Engineering Education:

Future Directions Using ABET Tools

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Outline

- Present status of Engineering
- Future of Engineering
- ABET Overview
- Use of ABET to Improve Engineering

Everyday questions

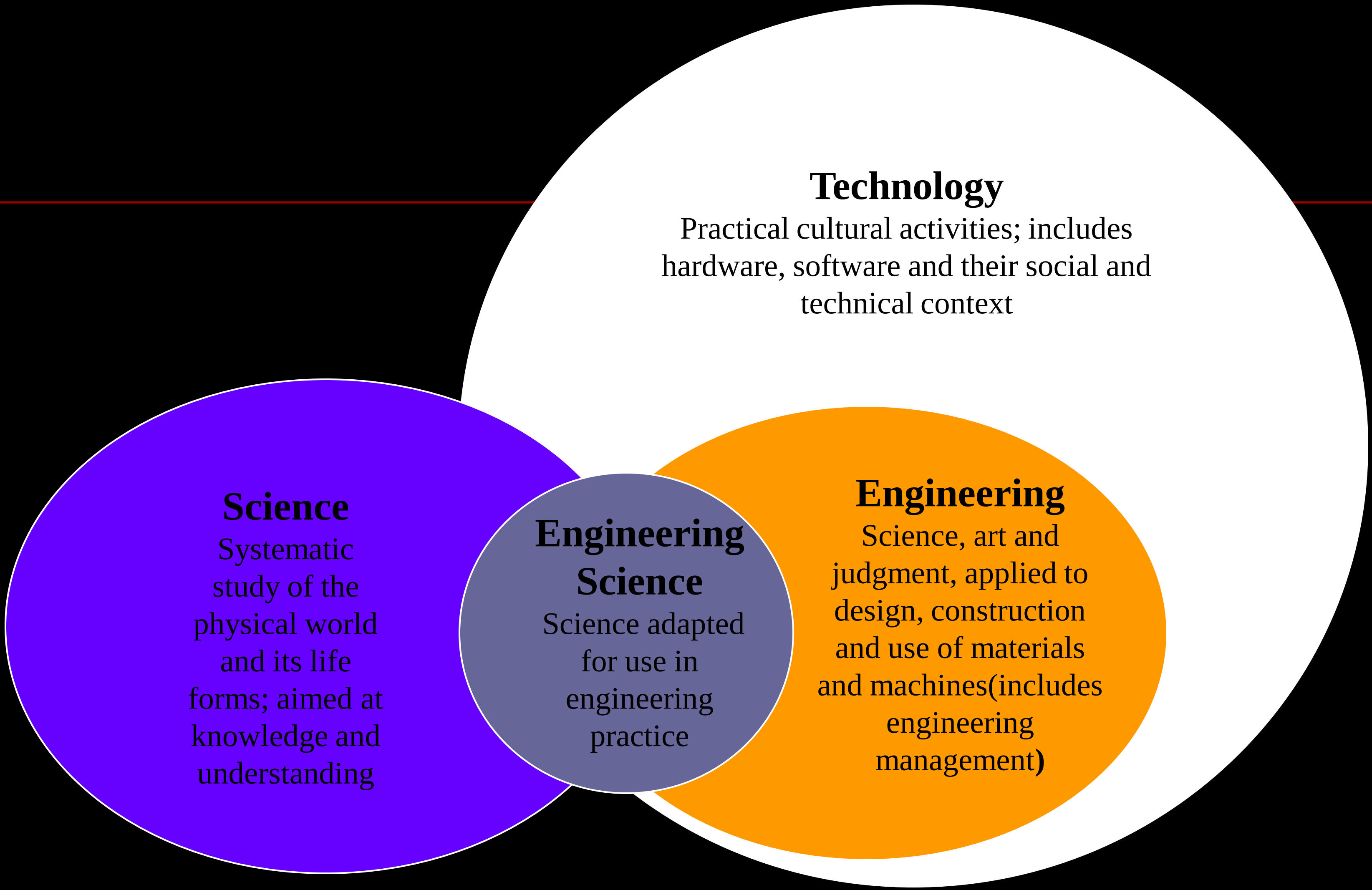
- What is engineering?
- When did engineering begin?
- How are engineering, science, and technology connected?
- How does society view engineering?
- How does the image effect engineers?

Technology, Science, and Engineering

Common characteristics:

- Areas of human endeavor.
- Distinctive human cultural activity.
- Total societal enterprise with an increasingly global character.

(Johnston, Gostelow, King-2000)


Technology
Practical cultural activities; includes hardware, software and their social and technical context
Science
Systematic study of the physical world and its life forms; aimed at knowledge and understanding
Engineering Science
Science adapted for use in engineering practice
Engineering
Science, art and judgment, applied to design, construction and use of materials and machines(includes engineering management)

What is technology?

A set of products , processes, and systems to solve the specific problems and needs. Major characteristics of technology are:

- It is a form of human cultural activity.
- It is for practical ends and purposes.
- It involves exercising choices (freedom and responsibilities)
- It forms and transforms the material world rather than ideas.
- It is typically done with the aid of tools and processes.

(Johnston, Gostelow, King-2000)

What is science?

- Body of a certain sort of knowledge organized, well founded, testable knowledge about natural phenomena.
- A complex of knowledge, methods, techniques, and materials and their outcomes.
- A process of discoveries, creating, disproving, reorganizing, and disseminating statements that accurately describe some portions of physical, chemical, biological, or social nature.

What is engineering?

- A kind of human cultural activity, including, design, research, development, manufacturing, testing, operation, maintenance, etc.
- A total societal enterprise, with significant influences on all aspects of human life and a major role to play in moving the world towards wealth creation, improved quality of life, and sustainability.

What is engineering? (cont'd)

- Highly specialized and personalized branch of technological activity devoted to systematic design, production, and operation of techniques and technical systems to meet practical human needs under constrains such as time, money, performance, reliability, etc.
  (McGinn-1997)
- The profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the benefit of mankind.
  (ABET-2000)

What is engineering? (cont'd)

- Engineers operate and maintain locomotive engines.

  (Popular myth in English speaking countries)

What is engineering? (cont'd)

Ingeniator

(ingenious person in Latin)

Engineer

(builds roads and bridges, and solves technical problems quickly, with a minimum of material, and equipment in Roman army)

Engineering Enrollments

	Fall 2005	Fall 2006	Fall 2007	Fall 2008
BS*	397,437	405,489	431,910	403,191
MS**	83,293	83,976	91,363	92,815
PhD**	57,077	55,929	56,035	59,450

* About 8% of undergraduate engineering students are part-time.
** About 38% of master's students are part-time.
*** About 12% of doctorate students are part-time.

Undergraduate Engineering Enrollment by Fields

	Fall 2006	Fall 2007	Fall 2008
Biomedical	15,892	16,671	18,315
Electrical/Computer	84,281	80,742	89,569
Mechanical	87,074	89,089	92,338
Total (all fields)	**407,426**	**405,533**	**435,019**

Engineering Degrees

	2005	2006	2007	2008
BS	73,602	74,185	75,823	77,107
MS	40,650	39,015	37,805	40,122
PhD	7,333	8,351	8,614	9,449

Engineering BS Degrees by Field (ASEE)

	2004	2005	2006	2007	2008
Biomedical	2,019	2,410	2,917	3,055	3,478
Computer	5,838	5,455	4,901	13,171	11,471
Electrical	15,200	15,373	11,915	13,783	13,113
Mechanical	14,182	14,947	16,063	16,172	17,865
Total	**72,893**	**73,602**	**74,186**	**75,823**	**77,107**

Engineering Workforce

- Number of employed engineers in USA is around 2.4 millions
  - 77% with BS degrees only
  - 20% with BS and MS degrees
  - 3% with BS, MS, and PhD degrees
- 78% of engineers work for-profit organizations

Engineering Workforce (cont'd)

- Percentage of full-time workers with BS degrees only:
  - Engineering 77%
  - Computer science 60%
  - Physical sciences 32%
  - Mathematics 19%
  - Life sciences 15%
  - Social sciences 7%
  - Psychology 6%

Critical Shortage of Engineers in US

- USA produces only 77,000+ engineers with BS degrees per year.
- USA imports more than 120,000 engineers and scientists from other countries every year.
- Europe produces more than twice as many engineering graduates as the US each year; Asia produces five times as many.
- Less than 2% of US high school graduates will earn engineering degrees.
- Less than 15% of high school graduates have enough math and science to pursue science or engineering in college.

Why aren't there more engineers in US?

- Engineering is academically challenging and demanding program.
- Mathematics and science preparation in middle and high schools are inadequate.
- There are not enough role models among women and underrepresented groups.
- Image of engineering needs improvement.

Future of Engineering

- New technologies
- Population shifts
- Changing economy
- Application of engineering principles to new areas
- MUST degree for 21st Century

Breakthrough Technologies*

- Biotechnology
  - tissue engineering, DNA modeling, micro surgery
- Nanotechnology
  - molecular engineering, biosensors, pharmaceuticals
- Material science and photonics
  - atomic scale machines, new materials
- Information and communication technology
  - wireless technology, denser chips
- Information explosion
  - Moore’s law, virtual humans
- Logistics
  - RFID technology, transportation

*The Engineer of 2020 by National Academy of Engineering

Technological Challenges*

- Physical infrastructure in urban settings
  - 2003 report card by ASCE (C+ to D-)
- Information and communication infrastructure
  - Denial of service, blackouts, privacy
- The environment
  - Water supply, fossil oil, electricity, green design
- Technology for an aging population
  - Assistive technology

*The Engineer of 2020 by National Academy of Engineering

Elements of Green Engineering

- Holistic approach for process and product design (impact of environment)
- Conserve and improve natural eco systems
- Use life-cycle thinking in engineering
- Use safe materials and energy inputs
- Minimize depletion of natural resources
- Prevent waste
- Use engineering solutions suitable for local geography, aspirations, and culture
- Create new engineering solutions to achieve sustainability
- Engage communities in developing engineering solutions

Engineering Practice in 2020

- Population and demographics
  - World population will be 8 billion (72% in Africa and Asia)
- Health and healthcare
  - Urban population will be 3.5 billion
- Youth bulge and security
  - More than half the population will be under 18
- Accelerating global economy
  - Skilled technical workforce in Africa and Asia

Attributes of Engineers in 2020

- Strong analytical skills
- Practical ingenuity
- Creativity
- Communication
- Business and management
- Leadership
- High ethical standards and sense of professionalism
- Dynamism, agility, resilience, and flexibility
- Lifelong learners

Engineer of 2020

Aspires to have the ingenuity of Lillian Gilbreth, the problem-solving capabilities of Gordon Moore, the scientific insights of Albert Einstein, the creativity of Pablo Picasso, the determination of the Wright brothers, the leadership abilities of Bill Gates, the conscience of Eleanor Roosevelt, the vision of Martin Luther King, and the curiosity and wonder of our grandchildren.

Neil Armstrong on Engineering

- I am, and ever will be, a white-socks, pocket-protector, nerdy engineer, born under the second law of thermodynamics, steeped in steam tables, in love with free-body diagrams, transformed by Laplace, and propelled by compressible flow.

February 2000

Review of ABET Accreditation and Outcomes Assessment Process

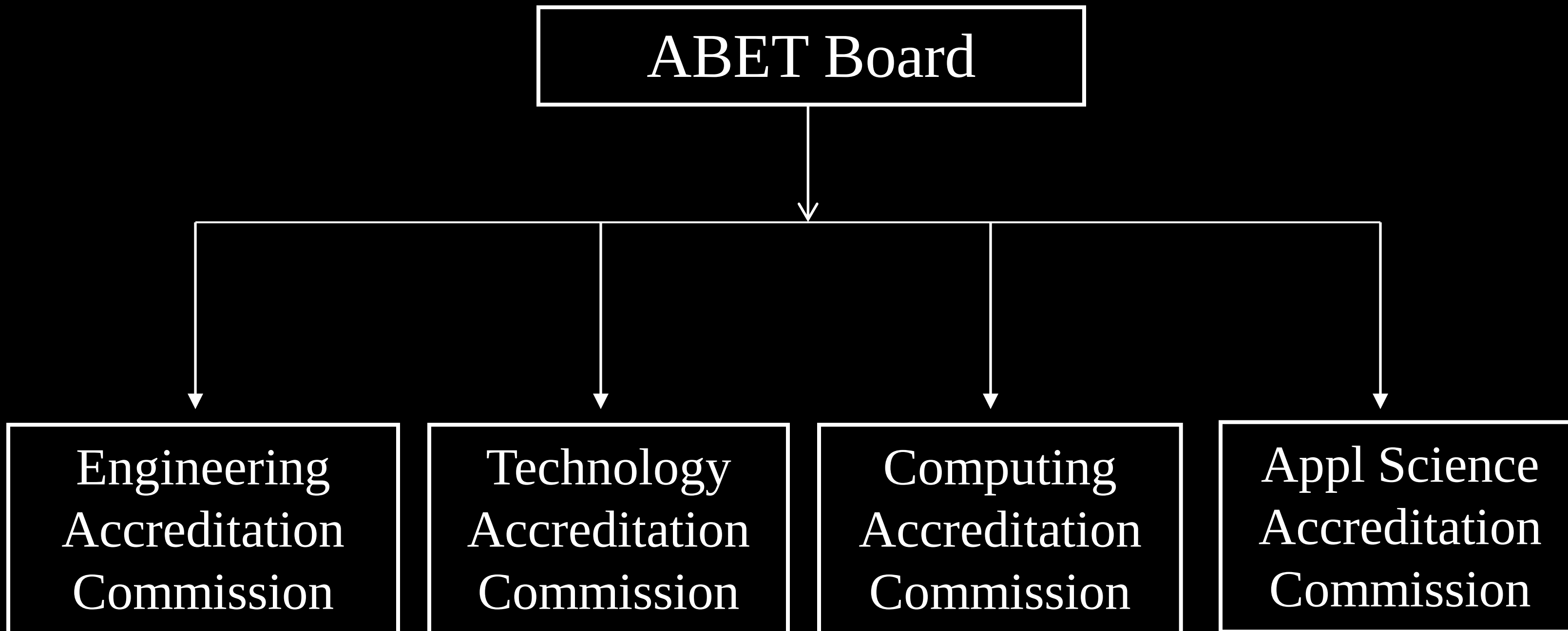
ABET

- Primary organization responsible for monitoring, evaluating, and certifying the quality of engineering, engineering technology, and engineering related education in the United States
- Recognized by the US Department of Education
- Federation of 30 engineering and technical societies representing over 1.8 million practicing engineering professionals

History

- Engineers' Council for Professional Development (ECPD)
  - 1932: seven organizing societies
  - 1936: first accreditation of engineering programs
  - 1946: first accreditation of engineering technology programs
- Accreditation Board for Engineering and Technology (ABET)
  - 1980: ECPD becomes ABET
  - 1984: first accreditation of engineering related programs
  - 1994: moved from New York to Baltimore

Governance


ABET Board
Engineering Accreditation Commission
Technology Accreditation Commission
Computing Accreditation Commission
Appl Science Accreditation Commission

What ABET Accredits

ABET Accredits

Programs of Study

That lead to Degrees in Engineering, Engineering Technology, Computing, and Applied Sciences

NOT

Departments, Colleges, or Institutions

Program of Study

- Leads to one degree in engineering or engineering technology or computing, or applied sciences
- Includes all possible paths of study

Accreditation Goals

- Assure that graduates of accredited program are adequately prepared to enter and continue the practice of engineering
- Stimulate the improvement of engineering education
- Encourage new and innovative approaches to engineering education and its assessment
- Identify accredited programs to the public

Philosophy

- Institutions and Programs define mission and objectives to meet needs of constituencies -- enable program differentiation
- Emphasis on outcomes -- preparation for professional practice
- Programs demonstrate how criteria and educational objectives are being met

Basic Level Accreditation Criteria

1. Students
2. Program Educational Objectives
3. Program Outcomes
4. Continuous Improvement
5. Curriculum
6. Faculty
7. Facilities
8. Support
9. Program Criteria

Criterion 1: Students

- The program must evaluate student performance, advise students regarding curricular and career matters, and monitor student's progress to foster their success in achieving program outcomes, thereby enabling them as graduates to attain program objectives.
- The program must have and enforce policies for the acceptance of transfer students and for the validation of courses taken for credit elsewhere.
- The program must also have and enforce procedures to assure that all students meet all program requirements.

Criterion 2: Program Educational Objectives

Each program…must have in place:

- Published educational objectives that are consistent with the mission of the institution and these criteria
- A process that periodically documents and demonstrates that the objectives are based on the needs of the program’s various constituencies
- An assessment and evaluation process that periodically documents and demonstrates the degree to which these objectives are attained.

Criterion 3:Program Outcomes

- Engineering programs must demonstrate that their students attain the following outcomes: (a) through (k).
- Program outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program.
- Program outcomes must foster attainment of program educational objectives.
- There must be an assessment and evaluation process that periodically documents and demonstrates the degree to which the program outcomes are attained.

Criterion 4: Continuous Improvement

- Each program must show evidence of actions to improve the program.
- These actions should be based on available information, such as results from Criteria 2 and 3 processes.

Criterion 5: Curriculum

- The curriculum requirements specify subject areas appropriate to engineering but do not prescribe specific courses.
- The faculty must ensure that the program curriculum devotes adequate attention and time to each component, consistent with the outcomes and objectives of the program and institution.

Criterion 5: Curriculum

The professional component must include:

- One year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline
- One and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study…
- A general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.

Criterion 5: Curriculum

- Students must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.

Criterion 6: Faculty

- The faculty must be of sufficient number and must have the competencies to cover all of the curricular areas of the program.
- There must be sufficient faculty to accommodate adequate levels of student-faculty interaction, student advising and counseling, university service activities, professional development, and interactions with industrial and professional practitioners, as well as employers of students.

Criterion 6: Faculty

- The program faculty must have appropriate qualifications and must have and demonstrate sufficient authority to ensure the proper guidance of the program and to develop and implement processes for the evaluation, assessment, and continuing improvement of the program, its educational objectives, and outcomes.
- The overall competence of the faculty may be judged by such factors as education, diversity of backgrounds, engineering experience, teaching effectiveness and experience, ability to communicate, enthusiasm for developing more effective programs, level of scholarship, participation in professional societies, and licensure as Professional Engineers.

Criterion 7: Facilities

- Classrooms, laboratories, and associated equipment must be adequate to safely accomplish the program objectives and provide an atmosphere conducive to learning. Appropriate facilities must be available to foster faculty-student interaction and to create a climate that encourages professional development and professional activities. Programs must provide opportunities for students to learn the use of modern engineering tools. Computing and information infrastructures must be in place to support the scholarly activities of the students and faculty and the educational objectives of the program and institution.

Criterion 8: Support

- Institutional support, financial resources, and constructive leadership must be adequate to assure the quality and continuity of the program. Resources must be sufficient to attract, retain, and provide for the continued professional development of a well-qualified faculty. Resources also must be sufficient to acquire, maintain, and operate facilities and equipment appropriate for the program. In addition, support personnel and institutional services must be adequate to meet program needs.

Criterion 9: Program Criteria

- Each program must satisfy applicable program criteria (if any). Program criteria provide the specificity needed for interpretation of the baccalaureate level criteria as applicable to a given discipline. Requirements stipulated in the program criteria are limited to the areas of curricular topics and faculty qualifications. If a program, by virtue of its title, becomes subject to two or more sets of program criteria, then that program must satisfy each set of program criteria; however, overlapping requirements need to be satisfied only once.

Outcomes Assessment

New Approach

- Practice of continuous improvement
  - Input of constituencies
  - Process focus
  - Outcomes and assessment linked to objectives
- Knowledge required for entry to the engineering profession
- Student, faculty, facilities, institutional support, and financial resource issues linked to program objectives

Continuous Quality Improvement

- A systematic pursuit of excellence and satisfaction of the needs of constituencies, in a dynamic and competitive environment

A Guide for Continuous Improvement

- Who are our constituencies?
- What are the services we produce? Are our objectives understood by our constituencies?
- What services, facilities, and policies must be present if we are to satisfy our constituencies? Do our suppliers and institutional leadership understand our needs?

A Guide for Continuous Improvement (cont'd)

- What steps do we perform to produce our services?
- How do we measure our results?
- How do we use these measurements to continually improve the services we provide?
- Are we achieving our objectives? Are we improving?
- Are our constituencies satisfied?

How is it Different?

- It is an assessment of the practice of continuous improvement and the achievement of the required level of knowledge for entry into the engineering profession
- It assesses whether the programs being evaluated have achieved outcomes consistent with the objectives of the program and the institution and whether there are processes in place that will assure their continuation and improvement

Self-Study Terminology

- Program educational objectives – broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve.

- Program outcomes – narrower statements that describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire in their matriculation through the program.

Self-Study Terminology (cont'd)

- Assessment – one or more processes that identify, collect, and prepare data to evaluate the achievement of program outcomes and program educational objectives.

- Evaluation – one or more processes for interpreting the data and evidence accumulated through assessment practices. Determines the extent to which program outcomes or program educational objectives are being achieved, and results in decisions and actions to improve the program.

Continuous Improvement Process

- Develop mission statement for each department that is in line and compatible with the college and university missions.
- Develop educational objectives for each program in the department.
- Develop outcomes for each program that map into educational objectives of the program.
- Assess students with respect to program outcomes.

Program Objectives and Outcomes

- Program Objectives apply to what graduates should accomplish in the work place few years after graduation (alumni, employer surveys)
- Program Outcomes apply to what the students should be able to accomplish at the time of graduation (exams, projects, etc.)
- Program Objectives and Program Outcomes are linked

Course Learning Objectives

- List of knowledge and skill sets students gain at the end of a subject (8-12 items)
- Each subject outcome is in turn linked to a program outcome
- All subject outcomes are mapped into a program outcomes matrix to assure that all outcomes will be met appropriately

Conclusions

- Engineers are vital for the future of every country.
- Globalization is crucial for engineering.
- Engineering education needs to change and evolve.
- ABET and/or similar continuous improvement tools are essential.