Engineering

Mathematics

Physics

Chemistry

Biology

Skills for the Millennium

A Guide for Curriculum Innovation in Science, Mathematics and Engineering based on Survey Results of Skills Required for Today's Graduate

Lueny Morell

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NSF PR LS-Alliance for Minority Participation
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Cover and layout design: Miguel A. Torres and Andrea J. Torres

The Need for Curriculum Innovation

Once upon a time, newly graduated scientists and engineers were expected by the organizations who hired them to be technically competent, but not necessarily to have strong skills in business, communication, leadership, teamwork, and other non-technical areas. In organizations such as large corporations and government institutions, such skills were learned on the job, over time and at the expense of the employer.

Universities and technical institutes were not required to prepare professionals in those non-technical areas.

Times have changed.

In today's highly competitive global market, many organizations (especially the fast-growing sector of small and medium-sized companies) can no longer afford the time or resources to offer intensive training programs for new employees, or to wait for much-needed skills to develop on the job. They now demand from universities a more complete professional. One who can, right from the beginning, solve highly technical problems *and* effectively use a wide range of non-technical skills.

Colleges and universities now must review their curricula to meet the demands of their graduates' new marketplace.

Accreditation boards are one of the driving forces behind the initiative for change. National organizations, such as professional associations, are working to help educators design innovative curricula that develop the skills being required in their graduates.

What are those skills?

This document attempts to answer that question by presenting the results of a literature search and of a number of surveys conducted by national organizations, educators and industry representatives. It provides information about the characteristics, abilities and traits that industries, universities and accreditation boards are demanding in today's graduates.

This document is intended for people like its authors: educators who want to help their students become well-rounded graduates with high professional aspirations and the ability to fulfill their professional potentials, graduates with strong marketability and the capacity to make meaningful contributions to their companies and to their local and global communities.

This work has been prepared by the Curriculum Innovation Center of the National Science Foundation Puerto Rico Louis Stoke Alliance for Minority Participation (PR-AMP). The authors do not assume this to be a comprehensive document, as there may be additional resources to be tapped. However, it is hoped that, as a sampling of the information available, this compendium of skills and competencies will be a useful tool for curriculum innovation in universities and colleges across the country.

The Need

Organizations who hire scientists and engineers now demand from universities a more complete professional. One who can, right from the beginning, solve highly technical problems and effectively use a wide range of non-technical skills.

Colleges and universities must review their curricula to meet the demands of their graduates' new marketplace.

Purpose of This Document

This document provides information about the characteristics, abilities and traits that industries, universities and accreditation boards are demanding in today's graduates.

Engineering

Mathematics

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Employers require the same basic non-technical skills from all graduates.

- **Communication**
- **Teamwork**
- **Ability to apply ethical principles**
- **Capacity for life-long learning.**

"Analysis of the data points towards trends in employers' desires for skills of decision-making, risk-taking, conflict-resolution and leadership."

Summary and Highlights

This document presents, in the form of lists, skills and competencies sought in today's graduates. In the fields of engineering and mathematics, we have presented the results of numerous surveys that were conducted by a variety of sources over the last ten years. In the areas of physics, biology and chemistry, we reviewed a sampling of recent (Spring 2000) job listings and identified typical skills required (in many cases, advanced degrees were sought).

Although employers look for different academic background and technical competencies from graduates of different disciplines, they require the same **basic non-technical skills** from all. While the lists vary in length and wording, the following four non-technical skills appear in nearly every list: **communication, teamwork, the ability to apply ethical principles, and the capacity for life-long learning.**

Analysis of the data points towards trends in employers' desires for skills such as decision-making, risk-taking, conflict-resolution and leadership. At least one survey highlighted the growing need for "foreign language skills and an understanding of foreign business philosophies and practices," as well as an appreciation of different cultures. Awareness of global issues, such as the economy and the environment, are now expected in new graduates. The entrepreneurial spirit is considered an asset to any small or large corporation in today's market.

Due to rapid changes in technology, today's graduates in science and engineering must be prepared for a wide range of challenges in the workplace. University curricula must respond quickly to that need. This report serves as a guide in helping educators design the best curriculum for their institutions and students, in order to better prepare graduates for the challenges that lie ahead, and give them the necessary *Skills for the Millennium*.

Non-Technical Skills for All Professionals

The skill listings presented in this document suggest the need for all recent graduates to be competent in a wide variety of non-technical skills. However, most frequently mentioned are communication skills, teamwork skills, the ability to apply ethical principles and the capacity for life-long learning.

Communication.

One of the most important non-technical skills outlined by the different surveys reviewed is communication. Due to the scientific and highly technical nature of the professions surveyed, scientists and engineers must have the ability to communicate accurately and effectively, both orally and in writing, with non-technical professionals as well as with their peers. Examples of communication tools used by scientists and engineers include:

- Oral presentations
- Progress reports
- Memos
- Business letters
- Instruction manuals
- Computer codes
- Funding proposals
- Tables and graphs

Graduates must feel comfortable with today's communication technologies, including the telephone (teleconferencing, videophoning, etc.), fax machine, and computer technologies such as word processing packages, spreadsheets, databases, presentation packages, computer-aided tools (e.g., AutoCad, MathLab, etc.), and Internet technologies, among others.

Listening and *speaking* skills are fundamental to any form of communication. Although these develop with time and experience, students should be exposed to the kinds of business activities that require use of those abilities, activities such as technical meetings, brainstorming sessions, client meetings and presentations. Exposure to these aspects of the business world will help young professionals improve their abilities to gather and prioritize information, organize their thoughts, build logical arguments, distinguish opinion from fact, develop patience and other interpersonal skills, observe different working styles and begin to discover styles of their own. At least one survey specified the need for foreign language skills in its new employees. In an increasingly globalized economy, communication skills that are appropriate to cross-cultural environments are necessary.

Due to the scientific and highly technical nature of the professions surveyed, scientist and engineers must have the ability to communicate accurately and effectively with non-technical professionals as well as with their peers.

The fundamentals of communication:

Listening & Speaking

At least one survey specified the need for foreign language skills in its new employees. In an increasingly globalized economy, communication skills that are appropriate to cross-cultural environments are necessary.

Science and engineering curricula should give students the opportunity to grapple with ethical problems and to begin developing a sense of their own ethical integrity.

Teamwork.

The complexity of today's technology and economy makes it imperative that professionals be able to work in teams, often under the pressure of tight budgets and deadlines. Expertise must be shared among people of different disciplines, generations, experiences, geographic locations and cultures. Among the most important teamwork skills are leadership, the ability to delegate and supervise, skills of negotiation, decision-making and problem-solving. All of these require an awareness of self, others and the environment; curricula should nurture that awareness.

Ability to apply ethical principles.

Emerging sciences and technologies have a more profound and direct effect on the individual, society and the environment than ever before. Computer viruses, invasion of e-mail privacy, cloning, and waste disposal are ethical issues that receive high visibility in the media. Less sensational but equally important are the day-to-day ethical questions that arise among scientists and engineers in the research and development laboratory. As evidenced by the survey results presented here, such professionals must be aware that their decisions and actions can have environmental, legal and financial ramifications, as well as impact on the company's image (especially in the eyes of its customers and shareholders) and its ability to do business in a competitive market. Science and engineering curricula should give students the opportunity to grapple with ethical problems and to begin developing a sense of their own ethical integrity.

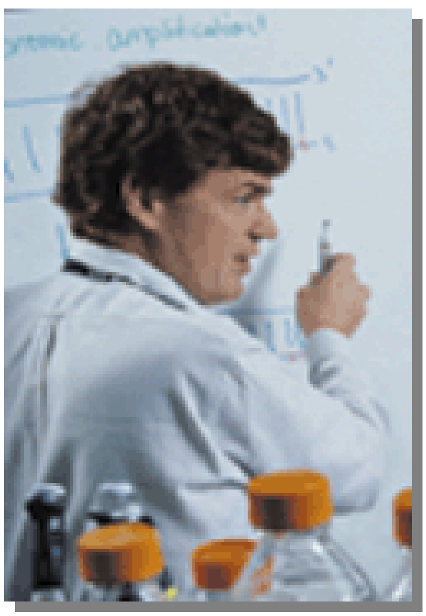
The surveys suggest that educators should provide role models for life-long learning keep curiosity fresh and give students the opportunity to experience the excitement of learning so that they will develop a life-long desire for that unique satisfaction.

Capacity for life-long learning.

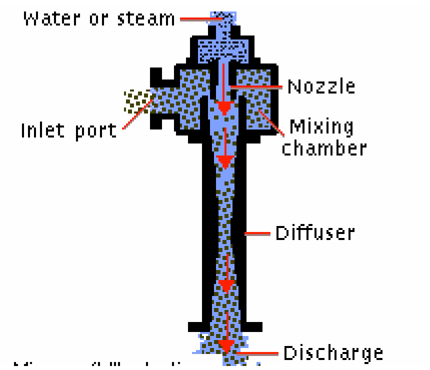
In a world where the frontiers of scientific and engineering knowledge are ever expanding, and technology is constantly changing, the new graduate must have a capacity for life-long learning. In order to continue contributing to the growth of industry, and to retain his or her value in the workforce, the young professional must continue acquiring knowledge and experience. The survey results compiled in this document indicate that the following skills and attitudes are associated with the capacity for life-long learning.

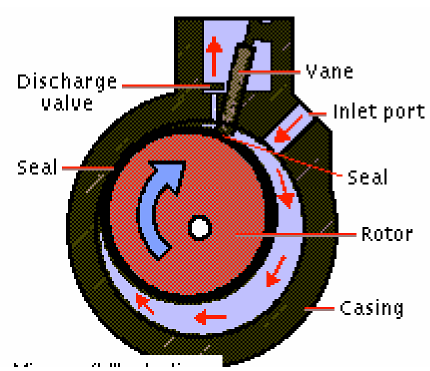
- Ability for self-learning
- Capacity to learn from mistakes
- Ability to adapt quickly to change
- Curiosity and an excitement for learning
- Ability to assess and take risks

These skills and attitudes will empower the science and engineering professional to become both leader and mentor. Educators, who can themselves serve as role models for life-long learning, must provide exciting educational experiences that will develop in students the joy and satisfaction of exploration, discovery and accomplishment.

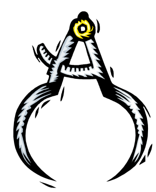


Skills for Today's Engineer





The survey results presented below in the field of **engineering** indicate that today's graduate must have a solid foundation in engineering science. In particular are the abilities to structure and solve problems, design and conduct experiments, and interpret and present data. Programming and other computer skills are highly desirable. The surveys also emphasize the need for same four *non-technical* skills discussed earlier in this document: communication, teamwork, the ability to apply ethical principles, and the capacity for life-long learning.



Survey Lists

www.NSPE.org October 1999

- Competency
- Teamwork
- Communication
- Commitment to ethics
- Commitment to personal growth
- Ethical conduct: protection of public health, safety and welfare

Ghazanshahi, Shahin and Kuo, Jeff. *Shaping Engineering Education for High Tech Industries*, October 1999.

1. Teamwork Capabilities

2. Effective Communications Skills
   - Ability to exchange ideas verbally, in writing or graphically.
   - Cross-disciplinary knowledge in marketing, finance, accounting, economics, business, time management, environmental and legal issues.

3. Leadership Potential
   - Ability to make decisions, assume responsibility, forge a team consensus and display self-confidence.

4. Broad-Based Management Skills

5. Creativity and Vision
    - Imagination and Competence

6. Awareness of a Wide Range of Knowledge
    - Well-versed in science and technology.
    - Knowledge of, and ability to use, various design tools and software for analysis, design and communication.

7. Commitment to Life-Long Learning
    - Ability to practice *asynchronous education* (self-learning at any time or place).

8. Strong Customer Focus
    - Awareness of product requirements that address the needs and values of customers (primarily reliability and cost-effectiveness)
    - Well-versed in the supplier-side relationship.

9. Safety-Oriented Approach
    - Ability to identify and mitigate risk.
    - Ability to design for safety, first and foremost.

10. Ability to Design for Performance, Reliability and Quality
    - Mastery of probability and statistics.
    - Ability to assist in improving operations while taking economic and political pressures into consideration.

11. Professional Ethics
    - Personal traits of honesty, sincerity, timeliness, loyalty and professionalism.

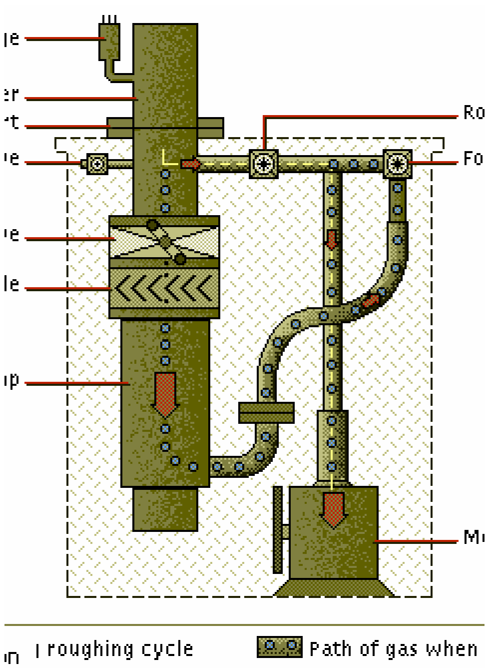
Leake, Woodrow. *Most Likely to Succeed*, ASEE Prism, April 1993, p. 9.

Today's engineer must have a broad, interdisciplinary worldview and the flexibility to adapt rapidly to the challenges of global competition. In particular, he or she must have:

- Versatility and flexibility
- Teamwork skills
- An interdisciplinary perspective
- Good communication skills
- Sensitivity to the environment
- Grounding in the basics of *Total Quality Management*
- An appreciation for how his/her work relates to the bottom line

Joint Task Force on Engineering Education Assessment. *A Framework for the Assessment of Engineering Education*, ASEE Prism, May - June 1996, pp. 19 – 26.

- Ability to apply knowledge of mathematics, science and engineering.
- Ability to design and conduct experiments, and analyze and interpret data.



- Ability to design a system, component, or process to meet desired needs.
- Ability to function on a multidisciplinary team.
- Ability to identify, formulate, and solve engineering problems.
- Understanding of professional and ethical responsibility.
- Ability to communicate effectively.
- The broad education necessary to understand the impact of engineering solutions in a global/societal context.
- Recognition of the need for, and ability to engage in, life-long learning.
- Knowledge of contemporary issues.
- Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Lih, Marshall M. *Educating Future Executives*, ASEE Prism, January 1997, pp. 30 – 34.

Today's graduates must have the skills to become:

- Decision makers
- Strategic thinkers
- Opinion shapers
- Planners of the corporation
- Leaders of the industry

They must have:

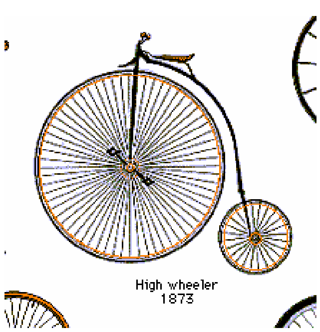
- Conceptual skills for thinking beyond the current paradigm.
- Effective communication skills, management skills and business knowledge.
- A global vision of things to come.

Engineering programs must:

- Offer curricula that are eclectic and integrative, allowing engineers to become first-rate integrators.
- Train engineers to be able to handle complexity along with simplicity; uncertainty as well as precision; flexibility in addition to efficiency; problem formulation as well as problem solving; individual work and teamwork.
- Help students develop the following leadership traits:

    1. Knowledge: the ability to understand empirical and theoretical concepts; the development of analytic and learning skills.
    2. Know-how: the ability to put knowledge to work, often in cross-disciplinary, integrative teams; the development of synthesizing skills.
    3. Judgment: the ability to set priorities in using time, energy and resources; a sense of ethical and societal responsibility; the development of risk-taking skills.
    4. Character: the ability to inspire others; motivation, perseverance, and integrity.

- Prepare students to lead a diverse workforce. Graduates must be able to integrate workers of different genders, ethnicities, races and national origins.



- Ensure that their graduates have foreign language skills and an understanding of foreign business philosophies and practices, as well as cultures.
- Enlist the help of the corporate world in giving students a stronger early exposure to "corporate culture" through seminars, visits, interviews, co-ops, and internships with leaders and executives. Someday *they* will have to change the corporate culture in accordance with the evolving needs and environment of their world, not simply be absorbed into the culture "as is."

Morgan, Robert P., Reid, Strickland, Donald E., Kannankutty, Nirmala, and Grillon, Joy *Research on Research Part II*, ASEE Prism, Nov 1994, pp. 30 – 35.

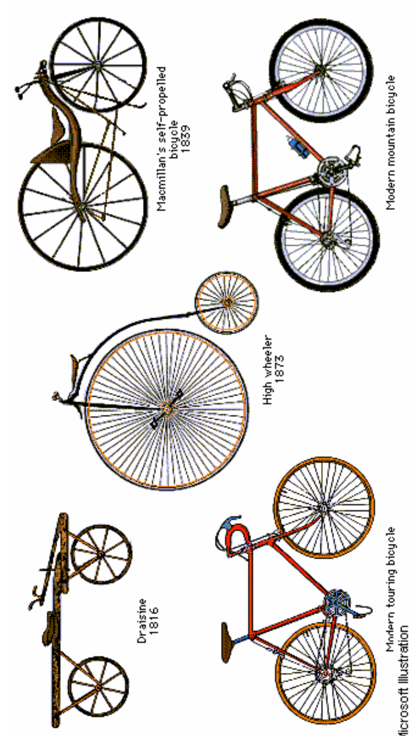
Benefits of university-based student research experiences:

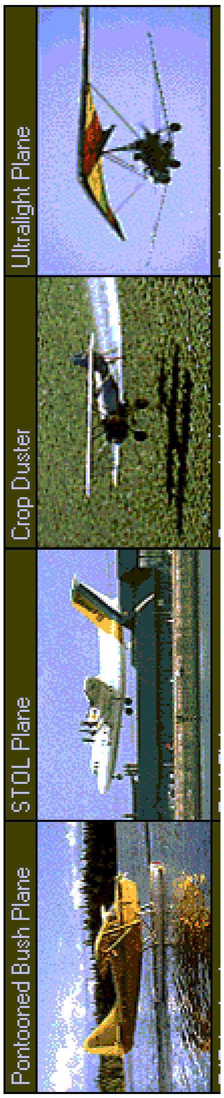
- Acquisition of knowledge in a specific area of interest.
- Acquisition of fundamental research skills.
- Acquisition of problem-solving skills.
- Acquisition of maturity and confidence as an independent researcher.
- Acquisition of improved communication skills.
- Utilization of cutting edge technology.
- Acquisition of cross-disciplinary research experience.
- Acquisition of an understanding of real-world industrial problems.
- Interaction with industrial researchers.
- Interaction with governmental researchers.

Morgan, Robert P., Reid, Proctor P., and Wulf, Wm. A. *The Changing Nature of Engineering*, ASEE Prism, May-June 1998, pp. 13 – 17.

Today's engineer must:

- Have the ability to adapt and respond to rapid changes in technology.
- Have the ability to work in teams.
- Focus less on fundamental research.
- Act more like a manager of technology than a practitioner.
- Respond to today's demands for continuing his/her education.
- Know how to incorporate more variables, to manipulate more complex systems, and to explore multiple designs in an economically and ecologically sound manner by using computer models to cope with more complex design demands.
- Be environmentally conscious.
- Be aware of society's acceptance of outcomes.
- Fuse technical, managerial, financial, and industrial skills.
- Possess strong communication skills.
- Possess strong research abilities.
- Be able to deal with diversity.
- Have knowledge of life sciences.
- Be familiar with information technology.
- Have business and management skills.
- Be socially and politically concerned.





Burroughs, Robert. *Technology and New Ways of Learning*, ASEE Prism, January 1995, pp. 20 – 23.

- Technical proficiency
- Teamwork and collaboration skills
- Project-oriented experience
- Problem-solving skills

Peterson, George D. *Engineering Criteria 2000: A Bold New Change Agent*, ASEE Prism, September 1997, pp. 30 – 34.

- Cutting-edge technical capabilities
- Ability to communicate
- Ability to work in teams
- Ability to think creatively
- Ability to learn quickly
- Ability to value diversity
- Innovativeness
- Commitment to continuous self-improvement

Panitz, Beth. *Evolving Paths*, ASEE Prism, October 1996, pp. 23 – 28.

- Understanding of technology
- Problem-solving skills
- Logical thinking skills
- Mathematical modeling skills
- Knowledge of computer databases, communication technology, software
- Life-long learning skills and desire
- Interdisciplinary knowledge and work experience; non-technical skills
- Teamwork and communication skills

***Report on surveys of opinions by engineering deans and employers of engineering graduates on the first professional degree,* NSPE – PEE Sustaining University Program, Publication No. 3059, November 1992, pp. 5, 9.**

The following skills are listed in order of the value surveyed organizations place on preparation in each area.

- Teamwork
- Product/System Design
- Leadership
- Integrative Thinking
- Social/Ethics/Environment
- Math and Science
- Market Environment
- Social Sciences

These areas would merit more time in a revised curriculum (listed in order of importance).

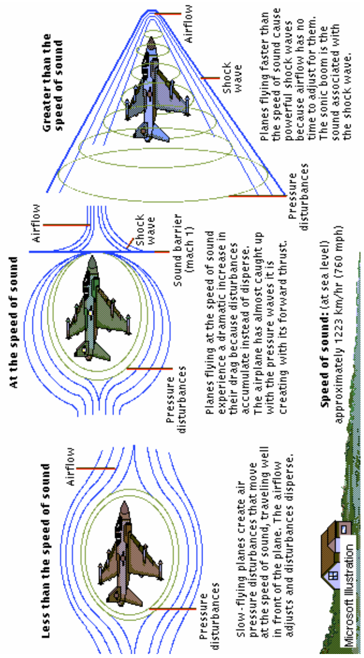
- Improvement of Communication Skills
- Practice and Internships
- More Basic Science
- More Engineering Design
- Self/Social Management
- Specialty Engineering
- Humanities/Ethics

Lang, James D., Cruse, Susan, McVey, Francis D., and McMasters, John *Industry Expectations of New Engineers: A Survey to Assist Curriculum Designers,* Journal of Engineering Education, January 1999, pp. 43 – 51.

Rank Order of Survey Results per ABET Criteria 2000:

A. An ability to apply knowledge of mathematics, science and engineering.
- Engineering courses with applications.
- Ability to structure, solve, and report on solutions in the engineering specialty.
- Ability to apply knowledge of General Physics.
- Single and multivariate calculus through ordinary differential equations.
- Linear algebra, vector analysis, and numerical analysis.
- Computer and information science – software development for an engineering specialty.
- Ability to structure, solve, and report on solutions in mathematics.
- Ability to structure, solve, and report on solutions in physical sciences.
- Probability theory and statistics with applications to engineering problems.
- Probability theory and statistics with applications to manufacturing process.
- Ability to apply knowledge of General Chemistry.

B. An ability to design and conduct experiments, as well as to analyze and interpret data.
- Demonstrated ability in data analysis and interpretation.
- Experience as a team member.
- Experience in executing designed experiments.
- Demonstrated ability in performing experiments.
- Demonstrated ability in design of experiments.
- One year of team experience.
- Understanding of methodology for design and analysis of experiments (single-variable problems).
- Two years of team experience.
- Experience in executing experiments in single-discipline teams.
- Experience in the design and analysis of experiments (single-variable problems).
- Experience using and interpreting results of designed experiments (single-variable problems).
- Experience in experiments to evaluate products at component level.
- Understanding of methodologies for design of experiments (multivariable problems).



- Experience in executing experiments in multidisciplinary teams.
- Experience using and interpreting results of designed experiments (multivariable problems).
- Experience in design and execution of experiments considering design-to-manufacturing productivity.
- Experience in the design and analysis of experiments (multivariable problems).
- Three years of team experience.
- Experience in the design and execution of experiments considering fabrication and assembly.
- Knowledge of the concept and application of manufacturing variability.
- Knowledge of the concepts of quality and cost of quality.
- Experience in experiments to evaluate products at subsystem (Black Box) level.
- Knowledge of, and experience in ,statistical process control.

C. An ability to design a system, component, or process to meet desired needs.
- Demonstrated ability to design a component.
- Demonstrated ability in an upper-division, team-based design project.
- Understanding of the concept “form follows function.”
- Demonstrated ability to design a subsystem (or Black Box).
- Demonstrated ability to design a process.
- Knowledge and understanding of the concept of “robustness.”
- Demonstrated ability to design a system.
- Knowledge of materials and materials science.
- Experience in designing systems considering performance requirements.
- Experience in the design of structures considering manufacturing and cost requirements.

D. An ability to function on multidisciplinary teams.
- Participation on a team in laboratory science or engineering courses.
- Participation in an upper-division, team-based design project.
- Participation on a problem-solving/decision-making team.
- Participation as an industry summer employee.
- Participation as an industry co-op student.
- Participation on a collaborative industry/student design team.
- Participation in reporting team results.
- Participation in developing team strategies, plans, and schedules.
- Participation on a computer simulation team.
- Participation in evaluating team products.
- Participation in evaluating team performance.
- Participation in development of risk management plans.
- Participation as a team leader.

E. An ability to identify, formulate, and solve engineering problems.
- Ability to identify problems.
- Ability to formulate problems.
- Ability to formulate a range of alternative problem solutions.
- Ability to choose a problem solution.
- Ability to resolve conflicts in problem solution decision-making.
- Skill in documenting problem formulation-to-recommend solution.

- Skill in conducting library and professional field research.
- Skill in developing creative solutions.
- Ability to solve problems with a multidisciplinary team.
- Ability to evaluate the critical path in the solution of a design problem.
- Experience in requirements development.

F. An understanding of professional and ethical responsibility.

- Demonstrated understanding of the importance of honesty in science and engineering.
- Demonstrated understanding of the importance of a code of ethics in engineering specialty.
- Personal commitment to a stated or documented code of ethics.
- Awareness of ethical issues of employment regarding accuracy of reporting and maintaining data.
- Understanding of the individual's responsibility associated with an agreement to recognize proprietary rights, trademarks and copyrights.
- Awareness of ethical issues of employment regarding an employer's code of ethics.
- Awareness of professional responsibility regarding product liability.
- Awareness of ethical issues of employment regarding an employer's work rules.
- Education in business and professional ethics and conduct.
- Understanding of the code of ethics of a specialty engineering society.
- Understanding of, and experience in, formulating individual and team roles and responsibilities.

G. An ability to communicate effectively.

- Interpersonal skills (verbal, non-verbal, and written) which maintain high professional quality, convey appropriate respect for individuals, groups and teams, and develop a productive working environment.
- Ability to give a solo presentation.
- Ability to write a concise business letter.
- Skill in technical report writing (organizing and presenting all pertinent information relative to a technical topic, including conclusions and recommendations).
- Skill in concise expository writing.
- Ability to write a team-based case-study report.
- Verbal presentation skills.
- Skill in sketching and illustrating to communicate technical information or concepts.
- Ability to write a concise ten-page essay.
- Ability to give a multimedia presentation (including viewgraph skills).
- Ability to give a team-based presentation.
- Ability to publish a technical paper.

H. The broad education necessary to understand the impact of engineering solutions in a global/societal context.

- Understanding that engineering solutions are affected by, and should be responsible to, limited resources.
- Resource availability.
- Understanding that engineering solutions impact the environment

- (e.g., CFCs, heavy metals, energy consumption, etc.).
- Understanding that engineering solutions alter the structure of society (e.g. air transportation).
- Knowledge of the history of developments in the technical field.
- Awareness of business and technical cycles.
- Understanding of the potential impact of science and technology on the economy, environment, industry, and educational needs.
- Knowledge of the history of science and technology.
- Knowledge of the transition from a task-based factory culture to an integrated product and process development culture.

I. A recognition of the need for, and an ability to engage in, life-long learning.

- Understanding that skill training is an employee's responsibility and a part of life-long learning.
- Plans and commitment to skill improvement in learning associated with the work environment.
- Understanding that life-long education is the professional responsibility of every engineer.
- Demonstrated ability to go beyond professors' course expectations.
- Demonstrated interest in pursuing advanced degree(s).
- Plans to acquire experience on multi-product, multi-disciplinary product design and development teams.
- Plans to participate in a life-long development reading plan.
- Plans and commitment to attain advanced educational degrees.
- Plans to secure choice assignments on multidiscipline product teams.

J. Knowledge of Contemporary Issues.

- Demonstrated understanding that engineering is affected by information technology issues.
- Understanding of the information superhighway.
- Demonstrated understanding that engineering is affected by environmental issues.
- Demonstrated understanding that engineering is affected by economic and business issues.
- Understanding of design principles to produce products that are environmentally safe.
- Demonstrated understanding that engineering is affected by socio-political issues.
- Understanding of global environmental issues.
- Understanding of national, regional, and local environmental issues.
- Understanding of diversity issues and their impact on industry.

K. An ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

- Computer literacy in data analysis tools used in engineering specialty.
- Computer literacy in design tools used in engineering specialty.
- Computer literacy in simulation and modeling tools used in engineering specialty.
- Skills in use of office, telecommunications, and information technology systems and tools.
- Skills in use of modern analysis tools.
- Skills in use of CAD/CAM tools.
- Computer literacy in data analysis and statistical methods.

- Skills in systematic evaluation of product design and of development team efforts.
- Skills in applying statistical methods to measure quality and customer satisfaction.
- Knowledge of probability theory to evaluate quality, design, development, and manufacturing processes.

***The Changing Nature of Engineering (Part II)*, ASEE, NAE Workshops, 1998.**

A. 1998 NAE Workshops: General Concerns.
Emphasis on Sciences and Engineering Practicality.

- A push to value the total system, including sales and manufacture areas.
- Awareness of the importance of research, discovery and innovation.
- New fundamentals in engineering education.
  - Knowledge of discrete mathematics
  - Digital design
  - Biomaterials
  - Information technology and computing
  - Business and management
  - Social and political concern
- Life-long learning as essential for all engineers.

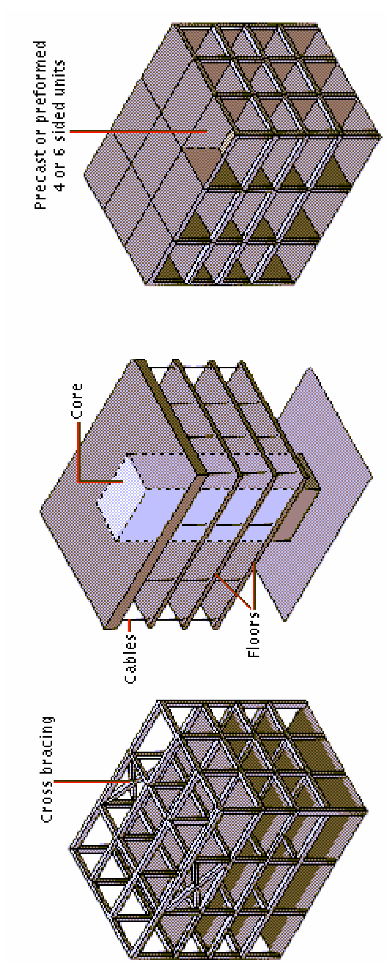
B. 1998 NAE Workshops: Participating Industries' Concerns.

- TRW Inc.
  - Engineers who can lead real and virtual teams.
  - Engineers who can reduce cycle time.
  - Engineers who can understand the total enterprise.
  - Engineers who can be effective globally.
  - Engineers who have the breadth of knowledge to handle complex objectives and multidisciplinary functions, and to understand non-engineering issues.
  - Engineers who can perform systems engineering in a loosely bound environment.

- Ford Motor Company
  - The importance of encouraging industry and academia to forge partnerships that benefit both parties.
  - Recommendation that engineering schools continue to focus on fundamentals and hands-on capabilities.

- Andersen Consulting
  - Engineers must learn how to operate in non-traditional engineering environments and to understand organizational constraints.
  - Engineers must have strong analytical skills.
  - Engineers need a variety of "soft" skills: innovation, coordination, integration and leadership skills.

***Student Outcomes Goal: Instill In Our Graduates Skills Appropriate To Their Professions and Life-Long Learning*, Rose-Hulman Institute of Technology, 1999.**



3a. Skeleton frame 3b. Cable hung 3c. Stacking

Microsoft Illustration

1. Ethics Objective: A recognition of ethical and professional responsibilities.
   When given the opportunity, students will:
   - Demonstrate knowledge of the code of ethics of the organizations of which they are members.
   - Evaluate the ethical dimensions of professional engineering, mathematical, and scientific practices.

2. Contemporary Issues Objective: An understanding of how contemporary issues shape and are shaped by mathematics, science and engineering.
   When applying the principles of mathematics, science and/or engineering to a problem, students will:
   - Demonstrate an awareness of how the problem is affected by social concerns and trends.
   - Demonstrate an awareness of how the proposed solution(s) will affect culture and the environment.
   - Demonstrate an awareness of the reciprocal impacts of culture and the environment on technology.

3. Global Objective: An ability to recognize the role of professionals in the global society and to understand diverse cultural and humanistic traditions.
   When given the opportunity, students will:
   - Perform, read, or otherwise engage in artistic, literary, and/or other expressive forms of culture.
   - Demonstrate an awareness of the historical development of culture, society, and their disciplines.
   - Show an awareness of the relationships of nations and the interdependence of peoples around the globe.
   - Acknowledge the valuable contributions of peoples from other cultures to their own professions and personal lives.
   - Demonstrate awareness of how their culture predisposes them to particular values and perspectives, and of the pitfalls of ethnocentrism, racism, and sexism.
   - Show a willingness to examine, adapt, and adopt practices, methods and ideas from perspectives very different from their own.

4. Teams Objective: An ability to work effectively in teams.
   When assigned to teams, students will:
   - Share responsibilities and duties.
   - Take on different roles when applicable.
   - Analyze ideas objectively.
   - Discern feasible solutions.
   - Develop a strategy for action.
   - Resolve differences.

5. Communication Objective: An ability to communicate effectively in oral, written, graphical, and visual forms.
   When given the opportunity, students will:
   - Identify the reader/audience for a communication task by assessing their technical knowledge and information needs.
   - Provide technical content that is factually correct, supported with evidence, explained in sufficient detail, and properly documented.
   - Test reader/audience response to communication tasks to determine how well ideas have been relayed.

- Organize and/or design information to meet reader/audience needs.
- Submit work that is free of errors in spelling, punctuation, grammar and usage.

6. Engineering Practices Objective: An ability to apply the skills and knowledge necessary for mathematical, scientific and engineering practices.

When solving problems, students will:

- Use appropriate resources to locate pertinent information.
- Estimate outcomes.
- Compare calculations to estimates to check for errors.
- Develop criteria for the evaluation of proposed solutions.

7. Interpreting Data Objective: An ability to interpret graphical, numerical and textual data .

When given the opportunity, students will:

- Select appropriate self-explanatory graph formats for data presentation.
- Summarize the graphical, numerical and textual information in the form of a short abstract.
- Use appropriate statistical procedures and interpret the results. Extract trends and demonstrate their importance from numerical data, graphs and text.
- Make a connection between the measured property and variables tested.

8. Experiments Objective: An ability to design and conduct experiments.

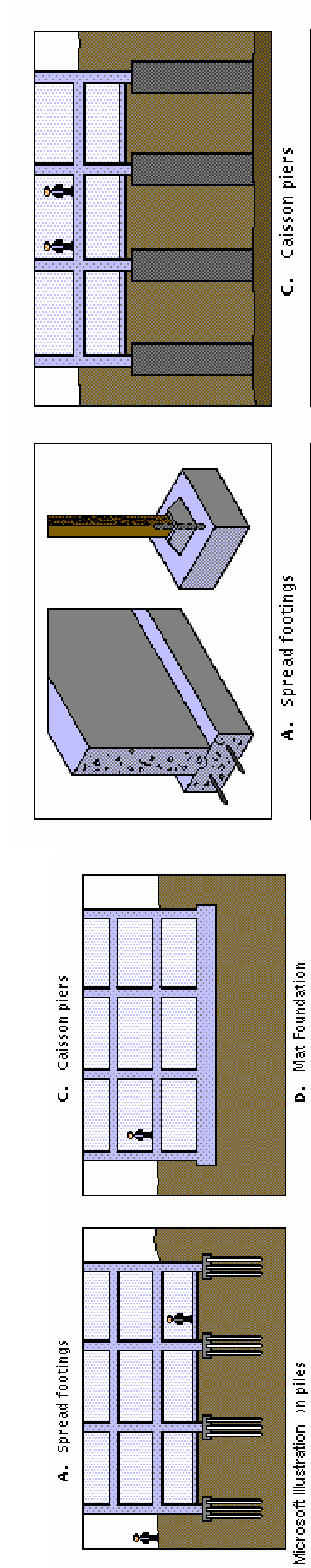
When given the opportunity, students will:

- Identify the problem.
- Develop a hypothesis.
- Determine what data are appropriate to collect.
- Select appropriate measurement techniques to collect data, and justify that selection.
- Specify and justify the assumptions made with the test conditions.
- Estimate experimental uncertainties.
- Collect and present data in an accurate and orderly way, with proper units.

9. Design Objective: An ability to design a product or process to satisfy a client's needs subject to constraints.

When given the opportunity, students will:

- Elicit customer needs and constraints.
- Develop a product or process design specification which addresses appropriate issues (such as initial costs, operating costs, power, size, testability, reliability, serviceability, manufacturability, controllability, schedule, ergonomics, safety, and environmental issues).
- Carry out a high-level product design by generating multiple solutions that address the issues above, evaluating the feasibility of the solutions, and choosing the appropriate solution.
- Carry out a detailed-level product or process design using appropriate design tools and methodologies.
- Test and refine the product or process implementation until the product or process design specifications are met or exceeded.
- Document the finished product or process as appropriate for the discipline according to standard practice.
- Present and transfer the product or process and documentation to the client.



Skills for Today's Mathematician

The academic mathematician might be seen as a single organism that has adapted to different environments. Those environments range from teaching multitudes in a community college to nurturing a few graduate students in a research university.
In contrast, the nonacademic mathematician exists in a variety of distinct forms. These include serving as a specialist among a large group of mathematicians, serving as a wide-ranging consultant, either singly or in a team, or even working in an environment where mathematics is not explicitly recognized in titles or job descriptions.

Paul W Davis
Thu Nov 30 21:10:14 EST 1995

In the field of mathematics the survey results presented below indicate that today's graduate must have strong training in areas such as probability and statistics, linear algebra, calculus, discrete mathematics and numerical analysis, as well as strong computer skills. The results also suggest the importance of the same four non-technical skills discussed earlier in this document: **communication, teamwork, the ability to apply ethical principles, and the capacity for life-long learning.**

Survey Lists

***Moving Beyond Myths*, NAP.edu, 1991.**

- Computer skills
- Use of technology
- Quantitatively literate
- Commitment

***Training Computing and Mathematical Biologist - Appendix D*, NAP.edu, pp. 97-106, 1993.**

- Strong disciplinary training (probability and statistics, linear algebra, calculus, discrete math and numerical analysis)
- Programming skills
- Algorithmic skills
- Quantitative skills
- Interdisciplinary work – solve problems, application to other fields
- Train students

Mathematics

Mathematician, National Security Agency, http://jobs.careermosaic.com.

- Ability to apply math to solve real world problems from a wide variety of mathematical disciplines.
- Able to learn fast.

From Analysis to Action, National Research Council, Understanding Education in SME&T, 1996.

- Scientific literacy
- Technical and computer Literacy
- Quantitative literacy
- Investigation experience
- Ability to express oneself fluently both oral and writing
- Ability to make close observations
- Creative insight
- Competency
- Knowledge of different subjects
- Skills in synthesizing and communicating information
- Ability to work in teams
- Capacity for life-long learning

Shaping the Future, New expectations for Undergraduate Education in SME&T. Review of Undergraduate Education, 26 June 1996

- Cognitive skills: problem-solving, decision-making, learning how to learn
- Adaptability
- Flexibility
- Openness to new ideas
- Empathy for ideas of others
- Innovative and entrepreneurial outlook
- Strong work ethic
- Organizational skills

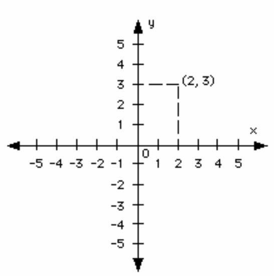


FIGURE 1
Two-Dimensional Cartesian Coordinates

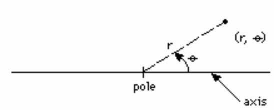


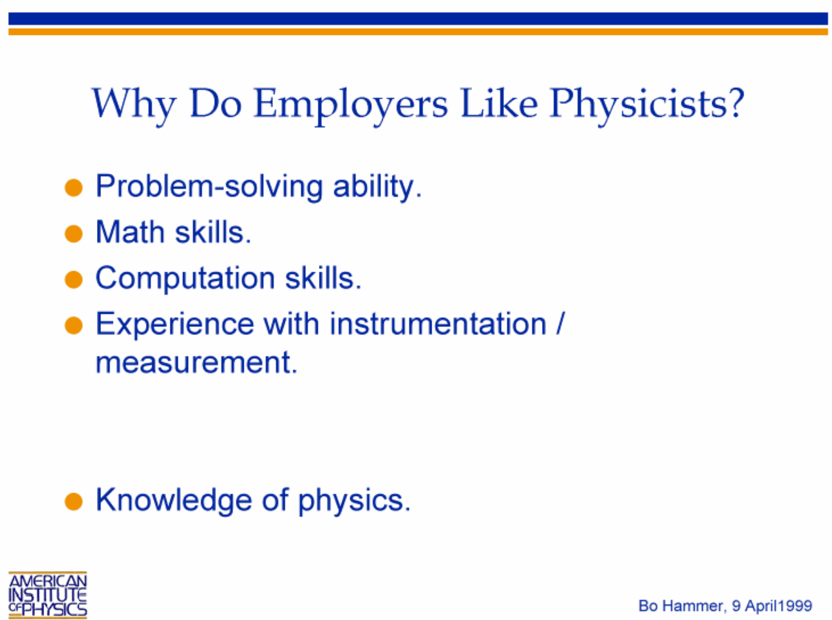
FIGURE 2
Polar Coordinates

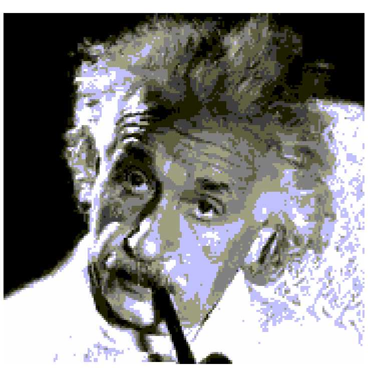
Microsoft Illustration

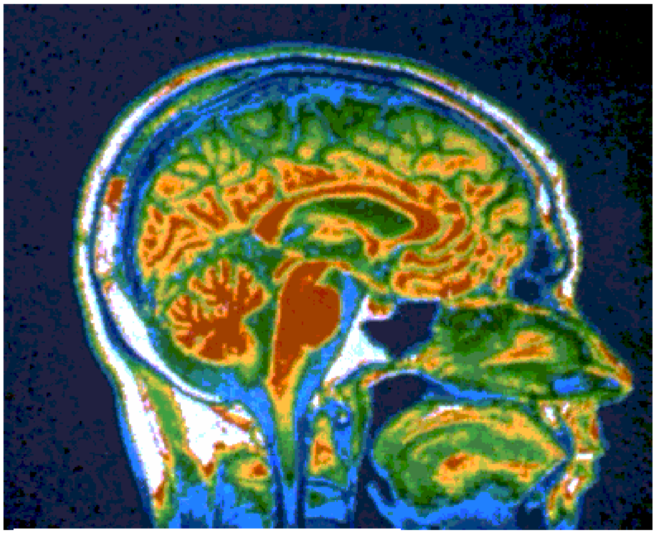
Skills for Today's Physicist

In the field of physics, we reviewed a sampling of current (Spring 2000) job listings from physics-related companies. While different types of companies sought different technical skills depending on the job advertised (and some required advanced degrees), nearly all required applicants to have the same four non-technical skills discussed earlier in this document: communication, teamwork, the ability to apply ethical principles, and the capacity for life-long learning. Sample technical and non-technical skills found to be desirable are listed below.

In addition, we have provided excerpts of statements from corporate personnel indicating skills and characteristics desired in today's job applicants, and trends in the field of physics.





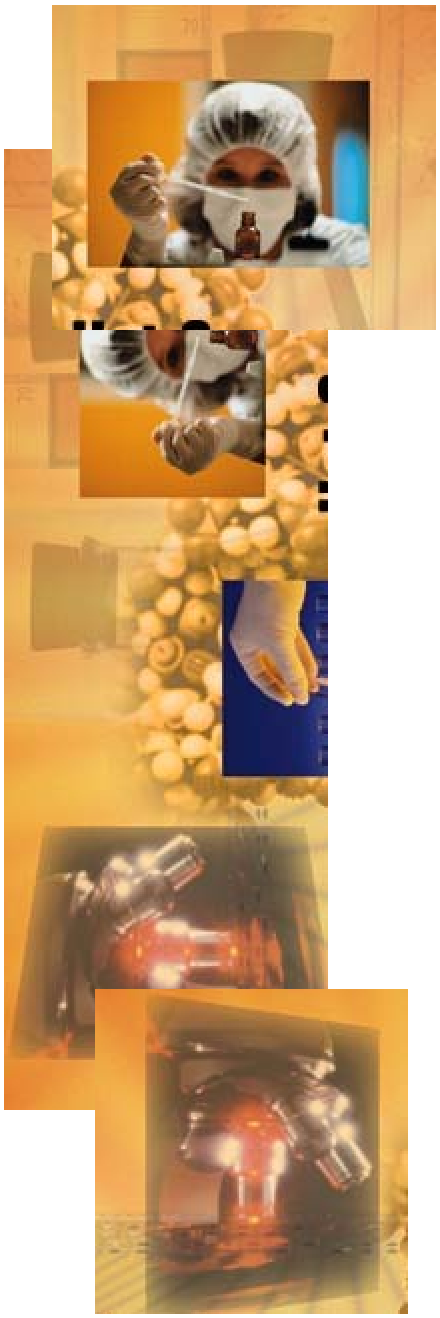


Physics

Skills List

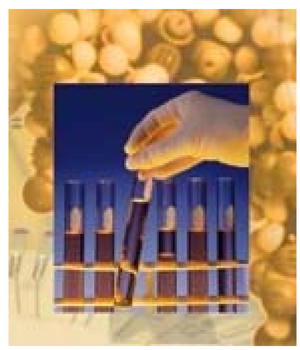
- Ability to apply mathematics and science to the solution of physics problems.
- Ability to design and conduct experiments, as well as to analyze and interpret data.
- Critical thinking
- Good skills of observation
- Written and oral communication skills
- Ability to work with multidisciplinary teams
- Interpersonal skills
- Self-motivation
- Entrepreneurial spirit
- Computer skills
- Teamwork

Skills for Today's Chemist



In the field of chemistry, we reviewed a sampling of current (Spring 2000) job listings from chemistry-related companies. While different types of companies sought different technical skills depending on the job advertised (and some required advanced degrees), nearly all required applicants to have the same four non-technical skills discussed earlier in this document: communication, teamwork, the ability to apply ethical principles, and the capacity for life-long learning. Sample technical and non-technical skills found to be desirable are listed below.

In addition, we have provided excerpts of statements from corporate personnel indicating skills and characteristics desired in today's job applicants, and trends in the field of chemistry.



Skills List

- Written and oral communication skills
- Mathematic skills
- Interpersonal skills
- Team skills
- Self-motivation
- Skills of analytic thinking
- Computer skills
- Ability to work with multiple projects.
- Problem-solving skills

Chemistry

"Today's chemists must have strong communication skills, both oral and written. Because of the number of cross-functional teams that exist in our organization, a scientist must understand the complete business objectives, from the discovery of a compound to the marketing and sale of the final product . . . . [Scientists] must have strong supervisory and managerial skills, and be able to work with and motivate employees with very diverse backgrounds and experiences." — Rick Harris, staffing manager, pharmaceutical products division, Abbott Laboratories

"Basically it's all about the person—moral fiber, work ethic, teamwork, personal stature, and eagerness to make a difference. The technology they bring with them is second to that." — Jeff Seilhamer, senior vice president, life sciences, Incyte Genomics, Inc.

"We need entry-level scientists because they reflect new training. We rely on the academic world to train our future scientists . . . . We look for people who are creative and innovative and can think out of the box. We want scientists at the edge of their training who are able to learn new disciplines." — Norton Peet, head of medicinal chemistry, U.S. research center, Aventis

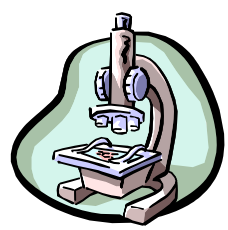
Skills for Today's Biologist

How important are computer skills?
Absolutely critical for individuals joining research programs in most field of biotechnology. — **Amy Murnane, Smith K. Line Beecham**

The applicant [research associate I/II] will be expected to function in a team environment and be driven to constantly improve skills and abilities. — **Amgen, Inc.**

In the field of biology, we reviewed a sampling of current (Spring 2000) job listings from biology-related companies. While different types of companies sought different technical skills depending on the job advertised (and some required advanced degrees), nearly all required applicants to have the same four non-technical skills discussed earlier in this document: communication, teamwork, the ability to apply ethical principles, and the capacity for life-long learning. Sample technical and non-technical skills found to be desirable are listed below.

In addition, we have provided excerpts of statements from corporate personnel indicating skills and characteristics desired in today's job applicants, and trends in the field of biology.



Skills List

- Statistics skills
- Written and oral communication
- Interpersonal skills
- Team skills
- Basic mathematical abilities
- Computer skills
- Organizational skills
- Attention to details
- Ability to follow directions
- Ability to work under strict deadlines
- Customer service skills
- Ability to handle multiple projects
- Problem-solving skills

"Flexibility is very important. Scientists should be open to the change that occurs as research emphases shift and new technology is introduced. In addition, I value candidates who possess the skills to apply strategic thinking. Curiosity, creativity and the ability to work effectively on a team are essential. I really stop and take notice when an applicant has hands-on experience in industry. A summer internship program during college . . . can really jump-start your career. Finally, a global outlook will be increasingly important for applicants. Science is an international endeavor, and this is a global industry. The United States is not the only place where researchers can do excellent science. More and more good career opportunities are opening up for scientists around the world." — **Tona M. Gilmer, head of cancer biology, research division, Glaxo Wellcome**

Applicant [research associate I/II] must have Interdisciplinary knowledge of laboratory concepts, practices, procedures, instrumentation and methodology. — **Amgen, Inc.**

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