special skills, such as muffler replacement or tire changing, that require the use of a car. Here students can apply the skills developed on simulators and mock-ups to real problems of automotive tune-up and repair. Each bay should provide for up to four students. A comprehensive auto mechanics program should include at least one single, double, and split-post lift and one front-end alignment unit. In advanced programs a one-chassis dynamometer is also desirable. If a service station is included, the auto bays should be adjacent to them.

Service Station. When a service station is to be operated by a school it should offer training in customer relations as well as in mechanics. The service station and office should reproduce their commercial equivalents and the service station should be visible from, and convenient to, entry drives to the school.

Body and Frame. Like auto mechanics, auto-body repair programs have undergone major restructuring in recent years as specialties have developed. Among these are the "glass" men and the seat-cover repairmen. Auto-body repair training also does not require a car. As pointed out earlier, development of basic skill in sheet metal pounding and shaping and in the use of plastics fall into this group. The removal of the car again reduces costs of fire protection.

The auto-body repair shop provides the facilities for students to acquire all the mechanical skill for repair and refinishing and to develop an understanding of the various paints and solvents used in metal finishing. They should also be able to estimate the cost of an auto-body job.

Work in this department ranges from straightening a twisted or bent frame to the final waxing of a repainted fender. Students learn to weld structural members and sheet metal (basic instruction takes place in the related specialty shops), knock dents out of sheet-metal areas, fill ripples and minor dents, sand the surface smooth with machines and by hand, undercoat, spray on a new finish, touch up small areas, sand and rub down a painted finish, repair and repaint fiberglass body sections, and adjust doors and hoods.

In most cases, full bays are needed. They can be used in rotation so that they are flexible enough for use in many preliminary experiences leading up to more complicated work. The extensive use of a space-sharing program places unusual demands on the laboratory's storage requirements. However, bench space is scarcely ever needed, except for work on repainting or straightening a small part.

Table 10 — Space Requirements for the Vehicle Maintenance Cluster

Laboratory	Station	Unit Area	Stations per Unit Area	Circulation Burden	Allocation of Total Class Stations	Remarks
Engine Mechanics	Auto Bays	14 x 25	1-4	25% or 700 sq ft (larger)	50%	Unit area includes allowance for standard workbench (5 x 5 ft. station). Circulation burden includes a general auto shop allowance for support equipment such as engine analyzer, spark plug cleaner, parts cleaner, etc. (Note: These space allowances are based on individual entry to each bay. See Note a.)
	Service Station	200 sq ft	2-4	-	10%	Plus 1/4 acre of adjacent outside space.
	Engine Tune-up	6 x 8 to 9 x 10	1-2	25%	25%	Station allowance does not provide for adjacent workbench.
	Dynamometer	10 x 12	2-4	25-80%	(1)	
	Engine Overhaul	8 x 10	1-2	-	25%	Station allowance includes workbench. Circulation allowance varies with support machinery.
	Transmission	5 x 6	1	40%	25%	
	Chassis	14 x 20	1-4	25%	25%	Half chassis (i. e., front-end or rear-end) requires half to two thirds of the unit area.
	Carrels/Trainers	4 x 6 to 6 x 8	1	25%	10-30%	Mock-up carrels and trainers for electrical systems, a/c systems, fuel systems, brake systems, etc.
	Small Engine	6 x 10	1-2	50%	Note b	Station allowance includes bench.
	Gen'l Circulation	(50-100% of total except auto bays)				Applied to each area in a physically subdivided laboratory.
	Storage	(10-15% of total)				
Aviation Mechanics	Piston Engine	6 x 9 to 10 x 12	1-2	25%	Note b	Station includes workbench.
	Jet Engine	9 x 10 to 12 x 16	2-4	100-150%	Note b	Jet engines to be "fired" will require special baffling and engine mounting stands.
	Aircraft	25 x 20	2-6	50-100%	Note b	
	Aircraft Control Mock-up	15 x 25	2-6	40-70%	Note b	Based on half an aircraft with skin removed.
	Landing Gear Mock-up	8 x 8	1-2	25%	Note b	
	Gen'l Circulation	(40-80% of total)				Allowance decreases with increased aircraft.
	Storage	(10-15% of total)				
Auto Body	Auto Bay	15 x 22	1-4	10%	100%	
	Panel Mock-up	5 x 7	1	40-70%	-	
	Spray Booth	16 x 24	1-2	-	(1)	
	Gen'l Circulation	(25-40% of total except spray booth)				
	Storage	(5% of total)				
Airframe	Workbenches	6 x 10	1-2	50%	Note b	Two station (opposite sides).
	Power Tools	500 +	-	-	Note b	Space allowance for general small tools such as drills, scroll saws, band saws, etc.
	Lamination Room	[illegible] +	1-4	-	(1) Note b	
	Project Area	150-200	1	-		Minimum of 2000 sq ft.

Notes: a - Traffic allowance in the garage area should provide a minimum of 15 ft of clearance between rows of cars for one-way traffic with angled bays. For two-way traffic and/or straight-in parking, a minimum traffic aisle of 25 feet is recommended. General circulation in the area of engine stands, simulator stations, etc. should represent a 50% burden for a minimum of 5 stations and slide to 10% for 30 or more stations. A general space allowance of 5% of the bay area should be allowed for support equipment such as static wheel balancers, valve resurfacers, oil cleaning bath, etc.

b - As required by program.

Reports from EFL

The following publications are available from EFL, 477 Madison Avenue, New York, N.Y. 10022.

DESIGN FOR ETV – PLANNING FOR SCHOOLS WITH TELEVISION.
A report on facilities present and future, needed to accommodate instructional television and other new educational programs. Prepared for EFL by Dave Chapman, Inc., Industrial Design. (1960) (Revised 1968) $2.00

THE EARLY LEARNING CENTER.
A Stamford, Conn., school built with a modular construction system provides an ideal environment for early childhood education. (1970) $0.50

EDUCATIONAL CHANGE AND ARCHITECTURAL CONSEQUENCES.
A report on school design that reviews the wide choice of options available to those concerned with planning new facilities or updating old ines. (1968) $2.00

ENVIRONMENTAL EDUCATION/FACILITY RESOURCES.
Illustrates where and how students learn about the environment of communities and regions using existing and designed facilities. (1972) $2.00

FOUND SPACES AND EQUIPMENT FOR CHILDREN'S CENTERS.
Illustrations of premises and low-budget materials ingeniously converted for early education facilities. Booklet lists general code requirements and information sources. (1972) $2.00

THE GREENING OF THE HIGH SCHOOL.
Reports on a conference on how to make secondary schools healthy. Includes the life-styles of adolescents and ways to accommodate them, open curriculums and alternative education programs. (1973) $2.00

GUIDE TO ALTERNATIVES FOR FINANCING SCHOOL BUILDINGS.
Chart and book explore conventional and unconventional routes for financing school construction. Includes case histories. (1971) $2.00

HIGH SCHOOL: THE PROCESS AND THE PLACE.
A "how to feel about it" as well as a "how to do it" book about planning, design, environmental management, and the behavioral and social influences of school space. (1972) $3.00

THE IMPACT OF TECHNOLOGY ON THE LIBRARY BUILDING.
A position paper reporting on EFL conference on this subject. (1967) $0.50

JOINT OCCUPANCY.
How schools can save money by sharing sites or buildings with housing or commerce. (1970) $1.00

PATTERNS FOR DESIGNING CHILDREN'S CENTERS.
A book for people planning to operate children's centers. It summarizes and illustrates all the design issues involved in a project. (1971) $2.00

PLACES AND THINGS FOR EXPERIMENTAL SCHOOLS.
Reviews every technique known to EFL for improving the quality of school buildings and equipment: Found space, furniture, community use, reach out schools, etc. Lists hundreds of sources. (1972) $2.00

PLACES FOR ENVIRONMENTAL EDUCATION.
Identifies types of facilities needed to improve environmental education. (1971) Single copies free, multiple copies $0.25

PHYSICAL RECREATION FACILITIES.
Illustrated survey of places providing good facilities for physical recreation in schools and colleges. Air shelters, roofing existing stadiums, shared facilities and conversions. (1973) $3.00

THE SCHOOL LIBRARY: FACILITIES FOR INDEPENDENT STUDY IN THE SECONDARY SCHOOL.
A report on facilities for independent study, with standards for the size of collections, seating capacity, and the nature of materials to be incorporated. (1963) $1.25

SCHOOLS FOR EARLY CHILDHOOD.
Ten examples of new and remodeled facilities for early childhood education. (1970) $2.00

SCHOOLS: MORE SPACE/LESS MONEY.
Surveys the alternatives for providing school spaces in the most economical manner. Includes extending school year, converting spaces, sharing facilities, open campus, etc. (1971) $2.00

SCHOOLS WITHOUT WALLS – open space and how it works. (1965) $0.50

STUDENT HOUSING.
A guide to economical ways to provide better housing for students. Illustrates techniques for improvement through administrative changes, remodeling old dorms, new management methods, co-ops and government financing. (1972) $2.00

SYSTEMS: AN APPROACH TO SCHOOL CONSTRUCTION.
Toronto, Montreal, and Florida projects and how they developed from the SCSD program. (1971) $2.00

Films

The following films [illegible]
and are available for [illegible]

NEW LEASE ON LEARNING
A 22-minute [illegible]
[illegible]
[illegible]
School [illegible]
children [illegible]
Film [illegible]
10003; rental [illegible]

ROOM TO [illegible]
A 22-minute [illegible]
[illegible]
school [illegible]
[illegible]
University Film Library [illegible]
N.Y. [illegible]