

APPENDICES

Appendix A: Measuring Degrees of Success

Appendix B: Core Curriculum Science Laboratories

APPENDIX A

MEASURING DEGREES OF SUCCESS

A. CREATING AND USING ASSESSMENT PROTOCOLS

The following is a framework designed to begin the process of assessing student learning outcomes. It is based on proven approaches that have been successfully implemented at universities internationally. However, the protocols used in assessing student learning at the PMU should be created using standards and expectations developed by the university faculty in close cooperation with the staff of the Teaching Development Center and the Learning Resources Center.

1. The Goals of Assessment

Learning assessment is designed to help students achieve two goals:

- To develop the skills of learning on their own.
- To take advantage of the lessons that experience and self-reflection can teach.

Assessment protocols are designed to become part of this process. The creation of protocols brings faculty together to discuss and determine their expectations for student performance. In this process, faculty learn from each other about different levels of behavior. Faculty also grow to better understand the student behavior that they observe. Ultimately, students benefit from the protocols, because they understand the expectations that faculty have of them.

2. A Guide to Learning not Grading

It will be important to review and revise assessment protocols for the PMU learning environment early in the university's development. It also will be necessary that the expectations presented to students remain in place over time. Students and faculty can become confused and frustrated when performance expectations are changed too often.

Equally important, however, is the need for everyone to understand that assessment protocols are not a grading system. They are a guide. Assessment protocols are a technique for achieving agreement within the learning community of student performance expectations.

Obviously, students will master the learning criteria in varying degrees. Moreover, each of the assessment courses, including the Assessment Capstone Series, will require different levels of mastery. The one semester course taken in the sophomore year will require less mastery than the two semester course taken in the junior year. And, the three semester hour assessment capstone will be most demanding.

3. The Protocol System

The protocols below are presented as examples of factors that faculty might take into consideration as they evaluate students' success in mastering PMU learning outcomes and competencies.

These protocols provide a number of guides for learning assessment.

- Expectation – the desired learning outcome and competency.
- Indicators – behaviors associated with the abilities students are expected to demonstrate.
- Criteria – qualities of student performance.
- Standards – behaviors associated with various levels of performance.

B. COMMUNICATION

1. Expectation

The student will be able to communicate effectively in both English and Arabic in professional and social situations.

2. Indicators of Success

1. Determines the nature and extent of information needs.
2. Accesses needed information.
3. Critically evaluates the quality of information in relation to need.
4. Prepares effective written and oral communications.
5. Delivers effective oral communication.
6. Adheres to ethical practices in the use and communication of information.

3. Communication Indicator 1

Determines the nature and extent of information needs.

Achievement criteria:

- Scope of content.
- Reliability of content and sources.

Standards of Performance		
Beginning	Intermediate	Advanced
Requires extensive assistance to identify an appropriate range of potential reliable content.	With minimal assistance, identifies a comprehensive range of potential reliable content; seeks expert consultation as needed.	Independently identifies an excellent and creative range of potential content; seeks expert consultation for new ideas.

4. Communication Indicator 2

Accesses needed information.

Achievement criteria:

- Effectiveness and efficiency of access and retrieval strategies.
- Comprehensiveness of information in relation to need.

Standards of Performance		
Beginning	Intermediate	Advanced
Requires extensive assistance to implement information search and retrieval strategies; information obtained is minimal in relation to need.	With minimal assistance, implements appropriate information and retrieval strategies; information obtained is comprehensive in relation to need.	Independently implements skillful, highly effective information search and retrieval strategies; information obtained is comprehensive and creative in relation to need.

5. Communication Indicator 3

Critically evaluates the quality of information in relation to need.

Achievement criteria:

- Reliability
- Relevance
- Breadth and depth

Standards of Performance		
Beginning	Intermediate	Advanced
Requires extensive assistance to evaluate content and to identify gaps in breadth and depth; is slow to recognize the need for critical evaluation.	With minimal assistance, identifies content appropriate to the need; has little difficulty identifying and overcoming gaps in breadth and depth.	Independently identifies high quality content appropriate to the need; discovers creative and unusual material; easily identifies and overcomes gaps in breadth and depth.

6. Communication Indicator 4

Prepares effective written and oral communications.

Achievement criteria:

- Relevance of communication to purpose.
- Organization of content.
- Quality of communication skills.
- Sensitivity to audience needs and interests.

Standards of Performance		
Beginning	Intermediate	Advanced
Requires extensive assistance to develop a purposeful communication; has difficulty focusing and organizing content; exhibits poor writing skills; exhibits little sensitivity to audience needs and interests; is unable to develop an oral presentation.	With minimal assistance, develops a purposeful communication; achieves good focus and organization of content; exhibits good writing skills; exhibits appropriate sensitivity to audience needs and interests; develops an effective oral presentation.	Independently develops a purposeful communication; achieves excellent focus and organization of content; exhibits excellent writing skills; exhibits high sensitivity to audience needs and interests; develops an excellent oral presentation.

7. Communication Indicator 5

Delivers an effective oral communication.

Achievement criteria:

- Quality of oral communication.
- Effectiveness of presentation strategy.
- Ability to adjust content as needed during delivery.
- Audience reaction.

Standards of Performance		
Beginning	Intermediate	Advanced
Exhibits poor oral communication skills; is unable to present material effectively; does not recognize and adjust to listeners' reactions; gets poor audience reaction.	Exhibits good oral communication skills; delivers an effective presentation; recognizes and adjusts to listener's reactions; gets mostly positive audience reaction.	Exhibits excellent oral communication skills; delivers an excellent presentation; recognizes and adjusts to listener's reactions; develops good rapport with audience; gets enthusiastic and positive audience reaction.

8. Communication Indicator 6

Adheres to ethical practices in the use and communication of information.

Achievement criteria:

- Knowledge of and adherence to ethical practices.

Standards of Performance		
Beginning	Intermediate	Advanced
Is aware of major ethical practice principles related to information use; understands the concept of plagiarism and the importance of acknowledging the work of others.	Explains and consistently applies ethical practice principles in information use.	Consistently applies ethical practice principles in information use; demonstrates a sophisticated understanding of the ethics of using information in a range of contexts.

C. TECHNOLOGICAL COMPETENCE

1. Expectation

The student will be able to use modern information technologies to acquire information, communicate, solve problems and produce intended results.

2. Indicators of Success

- a. Uses IT tools for productivity, communication, research, problem-solving and decision-making.
- b. Recognizes the implications and ethical issues associated with the widespread use of IT.

3. Technological Indicator 1

Uses IT tools for productivity, communication, research, problem-solving and decision-making.

Achievement criteria:

- Effectiveness and efficiency of IT skills.
- Consistency in performance.
- Range and depth of knowledge.
- Independence in performance.

Standards of Performance		
Beginning	Intermediate	Advanced
With assistance, demonstrates understanding of and utilizes the essential features of information technology tools; with assistance, produces acceptable information technology products.	Produces good information technology products, most of which meet a professional standard; makes informed decisions in the use of information technology tools; utilizes mid-level to advanced features of information technology tools.	Produces excellent information technology products, all of which meet a professional standard; utilizes a wide range and the advanced features of information technology tools.

4. Technological Indicator 2

Recognizes the implications and ethical issues associated with the widespread use of IT.

Achievement criteria:

- Awareness of and critical response to legal and ethical IT issues.
- Awareness of the potential impact of widespread IT use.

Standards of Performance		
Beginning	Intermediate	Advanced
Has a growing awareness about a range of legal and ethical issues associated with the use of information technology use; expresses opinions concerning the impact of these issues on individuals and society; is familiar with ethical principles related to the use of information technology.	Is well informed about a range of legal and ethical issues associated with information technology use; expresses well informed opinions concerning the impact of these issues on individuals and society; is consistently ethical in the use of information technology.	Is well informed about a wide range of ethical issues associated with the use of information technology; publicly advocates well reasoned opinions concerning the impact of these issues on individuals and society; expresses well reasoned opinions about the interrelationships among the social, economic, and political factors that arise from widespread use of information technology.

D. CRITICAL THINKING AND PROBLEM SOLVING

1. Expectation

The student will be able to reason logically and creatively, make informed and responsible decisions and solve problems.

2. Indicators of Success

1. Gathers and processes information for decision making.
2. Develops and reasonably defends arguments, positions and decisions.
3. Clarifies problems and develops effective solutions.
4. Executes plans and evaluates results effectively.

3. Critical Thinking Indicator 1

Gathers and processes information for decision making.

Achievement criteria:

- Selects information relevant to purpose.
- Accurately interprets information and evidence.
- Identifies salient arguments and different points of view.
- Recognizes assumptions and perspectives.
- Evaluates the logic, validity and relevance of data.

Standards of Performance		
Beginning	Intermediate	Advanced
With assistance, identifies a limited range of information suited to purpose; interprets information accurately but simply; identifies some arguments, assumptions and perspectives; conducts minimal evaluation of material.	Identifies a good range of information suited to purpose; accurately interprets information; identifies salient arguments, assumptions, perspectives and alternative points of view; conducts well reasoned and comprehensive evaluations of material selected for use.	Identifies a comprehensive range of information suited to purpose; relates and synthesizes information from multiple sources; accurately interprets information; recognizes subtle patterns and meanings; draws insightful, logical, and creative conclusions; conducts excellent evaluation of material selected for use.

4. Critical Thinking Indicator 2

Develops and reasonably defends arguments, positions and decisions.

Achievement criteria:

- Analyzes and evaluates information and alternative points of view.
- Draws well-reasoned conclusions.
- Justifies results by explaining assumptions and reasons for choices.

Standards of Performance		
Beginning	Intermediate	Advanced
With assistance, recognizes the differences and varied perspectives in information sources; draws some reasonable conclusions; provides limited explanation for arguments, positions, and decisions.	Recognizes the differences and varied perspectives in information sources; draws well reasoned conclusions; provides good explanation for arguments, positions, and decisions.	Recognizes the differences and varied perspectives in information sources; is sensitive to implicit assumptions and subtle bias; draws well reasoned, insightful conclusions; provides excellent explanations for arguments, positions, and decisions.

5. Critical Thinking Indicator 3

Clarifies problems and develops effective solutions.

Achievement criteria:

- Identifies and clearly describes the problem.
- Develops and evaluates suitable alternative solutions.
- Proposes an appropriate solution.

Standards of Performance		
Beginning	Intermediate	Advanced
With assistance, describes a problem; explains what can be done about it; identifies several possible solutions; proposes a solution; inadequately defends the appropriateness of the solution.	Clearly and concisely states a problem; seeks input from others; explains what should be done and why; proposes several suitable solutions; presents logical pros and cons for each; proposes an appropriate solution and offers good reasons for choice.	Clearly and concisely states a problem; seeks input from others; insightfully explains what should be done and why; proposes several appropriate and creative solutions; presents logical pros and cons for each; proposes the most appropriate solution and offers excellent reasons for choice.

6. Critical Thinking Indicator 4

Executes plans and evaluates results effectively.

Achievement criteria:

- Determines needed resources.*
- Identifies, organizes and schedules critical tasks.
- Follows-through, adapts and persists to problem resolution.
- Evaluates results.

**Resources could include decisions, permissions, people, and material.*

Standards of Performance		
Beginning	Intermediate	Advanced
With assistance, identifies most needed resources; organizes and sequences critical tasks; poorly executes some tasks; achieves inadequate results; recognizes and explains some but not all strengths and deficiencies of the intended solution.	Identifies and acquires needed resources; logically sequences critical tasks; adjusts implementation as needed; executes most tasks effectively and on schedule; explains the strengths and deficiencies of the solution; makes suggestions for future improvement and problem prevention.	Identifies and achieves all needed resources; organizes and implements critical tasks very well; makes timely and creative adjustments; provides excellent explanations of the strengths and deficiencies of the solution; makes excellent suggestions for improvement and future problem prevention.

E. PROFESSIONAL COMPETENCE

1. Expectation

The student will be able to perform professional responsibilities effectively in both local and international contexts.

2. Indicators of Success

1. Maintains a good work ethic.
2. Sustains positive relations with supervisors, co-workers and clients.
3. Performs professional tasks effectively and efficiently in local and international contexts.
4. Improves and increases professional competence over time.
5. Demonstrates integrity and ethical behavior.

3. Professional Indicator 1

Maintains a good work ethic.

Achievement criteria:

- Adheres to rules and procedures.
- Takes responsibility as necessary to produce expected results.

Standards of Performance		
Beginning	Intermediate	Advanced
With guidance, can adhere to rules and procedures; rarely works extra to meet deadlines; sometimes accepts extra work assignments.	Adheres to rules and procedures; works as needed to meet deadlines; volunteers extra work to complete assignments.	Adheres to rules and procedures; completes assignments by or before deadlines; volunteers work that promotes employer's success.

4. Professional Indicator 2

Sustains positive relations with supervisors, co-workers and clients.

Achievement criteria:

- Maintains positive interpersonal relations.
- Supports and promotes employer’s vision and goals.

Standards of Performance		
Beginning	Intermediate	Advanced
Has difficulty maintaining positive working relationships; sees job primarily in terms of personal benefits.	Maintains positive working relationships; supports employer’s goals; sees job as helping employer meet goals and in terms of personal benefit and professional opportunity.	Maintains excellent working relationships; supports and promotes employer’s goals; accepts and volunteers work that promotes employer’s success; sees job in terms of personal benefit and future professional opportunity.

5. Professional Indicator 3

Performs professional tasks effectively and efficiently in local and international contexts.

Achievement criteria:

- Quality of professional performance.
- Organizational skills and time management.
- Attention to quality.

Standards of Performance		
Beginning	Intermediate	Advanced
Has difficulty performing at a professional level; is uncomfortable outside a local context; needs to improve time management and organization; rarely recognizes inferior quality.	Consistently performs at a professional level; is increasingly effective in both local and international contexts; organizes and manages time effectively; usually recognizes quality problems and corrects them.	Consistently performs at a high professional level; is very effective in both local and international contexts; organizes and manages time very effectively, produces excellent results; often suggests ways to improve quality.

6. Professional Indicator 4

Improves and increases professional competence over time.

Achievement criteria:

- Keeps professional knowledge and skills current.
- Maintains an active program of professional development.
- Improves performance through disciplined reflection and self-assessment.

Standards of Performance		
Beginning	Intermediate	Advanced
Knowledge and skills are not always current; needs encouragement to engage in professional development activities; rarely reflects on personal performance to identify ways to improve.	Knowledge and skills are current; maintains a regular professional development program; regularly reflects on personal performance and finds ways to improve performance.	Knowledge and skills are at the leading edge; maintains an aggressive professional development program; frequently reflects on personal performance and regularly improves performance.

7. Professional Indicator 5

Demonstrates integrity and ethical behavior.

Achievement criteria:

- Knowledge of and commitment to practice ethical principles in personal and professional life.

Standards of Performance		
Beginning	Intermediate	Advanced
Is honest and behaves with integrity; sometimes is unaware of professional ethical expectations.	Is honest and trustworthy; understands and meets personal and professional ethical expectations; is recognized and respected by others for principled behavior.	Is honest and trustworthy, understands and always meets personal and professional ethical expectations; is recognized and respected by others as a role model for principled behavior; promotes ethical behavior of others.

F. TEAMWORK

1. Expectation

The student will be able to work effectively with others to accomplish tasks and achieve group goals.

2. Indicators of Success

1. Cooperates and assumes responsibility for individual contributions and group results.
2. Uses effective interpersonal and group process skills.
3. Facilitates consensus through negotiation and compromise.

3. Teamwork Indicator 1

Cooperates and assumes responsibility for individual contributions and group results.

Achievement criteria:

- Sensitivity to others' needs interests and concerns.
- Openness to ideas and suggestions.
- Willingness to accept responsibility and take accountability for results.

Standards of Performance		
Beginning	Intermediate	Advanced
May disagree with others' opinions but tolerates their expression; rarely responds to others' ideas and suggestions; seldom produces results.	Listens and responds to others' ideas in a positive and constructive manner; contributes useful ideas and suggestions and makes appropriate adjustments based on feedback; offers to take responsibility; produces good results, willingly accepts accountability for outcome.	Consistently listens and responds to others' ideas in a positive and constructive manner; frequently offers excellent ideas and suggestions and makes appropriate adjustments based on feedback; guides the group toward ideas and suggestions with greatest potential; often takes responsibility; produces excellent results and always accepts accountability for outcome.

4. Teamwork Indicator 2

Uses effective interpersonal and group process skills.

Achievement criteria:

- Understands and accepts the strengths and limitations of group members.
- Makes constructive contributions to group discussions and debates.
- Appropriately responds to others' confusion, anger, and distress.
- Suggests ways to improve the efficiency and effectiveness of the group.

Standards of Performance		
Beginning	Intermediate	Advanced
Has difficulty identifying the potential of group members; rarely makes constructive contributions to discussions or debates; responds poorly to others' frustrations; rarely offers suggestions that could improve group process.	Identifies and acknowledges the potential of each group member; makes constructive contributions to discussions and debates; responds appropriately to others' frustrations; suggests ways to improve group process.	Identifies and publicly praises the contributions and potential of each group member; frequently makes constructive contributions to discussions and debates; empathizes and skillfully supports others through frustrating experiences; takes action that improves group process.

5. Teamwork Indicator 3

Facilitates consensus through negotiation and compromise.

Achievement criteria:

- Offers useful and creative ideas that improve group goals and process.
- Offers and accepts feedback that moves the group toward agreement.
- Promotes modifications or alternatives that foster consensus.
- Acknowledges and supports others' contributions.

Standards of Performance		
Beginning	Intermediate	Advanced
Occasionally suggests ideas that contribute to agreement; has difficulty building forward from others' ideas; offers weak or negative feedback; sometimes acknowledges others' contributions.	Assists the group to focus on the goal; offers good ideas that contribute to agreement and improve group performance; offers and readily accepts constructive feedback; supports alternatives and modifications that foster consensus; usually acknowledges and supports others' contributions.	Assists the group to focus on the goal; offers excellent ideas that contribute to agreement and improve group performance; encourages and easily accepts feedback from others; facilitates group analysis and acceptance of better ideas; summarizes agreements to foster consensus; frequently acknowledges and supports others' contributions.

G. LEADERSHIP

1. Expectation

The student will be able to function as an informed, effective and responsible leader in family, community and the nation.

2. Indicators of Success

1. Offers vision and purpose that inspires others' confidence and following.
2. Effectively plans and organizes projects.
3. Effectively delegates responsibility and coordinates group work.
4. Produces quality results.

3. Leadership Indicator 1

Offers vision and purpose that inspires others' confidence and following.

Achievement criteria:

- Communicates visionary and appropriate goals.

Standards of Performance		
Beginning	Intermediate	Advanced
Rarely convinces others to participate in a project he/she proposes; has difficulty sustaining others' commitment and participation over the project's duration.	Convinces others to participate in a project he/she proposes; usually sustains their commitment and participation over the project's duration.	Easily convinces other to participate in a project he/she proposes; sustains their commitment and enthusiastic participation over the project's duration.

4. Leadership Indicator 2

Effectively plans and organizes projects.

Achievement criteria:

- Determines and sequences tasks required to meet objectives.
- Develops timelines and schedules that satisfy deadlines.
- Acquires needed resources. *

**Resources include policies, agreements permissions, financing, personnel and materials.*

Standards of Performance		
Beginning	Intermediate	Advanced
With assistance, identifies and sequences project tasks; has difficulty plotting realistic timelines; identifies some, but not all required resources.	Identifies and sequences project tasks; plots realistic timelines; identifies and procures all needed resources.	Identifies and sequences project tasks; plots realistic timelines that include contingency strategies; identifies and procures all needed resources.

5. Leadership Indicator 3

Effectively delegates responsibility and coordinates group work.

Achievement criteria:

- Communicates goals effectively.
- Respect for individual abilities in the delegation of tasks.
- Motivates, sustains morale and positive interpersonal relations.
- Monitors progress and takes corrective action as needed.

Standards of Performance		
Beginning	Intermediate	Advanced
Communicates unclear goals; has difficulty delegating tasks to the most qualified individuals; has difficulty identifying problems and taking corrective action; does not consistently sustain productivity and morale of workers.	Usually communicates clear goals; delegates tasks to the most qualified individuals; resolves conflicts; sometimes prevents problems and takes timely corrective action; sustains worker productivity and morale over time.	Communicates clear goals; delegates tasks to the most qualified workers; prevents most conflicts and resolves them quickly if they arise; prevents most problems and takes timely corrective action; sustains worker productivity and morale over time.

6. Leadership Indicator 4

Produces quality results.

Achievement criteria:

- Motivates and supports quality performance from others.
- Effectively supervises and monitors work.
- Adjusts to context.
- Meets or exceeds quality expectations and standards.

Standards of Performance		
Beginning	Intermediate	Advanced
Has difficulty communicating quality expectations; provides erratic supervisory oversight; is uncomfortable outside a local context; produces poor quality results.	Communicates expectations consistent with recognized quality standards; generally provides effective supervisory oversight; regularly monitors output for adherence to quality expectations; takes corrective action as needed; usually produces results that meet quality expectations.	Communicates quality expectations that exceed recognized quality standards; effectively motivates others to better performance; is very effective in both local and international contexts; provides effective and supportive supervisory oversight; closely monitors output and frequently encourages quality improvement; usually produces results that exceed quality expectations.

APPENDIX B

CORE CURRICULUM SCIENCE LABORATORIES

I. INTRODUCTION

Prince Mohammad Bin Fahd University (PMU) will provide education in a number of technical and scientific areas in both the academic majors and the Core Curriculum. Key to successful training in these areas is the creation and maintenance of state-of-the-art laboratory facilities. Students must be trained in great depth in the practical aspects of their chosen disciplines. They must have more than a superficial knowledge of the techniques and technical demands and challenges of all of the sciences.

The Undergraduate Core Curriculum, which requires that all PMU students take a minimum of eight hours of laboratory science courses (a requirement that is increased by some of the university's major courses of study) provides the framework for a rigorous science curriculum. This addendum to the report *Undergraduate Core Curriculum Design* therefore expands specifically upon the infrastructure requirements that the PMU must accommodate for its Core Curriculum science laboratories.

II. MULTIPURPOSE VS. DEDICATED SPACE

Laboratory planning and design have gone through many phases as curricular needs have changed and evolved. Yet a common thread appears – the most robust designs involve a partnership between architects, facilities planners, and the scientists and educators who will occupy the laboratories. Too often forgotten are the needs associated with the laboratory staff – those who teach the labs sessions as well as those who set up the labs, prepare the labs, and finally clean up afterwards.

A modern view of laboratories, their planning, and their construction is therefore an integration of the needs of the students, the needs of the instructional personnel, and the requirements of the technical facilities themselves.

In order to provide the PMU with state-of-the art facilities teaching methods, this report therefore recommends multi-purpose laboratory spaces for the Core Curriculum science courses.

A. ADVANTAGES OF MULTIPURPOSE SPACE

In the beginning, the PMU will offer a schedule of sciences classes at the introductory level. Keeping this fact in mind, this report focuses on the needs of the introductory courses in physics, chemistry, biology and geology. (Potential needs of upper level courses are discussed briefly at the end of the report.)

Because introductory science courses such as these have more needs that are common than different, the recommendation of this report is that the PMU create “multipurpose” or “generic” rather than “dedicated” or “unique” laboratory spaces. The advantages of multipurpose labs – that is, those labs with similar if not identical floor plans, which are typically similarly outfitted with respect to utilities – are discussed below.

1. Greater Scheduling Flexibility and Efficiency

Multipurpose laboratory space generally provides for greater efficiency in space utilization and planning. If, for example, physics proved over time to be a more popular course with higher demand than at first anticipated, laboratory space that had been used by a course in less demand could simply be re-assigned without major reconfiguration of the laboratory room.

2. Reduced Cost

Multipurpose laboratories typically achieve economies of scale. Since multipurpose laboratories are similarly or almost identically outfitted, the university can realize significant savings by ordering standard, non-custom furniture and fittings in bulk.

3. Broader Design Choices

In recent years, a large number of vendors have capitalized on the trend toward the design and construction of multipurpose labs. These vendors’ designs and patterns for undergraduate teaching laboratories have proven to be both functional and durable.

II. A MULTIPURPOSE SCIENCE LABORATORY CONFIGURATION

Traditionally, each science discipline was given its own space -- chemistry departments with their own teaching labs in the chemistry building and biology labs in the biology building, for example. While research and faculty office infrastructure continues to be organized along these lines, many universities are now moving to common introductory laboratory facilities situated in a single building designed for that purpose.

A. ORGANIZATIONAL ADVANTAGES

The change is not simply an architectural fad. Rather, there are compelling reasons for this organization of facilities.

1. Eliminating Redundancy in Equipment

Foremost among them is the ability to create common areas that eliminate redundancy. The creation of such common areas means there is no need for equipment to occur in each multipurpose laboratory. For example, almost every lab will need an ice machine for at least one exercise during

the semester, but not every lab will need an ice machine for each of its labs. A centrally located common facility room with a single large ice-machine that is frequently used therefore is more efficient than equipping each laboratory with a small, infrequently used ice machine.

2. Increasing Efficiency of Staff

The requirements of staffing also drive this trend in laboratory arrangement. Staff not only instruct in the laboratories, but they also set up the lab equipment, prepare materials for each lab, and clean up and disassemble the equipment once a lab has finished. A common area for housing laboratory staff makes the most efficient use of time and space. Remotely located laboratories for each discipline require dedicated staff for each program. Multipurpose labs, by contrast, can be serviced by a common group of support staff working in collaboration with the discipline-specific instructor for each lab.

B. REQUIREMENTS FOR A “UNIT” MULTI-PURPOSE LAB

1. Key Assumptions

The recommendation for a multi-purpose teaching laboratory configuration makes several key assumptions:

a. Degree of Specialization

The teaching laboratory will be sufficiently specialized to provide instruction of any one of the disciplines taught in the PMU Core Curriculum: Physics, Chemistry, Biology or Geology. Yet, the teaching laboratory will be sufficiently generic to permit instruction in any these disciplines on a rotational basis

b. Number of Students

The optimal number of students to be accommodated in any one laboratory session is 24. This is derived from the creation of an average of 6 teams consisting of an average of 4 students each.

c. Number and Size of Labs

At 24 students per lab, the PMU Core Curriculum will require four labs for male students and three labs for female students. The recommended space per student in a generic wet lab is 2.5 square meters..

A detailed discussion of space requirements for a full range of Core Curriculum classroom and lab facilities, calculated from the anticipated enrollment of the PMU, is contained in the May 3, 2004 memorandum titled *PMU Space Program: Report of Zuhair Fayed Architect visit to Austin, Texas.*

d. Configuration of Work Space

A laboratory is most efficiently organized on the basis of “pods” or “clusters” of four to five students, rather than the linear alignment of benches facing a podium and backed by a board. A typical configuration is shown in Figure 1.



Figure 1.
Biology teaching laboratory, Francis Marion University, Florence, South Carolina, USA.

2. Utilities Required

a. Laboratory Clusters

Each laboratory cluster will require the following utilities.

- Electrical: 120 and 240 volts, with one 20 amp circuit per room cluster, and GRCI-protected electrical outlets.
- Hot and cold water
- De-ionized water
- Plumbing drain
- Distilled water (optional, but very useful)
- Natural gas
- Compressed air
- Vacuum

b. Laboratory Rooms

Each laboratory room will also require:

- Three white boards behind a raised instructor's podium or bench
- Audio-visual equipment, including data projection equipment linked to instructors computer and monitor. Equipment is used for projecting results and other instructional information
- Wireless network to enable students to access data via their laptop computers
- telephone
- Safety equipment, including the following readily accessible items:
 - smoke detectors
 - carbon monoxide detectors
 - fire extinguishers
 - fire blankets
 - safety shower
 - safety eye flush station
 - safety goggles
 - emergency utility cutoff panel.
- Bright lighting, either fluorescent or natural. If lighting is natural, window shades should be provided.
- Waste disposal facility with the ability to handle potentially hazardous waste.
- Fume hood
- Flammable storage cabinet
- Vented acid cabinet

NOTE: With the exception of drains, overhead delivery of utilities is preferable, as it provides maximum flexibility. This will simplify modifications if changes in use become necessary.

c. The Laboratory Complex

The entire laboratory complex is ideally arranged so that laboratories are adjacent to each other, with easy access to prep rooms, storage and support staff offices.

Figure 2 shows a configuration of three multi-purpose laboratory rooms separated by preparation and storage areas. This configuration also shows two offices for laboratory support staff. A specialized facility (in this example, a greenhouse in support of biological laboratories) is located nearby.

The common areas in such a laboratory complex should contain:

- fume hood
- extensive storage areas for laboratory equipment
- preparation areas for washing and storing glassware
- weighing area and chemical storage (including vented acid cabinet and flammable liquid storage)

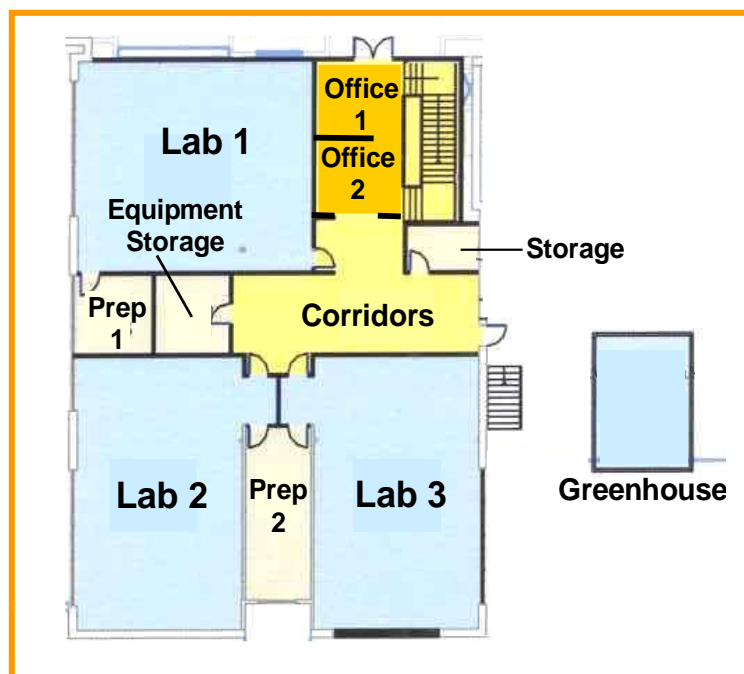


Figure 2.
A Typical configuration of an integrated science laboratory.
("Prep" indicates preparation room.)

C. EQUIPPING THE LABORATORIES

Providing the necessary equipment for each of these laboratories will be a time-consuming process. At least six months and preferably 12 months should be provided to ensure that all equipment has arrived and been set up (and calibrated, if necessary).

A planning team therefore should be assembled early that includes experienced laboratory instructors from each of the disciplines (physics, chemistry, biology, and geology) that will be taught in the PMU Core Curriculum. Working with PMU enrolment data and the syllabi for the Core Curriculum science courses, the team will be able to develop a detailed, comprehensive equipment and supplies list, with current prices, for each undergraduate discipline.

The team typically will create independent lists for each discipline taught. An important step in the process, however, is that the team then examines the independent lists for common pieces of equipment that could reasonably be moved from lab to lab rather than purchased for each lab.

An example of such equipment might be balances (or possibly even computers), which can be shared depending upon scheduling of laboratories and laboratory exercises.

D. PLANNING FOR THE FUTURE

As The PMU grows in stature and enrolment, it is quite feasible that upper level courses will be offered in biology, chemistry, physics, and geology. These more sophisticated laboratory offerings will typically require more specialized space. While some of the Core Curriculum's multi-purpose laboratories could host upper level activities with relatively little modification, they likely will be unavailable. The program's initial complement of labs likely will remain fully occupied by freshmen students.

Consequently, any plan for science laboratories at the PMU should plan for the possibility of future expansion. It is common for multipurpose laboratories to be placed in a centralized location in a conjoined arrangement (as in Figure 2), but for more specialized laboratories to be located closer to faculty research labs and offices.

A strong and growing trend in science higher education is the establishment of "student research" programs, where students learn how to conduct original research. Typically, the equipment and space for such activities is integrated into the upper level teaching facilities.