Biomedical Engineering

8467 36 weeks

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Course Description

Suggested Grade Level: 11 or 12

The biomedical engineering course focuses on the design of biomedical devices and their contributions to human health. Students engage in the design of a variety of biomedical engineering solutions such as artificial limbs, replacement organs, assistive devices, and clinical instruments. Students explore career and postsecondary education opportunities related to the field.

Task Essentials Table

- Tasks/competencies designated by plus icons (⊕) in the left-hand column(s) are essential
- Tasks/competencies designated by empty-circle icons (○) are optional
- Tasks/competencies designated by minus icons (⊖) are omitted
- Tasks marked with an asterisk (*) are sensitive.

Task Number	8467	Tasks/Competencies	
Exploring Foundations of Biomedical Engineering			
39	⊕	Describe biomedical engineering.	
40	⊕	Define terms related to biomedical engineering.	
41	⊕	Relate biomedical engineering milestones to the current historical context.	
42	⊕	Explain the nature and manufacturing of biomaterials.	
43	⊕	Demonstrate laboratory safety.	
44	⊕	Describe sociocultural effects of biomedical engineering.	
45	⊕	Practice the engineering design process to solve biomedical problems.	
46	⊕	Analyze data generated from lab activities.	
47	⊕	Identify postsecondary opportunities related to biomedical engineering.	
Exploring Cell and Tissue Engineering and Regenerative Medicine			
48	⊕	Apply mathematics and science in cell and tissue engineering and regenerative medicine.	
49	⊕	Produce cellular models and simulations.	
50	⊕	Explain techniques of cellular and tissue engineering.	
51	⊕	Explain techniques of genetic engineering.	
52	⊕	Perform experiments related to cell function.	
53	⊕	Design a solution for a regenerative medicine problem.	

54	⊕	Describe bioinformatics as a database technology.	
Exploring Medical Imaging and Bioinstrumentation			
55	⊕	Apply mathematics and science in imaging and instrumentation.	
56	⊕	Produce models and simulations of bioinstruments.	
57	⊕	Analyze images and biosignals.	
58	⊕	Perform experiments using basic biosensors.	
59	⊕	Design solutions requiring creation of a bioinstrument.	
60	⊕	Compare the mechanisms of medical imaging technologies.	
61	⊕	Analyze the design of biomedical instruments and devices.	
62	⊕	Identify the role of computational modeling in bioinstrumentation.	
Exploring Biomechanics and Biomaterials			
63	⊕	Apply mathematics and science in biomechanics.	
64	⊕	Apply scientific principles to biomaterials for biocompatibility.	
65	⊕	Use models and simulations in biomechanics.	
66	⊕	Perform experiments related to biomaterials and biomechanics.	
67	⊕	Design solutions to a biomechanics problem.	
68	⊕	Analyze the design of implants.	
Exploring Rehabilitation			
69	⊕	Explain concepts related to disability and rehabilitation.	
70	⊕	Explain the different areas of rehabilitation engineering.	
71	⊕	Examine the design of assistive technologies.	
72	⊕	Examine the design of prosthetics.	
73	⊕	Examine the design of rehabilitative devices.	
74	⊕	Synthesize biomedical engineering concepts to produce solutions.	

75	⊕	Describe the effects of human factors.	
76	⊕	Produce models and simulations for rehabilitation.	
77	⊕	Perform experiments to determine rehabilitation need.	
78	⊕	Design solutions for a rehabilitation problem.	
Using the Engineering Design Process to Solve a Biomedical Problem			
79	⊕	Document the design process.	
80	⊕	Define a biomedical engineering design problem.	
81	⊕	Identify the constraints and criteria of the design problem.	
82	⊕	Research potential solutions to the design problem.	
83	⊕	Generate multiple solutions to the design problem.	
84	⊕	Sketch the solutions to the design problem.	
85	⊕	Evaluate the constraints and criteria of each solution to the design problem.	
86	⊕	Explain the application of quality control and the importance of regulatory agencies to the manufacture of biomedical products.	
87	⊕	Justify an optimal solution to the design problem.	
88	⊕	Determine the objectives for a biomedical engineering test of the solution to the design problem.	
89	⊕	Create a prototype for the chosen solution to the design problem, using appropriate materials and processes (e.g., 3D rapid prototyping).	
90	⊕	Test the solution to the design problem.	
91	⊕	Evaluate test results.	
92	⊕	Formulate an improved solution to the design problem.	
93	⊕	Prepare the final project report.	
94	⊕	Present the final project report.	

Legend: ⊕Essential ○Non-essential ⊖Omitted

Curriculum Framework

Exploring Foundations of Biomedical Engineering

Task Number 39

Describe biomedical engineering.

Definition

Description should include

- a definition of *biomedical engineering* as the applications of engineering principles (e.g., chemical, electrical, mechanical, computer, etc.) to medicine and biology for healthcare purposes
- the role of imagination and creativity in design and innovation in the field of biomedical engineering (e.g., robotics, prosthetics, personalized medicine).

Process/Skill Questions

- What are some examples of biomedical devices or innovations?
- What skill sets are needed to solve biomedical engineering problems?
- What are some of the ethical and legal issues associated with biomedical engineering?

ITEEA National Standards

14. Medical Technologies

TSA Competitive Events

Biotechnology Design

Engineering Design

Essays on Technology

Task Number 40

Define terms related to biomedical engineering.

Definition

Definitions should include terms related to the application of biomedical engineering within areas such as

- cell and tissue engineering and regenerative medicine
- medical imaging and bioinstrumentation
- biomechanics and biomaterials
- rehabilitation (e.g., prosthetics, rehabilitative devices, assistive technology).

Process/Skill Questions

- What resources are useful for researching biomedical engineering terms?
- What is the role of computation in biomedical engineering?
- What is the role of experimentation in biomedical engineering?
- What is the role of design in biomedical engineering?

TSA Competitive Events

Biotechnology Design

Task Number 41

Relate biomedical engineering milestones to the current historical context.

Definition

Relationships should include

- examples of biomedical engineering milestones in early cultures (e.g., prosthetics) as well as more recent milestones
- origins of biomedical engineering in relation to other inventions, discoveries, devices, and processes.

Process/Skill Questions

- What discoveries have increased the pace of breakthroughs in biomedical engineering? How has each done so?
- What are some environmental effects of biomedical engineering developments?
- What are some socio-cultural effects of biomedical engineering developments?

ITEEA National Standards

6. The Role of Society in the Development and Use of Technology

7. The Influence of Technology on History

Task Number 42

Explain the nature and manufacturing of biomaterials.

Definition

Explanation should include

- definition of *biomaterials*
- manufacturing processes
- naturally occurring materials (e.g., collagen)
- current materials (e.g., vaccines, implants, prosthetics)
- emerging materials and processes (e.g., nanotechnology).

Process/Skill Questions

- What types of ceramics, metals, elastomers, plastics, and composite materials are used in biomedical engineering?
- How have naturally occurring materials been repurposed?
- How are biomaterials sterilized?

ITEEA National Standards

2. The Core Concepts of Technology

TSA Competitive Events

Biotechnology Design

Engineering Design

Task Number 43

Demonstrate laboratory safety.

Definition

Demonstration should include

- applying knowledge of general safety rules (including those related to fire, machine use, and tool use), aseptic technique, and industry-specified guidelines (including Occupational Safety and Health Administration [OSHA] guidelines)
- following manufacturers' guidelines for equipment and material use
- following specialized safety procedures related to use of potentially dangerous items.

Note: Instructors must ensure compliance with all requirements of the Regulations Governing Career and Technical Education in the Virginia Administrative Code 8VAC20-120-160 — Student Safety.

Process/Skill Questions

- What are clean-up procedures for hazardous materials?
- Why are aseptic rules important?
- What are the specific rules and procedures involved in asepsis?
- What is a safety data sheet (SDS)? Why are these sheets important?
- Why is documentation important to safety?
- What is the *chain of infection*? Why is it important?

ITEEA National Standards

2. The Core Concepts of Technology

Task Number 44

Describe sociocultural effects of biomedical engineering.

Definition

Description should include

- foreseen and unforeseen outcomes

- positive and negative effects
- cultural, medical, financial, political, ethical, and legal or regulatory effects.

Process/Skill Questions

- What is the origin of Ethical, Legal, and Social Issue (ELSI), a program of the Human Genome Project?
- What are the biomedical engineering issues associated with ELSI?
- How does the term *trade-off* apply to the social effects of biomedical engineering?
- When making biomedical engineering decisions, why is it important to include cultural issues in the decision-making process?
- For a given medical innovation, what are some ethical considerations?
- How does biomedical engineering design differ around the world?
- How is biomedical engineering research and development funded?
- Why is it important to understand statistical analysis in relation to the social effects of biomedical engineering?
- What resources may be used to research social impacts of biomedical engineering?
- What are ethical issues involved in the use of live subjects/animals?

ITEEA National Standards

4. The Cultural, Social, Economic, and Political Effects of Technology

TSA Competitive Events

Debating Technological Issues

Essays on Technology

Extemporaneous Speech

Task Number 45

Practice the engineering design process to solve biomedical problems.

Definition

Practice should include

- defining the problem (i.e., human need), including constraints and criteria

- performing background research
- generating ideas
- selecting a solution
- making the prototype
- testing the solution
- evaluating the solution.

Practice must include communicating, documenting, and reiterating the process as necessary.

Process/Skill Questions

- What is the importance of following a defined process?
- When and how should one document the procedures in solving a problem?
- What mathematical and scientific skills are needed by biomedical engineers? How might biomedical engineers apply these skills?
- How can mathematical and scientific solutions be graphically illustrated?
- How does the end user influence the process?

ITEEA National Standards

9. Engineering Design

TSA Competitive Events

Biotechnology Design

Task Number 46

Analyze data generated from lab activities.

Definition

Analysis should include

- comparative research
- observations
- documentation (e.g., lab journals, logs)
- application of formulas
- conclusions
- quality control (e.g., identification of quality standard, data validation).

Process/Skill Questions

- How and why are data collected from lab activities?
- How is data documented?
- Why is it important to understand data analysis before collecting data?
- How are quality controls maintained? What would happen if quality controls were not maintained?
- How are data standards identified?
- What is *bias*?

ITEEA National Standards

3. The Relationships Among Technologies and the Connections Between Technology and Other Fields

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Task Number 47

Identify postsecondary opportunities related to biomedical engineering.

Definition

Identification should include the responsibilities, work environments, education/training needed, salaries, and job outlooks for various biomedical engineering careers. Careers can be in areas such as research, design, product development, manufacturing/production, sales, and education/training.

Identification should also include pursuing further education in medicine and other health care-related fields.

Teacher resource: O*Net Online U.S. Department of Labor

Process/Skill Questions

- What employment opportunities in biomedical engineering are available to entry-level employees?
- What career paths in biomedical engineering might an employee pursue?
- What certifications, licensure, and other credentials are required for careers in biomedical engineering?
- What is the outlook for careers in biomedical engineering?
- What sources are useful for learning about careers in biomedical engineering?
- What biomedical engineering programs are available in higher education?

ITEEA National Standards

14. Medical Technologies

Exploring Cell and Tissue Engineering and Regenerative Medicine

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Task Number 48

Apply mathematics and science in cell and tissue engineering and regenerative medicine.

Definition

Application should include examples of problem-solving and mathematical and scientific concepts, such as

- sequence analysis (e.g., genotype)
- descriptive statistics and statistical comparisons (e.g., phenotypes, cell matrix).

Process/Skill Questions

- What is the purpose of sequence analysis?
- What is the purpose and importance of biostatistics?
- What other biological applications might be studied using these techniques?

ITEEA National Standards

3. The Relationships Among Technologies and the Connections Between Technology and Other Fields

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Task Number 49

Produce cellular models and simulations.

Definition

Producing cellular models and simulations should explore alternatives to the design solution using computation or mathematics (e.g., adequate blood flow in artificial organs or vessels).

Process/Skill Questions

- How can biostatistics and mathematical modeling be used to study artificial tissues?
- What are the benefits and limitations of using modeling to find alternative solutions?
- Why are alternative solutions important?
- When would it be appropriate to use computation? When would it be appropriate to use mathematics?

ITEEA National Standards

3. The Relationships Among Technologies and the Connections Between Technology and Other Fields

TSA Competitive Events

Scientific Visualization (SciVis)

Task Number 50

Explain techniques of cellular and tissue engineering.

Definition

Explanation should include

- techniques used for collection, storage, multiplication, and transportation of tissue cultures
- the importance of documentation and data tracking to ensure proper identification
- the concept of tissue remodeling.

Process/Skill Questions

- What procedures are used to track laboratory cultures?
- How are cultures collected and stored?
- How are engineered tissues (e.g., skin, cartilage, organs) created?
- What other biological applications might be studied using these techniques?

ITEEA National Standards

3. The Relationships Among Technologies and the Connections Between Technology and Other Fields

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Task Number 51

Explain techniques of genetic engineering.

Definition

Explanation should include

- a definition of *genetic engineering*
- the recombinant deoxyribonucleic acid (DNA) method, using plasmids and vectors
- the electroporation and chemical poration methods
- polymerase chain reaction (PCR)
- electrophoresis.

Process/Skill Questions

- What tools, materials, and processes are used to manipulate genetic material?
- When would one use these specific techniques?
- How do genetic mutations affect cell function?

ITEEA National Standards

3. The Relationships Among Technologies and the Connections Between Technology and Other Fields

TSA Competitive Events

Debating Technological Issues

Extemporaneous Speech

Task Number 52

Perform experiments related to cell function.

Definition

Performance may include experiments related to

- microscopy
- cell culture
- growth patterns
- cell matrix
- bacterial transformation.

Process/Skill Questions

- What are the consequences of contamination in cell cultures?
- What is the use of cell matrix in cell cultures?
- Why is it important to change only one variable at a time in an experiment?
- What are some useful applications of transformation?

ITEEA National Standards

3. The Relationships Among Technologies and the Connections Between Technology and Other Fields

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Task Number 53

Design a solution for a regenerative medicine problem.

Definition

Design should include

- defining the problem
- performing background research
- generating ideas
- selecting a solution
- justifying the design
- sketching the prototype
- conceiving a test protocol
- documenting the process.

Process/Skill Questions

- What are the consequences of not following a defined process?
- What are the particular challenges of designing a regenerative medicine solution?

- What are the benefits and limitation of regenerative medicine vs. artificial organs?

ITEEA National Standards

11. Apply the Design Process

TSA Competitive Events

Engineering Design

Task Number 54

Describe bioinformatics as a database technology.

Definition

Description should include

- the content of databases (e.g., genome, protein) that make use of bioinformatics
- the positive effects (e.g., personalized medicine)
- the negative effects (e.g., profiling)
- legal and ethical considerations.

Process/Skill Questions

- How has the development of computer technologies affected bioinformatics?
- What are the benefits of integrated databases related to bioinformatics? What are the drawbacks?
- Who should have access to the informatics and database?

Exploring Medical Imaging and Bioinstrumentation

Task Number 55

Apply mathematics and science in imaging and instrumentation.

Definition

Application may include

- matrix and vector manipulation
- basic biostatistics
- circuits.

Process/Skill Questions

- How are images and signals represented numerically?
- How can raw data be processed to improve diagnoses?
- What is the role of circuitry in bioinstrumentation?
- What is the purpose and importance of biostatistics?

ITEEA National Standards

3. The Relationships Among Technologies and the Connections Between Technology and Other Fields

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Task Number 56

Produce models and simulations of bioinstruments.

Definition

Production should include

- hardware (e.g., mechanical simulation of a part in computer-aided design [CAD])
- electrical simulation.

Process/Skill Questions

- What are the limitations of using design tools?
- What are the benefits of using models and simulation?
- How important is numerical accuracy in simulation?

ITEEA National Standards

11. Apply the Design Process

TSA Competitive Events

Scientific Visualization (SciVis)

Task Number 57

Analyze images and biosignals.

Definition

Analysis may include

- biometrics
- conversion of signals to numbers
- statistical analysis
- biosensors
- control systems
- image analysis (e.g., measuring size, shape, number, and location)
- low-, high-, band-pass filters
- edge detection
- applications for diagnosis or monitoring.

Process/Skill Questions

- Why is it important to select the correct analytical tool? What criteria are used to select it?
- Why is understanding normalcy and its variabilities important?
- Why are ambient environmental factors (e.g., lighting, electrical noise, vibrations, temperature) important considerations when collecting and analyzing data?

ITEEA National Standards

13. Assess the Impact of Products and Systems

Task Number 58

Perform experiments using basic biosensors.

Definition

Performance should include

- collecting data using basic biosensors (e.g., heart rate, blood pressure, oxygen saturation, temperature)
- analyzing data.

Process/Skill Questions

- What is the principle of basic biosensors?
- Why are environmental considerations important to sensor design?
- What environmental factors affect biosensors?
- What is the effect of a patient's physiological state on measurements?

ITEEA National Standards

12. Use and Maintain Technological Products and Systems

TSA Competitive Events

Biotechnology Design

Task Number 59

Design solutions requiring creation of a bioinstrument.

Definition

Design should include

- defining the problem
- performing background research
- generating ideas
- selecting a solution
- justifying the solution
- sketching a prototype
- making a prototype of the bioinstrument
- documenting the process
- evaluating the bioinstrument
- reiterating the process.

Process/Skill Questions

- Why are human-machine interface design criteria important?
- What is the progression of assessment from prototype to finished product for a new bioinstrument?
- Why is reiteration important?
- What are special considerations when designing for humans?

ITEEA National Standards

11. Apply the Design Process

TSA Competitive Events

Essays on Technology

Extemporaneous Speech

Task Number 60

Compare the mechanisms of medical imaging technologies.

Definition

Comparison should include

- biomedical engineering influences on imaging technologies
- the benefits of manipulating and enhancing medical images with computer technology, including making a 3D model from 2D images
- explanations of mechanisms in technologies such as
    - radiography (X-ray)
    - computerized tomography (CT) scan
    - magnetic resonance imaging (MRI)
    - sonography
    - positron emission tomography (PET) scan.

Process/Skill Questions

- What are current medical imaging techniques?
- What are the benefits of manipulating and enhancing medical images?
- How has the development of computer technologies affected medical imaging?

ITEEA National Standards

13. Assess the Impact of Products and Systems

TSA Competitive Events

Computer-Aided Design (CAD), Engineering

Task Number 61

Analyze the design of biomedical instruments and devices.

Definition

Analysis should include

- identifying the purpose(s) of each type of instrument and device (i.e., data collection, preservation, documentation, and analysis)
- identifying the subcomponents and their functions
- describing safety features unique to bioinstruments.

Process/Skill Questions

- What materials are used in biomedical instruments and devices?
- How does the design principle *form follows function* apply to biomedical instruments and devices?
- When does function constrain form and other factors?
- What safety issues should be considered when designing biomedical instruments? Where can regulations be found?

ITEEA National Standards

13. Assess the Impact of Products and Systems

TSA Competitive Events

Biotechnology Design

Task Number 62

Identify the role of computational modeling in bioinstrumentation.

Definition

Identification may include

- signal analysis computational toolboxes
- finite element analysis (FEA)
- computational fluid dynamics (CFD)
- CAD
- electrical simulation.

Process/Skill Questions

- What are the strengths and weaknesses of computational modeling?
- What are the benefits and limitations of using computational toolboxes vs. constructing them?
- What skill sets are needed for experimental and computational modeling?

ITEEA National Standards

3. The Relationships Among Technologies and the Connections Between Technology and Other Fields

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Exploring Biomechanics and Biomaterials

Task Number 63

Apply mathematics and science in biomechanics.

Definition

Application should include

- the anatomy involved in systems biomechanics
- vector summation and vector decomposition
- the concept of moment to produce a rotation about a point
- stress and strain.

Process/Skill Questions

- How do anatomical factors affect the result of applied forces?
- What are the forces applied in a given biological system?
- How does one account for stresses and strains in a biomechanical system?
- How does biomechanical stress and strain apply to everyday life?

ITEEA National Standards

3. The Relationships Among Technologies and the Connections Between Technology and Other Fields

TSA Competitive Events

Biotechnology Design

Scientific Visualization (SciVis)

Task Number 64

Apply scientific principles to biomaterials for biocompatibility.

Definition

Application should consider

- the mechanical and chemical properties of biological materials (e.g., bone)
- the selection process for manufactured materials
    - mechanical
    - physical
    - chemical.

Process/Skill Questions

- Why is it important to match the properties of a biological material and a device?

- How do material properties affect longevity in a device?
- What are criteria for biomedical product recalls?

ITEEA National Standards

3. The Relationships Among Technologies and the Connections Between Technology and Other Fields

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Task Number 65

Use models and simulations in biomechanics.

Definition

Use of models and simulations should explore alternatives to the design solution using computation or mathematics (e.g., putting forces on muscles, changing insertion points in bone models).

Process/Skill Questions

- What criteria should be considered in the level of detail of a model?
- How does one determine the appropriate materials to be used in a model?
- When would one use generic models vs. customized models?

ITEEA National Standards

10. The Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving

TSA Competitive Events

Engineering Design

Task Number 66

Perform experiments related to biomaterials and biomechanics.

Definition

Performance should include collecting and analyzing data for use in designing solutions (e.g., stress, strain, and failure of a biomaterial).

Process/Skill Questions

- What equipment is typically used for biomechanical testing?
- What alternative biological models can be used in experimentation?
- How does biomaterial failure affect iteration of design?
- What is material variability? How does it affect biomechanical failure?

ITEEA National Standards

10. The Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving

TSA Competitive Events

Biotechnology Design

Task Number 67

Design solutions to a biomechanics problem.

Definition

Design should include

- defining the problem
- performing background research
- generating ideas
- selecting a solution
- justifying the solution
- sketching a prototype
- documenting the process.

Process/Skill Questions

- How can one ensure that variability among people is taken into account in the design of biomechanical solutions? Why is it important?
- What are the benefits of iteration?

- What are special considerations when designing for humans?

ITEEA National Standards

11. Apply the Design Process

TSA Competitive Events

Engineering Design

Task Number 68

Analyze the design of implants.

Definition

Analysis should include

- any substance engineered to interact with biological systems for a medical purpose
- the mechanical principles of the human system and biomedical devices that interact with it.

Process/Skill Questions

- Why should materials that are being used with living tissue be inert (nonreactive), surface active (able to bond with tissue), or resorbable (able to be dissolved and assimilated)?
- How would analyses vary between a prosthetic and an implant?
- What are some causes of implant rejection?

ITEEA National Standards

13. Assess the Impact of Products and Systems

Exploring Rehabilitation

Task Number 69

Explain concepts related to disability and rehabilitation.

Definition

Explanation should include the following:

- The reality that every person is likely to be disabled at some point in his/her life
- A person's autonomy and control of their environment
- Self-concept among persons with disabilities and how they want to be perceived
- Quality of life as the focus of rehabilitation
- The importance of taking the end user into account

Process/Skill Questions

- What are the most common types of disabilities?
- How does one perceive disability in others?
- How does perception of disability vary even among persons with the same disability?
- How does perception of the various users affect design?

ITEEA National Standards

6. The Role of Society in the Development and Use of Technology

TSA Competitive Events

Engineering Design

Extemporaneous Speech

Task Number 70

Explain the different areas of rehabilitation engineering.

Definition

Explanation should include

- assistive technology (e.g., hearing aids, text-to-speech technology, speech-recognition technology, mobility aids)

- prosthetics (e.g., limb, eye, ear)
- rehabilitative devices (e.g., rehabilitation robotics, virtual reality, telerehabilitation).

Process/Skill Questions

- How does assistive technology differ from rehabilitation technology?
- What are some sources for information about the field of rehabilitation engineering?

ITEEA National Standards

6. The Role of Society in the Development and Use of Technology

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Task Number 71

Examine the design of assistive technologies.

Definition

Examination should include examples of assistive technologies that address impairments in

- vision
- hearing
- motor skills
- cognition.

Process/Skill Questions

- What are some assistive devices? What is the importance of each?
- How does assistive technology accommodate differences among users?
- How have smartphones and tablets affected the development of assistive technology?

ITEEA National Standards

6. The Role of Society in the Development and Use of Technology

TSA Competitive Events

Biotechnology Design

Task Number 72

Examine the design of prosthetics.

Definition

Examination should include examples of prosthetics that address impairments in

- vision
- hearing
- motor skills.

Process/Skill Questions

- How have computers and numerically controlled machinery affected the manufacture of prosthetics and implants?
- What are some prosthetic devices? What is the importance of each?
- How does design address the life expectancy of a prosthesis?
- How does the advent of small, cheap microcontrollers and high-density batteries affect advancements in this field?

ITEEA National Standards

10. The Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving

TSA Competitive Events

Biotechnology Design

Task Number 73

Examine the design of rehabilitative devices.

Definition

Examination should include examples of

- mechanical devices (e.g., exercise equipment, rehabilitation robotics)
- adherence
- other rehabilitation (e.g., virtual reality, telerehabilitation).

Process/Skill Questions

- What are some rehabilitative devices? What is the importance of each?
- What is adherence? Why is it important to design for it?
- What is virtual reality? How is it used in rehabilitation? Why is it important?

ITEEA National Standards

10. The Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving

TSA Competitive Events

Engineering Design

Task Number 74

Synthesize biomedical engineering concepts to produce solutions.

Definition

Synthesis includes producing solutions by drawing from various biomedical engineering areas, such as

- neural interfaces
- imaging
- bioinstrumentation
- biomechanics
- biomaterials.

Process/Skill Questions

- How are neural interfaces integrated with other aspects of biomedical engineering to produce devices?
- What are the challenges when integrating multiple engineering areas?
- What postsecondary pathways are available to prepare for a career in different areas of biomedical engineering?

ITEEA National Standards

11. Apply the Design Process

Task Number 75

Describe the effects of human factors.

Definition

Description should include the effect of the knowledge of human systems on the design of assistive and rehabilitative technology.

Process/Skill Questions

- What human factors should be considered in designing for visual, auditory, cognitive, and motor impairments?
- Why is it important to know about human physiology in design?
- How does the degree of disability and/or experience affect the design?

ITEEA National Standards

4. The Cultural, Social, Economic, and Political Effects of Technology

TSA Competitive Events

Debating Technological Issues

Task Number 76

Produce models and simulations for rehabilitation.

Definition

Producing models and simulations should explore alternatives to the design solution using computation or mathematics (e.g., prosthetic arm).

Process/Skill Questions

- What situations would dictate the use of mathematical models?

- What types of models are used to prevent disabilities?
- How does the quality of the simulation affect conclusions?

ITEEA National Standards

12. Use and Maintain Technological Products and Systems

TSA Competitive Events

Engineering Design

Task Number 77

Perform experiments to determine rehabilitation need.

Definition

Performance should include collecting and analyzing data for use in designing solutions (e.g., gait analysis, grip strength, range of motion, anthropometric data for wheelchairs).

Process/Skill Questions

- What equipment is typically used to determine needs in rehabilitation?
- Where can one find relevant data?
- How does one determine if data is accurate?
- How does human variability affect experimental design and data collection?

ITEEA National Standards

10. The Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving

TSA Competitive Events

Essays on Technology

Task Number 78

Design solutions for a rehabilitation problem.

Definition

Design should include

- defining the problem
- performing background research
- generating ideas
- selecting a solution
- justifying the solution
- sketching a prototype
- making a prototype of the device
- documenting the process
- evaluating the device
- reiterating the process.

Process/Skill Questions

- Why is user involvement crucial for design?
- At which points in the design process should users be involved?
- Why is it important to test functionality and user interface long before the prototype is fully implemented?

ITEEA National Standards

11. Apply the Design Process

TSA Competitive Events

Engineering Design

Using the Engineering Design Process to Solve a Biomedical Problem

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Task Number 79

Document the design process.

Definition

Documenting the design process includes keeping a detailed design notebook with regular dated entries, with information such as

- diagrams, sketches
- research findings
- interview information
- contacts
- test results
- calculations
- procedures
- obstacles encountered with solutions.

Process/Skill Questions

- How can a design notebook affect intellectual property (i.e., patents)?
- What details should go into a design notebook?
- How often should one make entries in a design notebook?
- What use is the design notebook to the designer?

ITEEA National Standards

11. Apply the Design Process

TSA Competitive Events

Biotechnology Design

Engineering Design

Task Number 80

Define a biomedical engineering design problem.

Definition

Definition should include

- the essential components of a biomedical engineering design problem
- the reasons it is important to have a clear concept of a problem before attempting to solve it
- an explanation of a biomedical engineering design brief (i.e., a statement that explains what the solution to a biomedical engineering design problem must accomplish)
- essential components of a design brief.

Process/Skill Questions

- Why is it important to have a clear definition of a problem before attempting to solve it?
- What might be the consequences of not having a clear concept of a biomedical engineering design problem before attempting to solve it?
- How can a biomedical engineering design problem be stated succinctly?
- How is a design brief used in a biomedical engineering design process?
- How does iteration address lack of clarity in the original problem statement?

ITEEA National Standards

9. Engineering Design

TSA Competitive Events

Biotechnology Design

Engineering Design

Task Number 81

Identify the constraints and criteria of the design problem.

Definition

Identification should include what the design must do to be considered a success, the resources required, and the availability of all required resources.

Process/Skill Questions

- What are constraints? How do they affect design?
- What is the difference between a specification and a criterion?
- Where can one locate resources required to solve a biomedical engineering design problem?
- What steps may be taken when resources are not available?

ITEEA National Standards

9. Engineering Design

TSA Competitive Events

Engineering Design

Task Number 82

Research potential solutions to the design problem.

Definition

Research should include

- use of multiple resources from the library, Internet, and other sources of information
- examples of current solutions to the problem
- critique and evaluation of current solutions to the problem
- proper citations or documentation as needed.

Process/Skill Questions

- How does one identify quality resources?
- What are the dangers of using the Internet as the only source of information?
- Why is it important to use multiple sources to research a given topic?
- What are the benefits of using multiple media sources of information for research?

ITEEA National Standards

9. Engineering Design

TSA Competitive Events

Engineering Design

Task Number 83

Generate multiple solutions to the design problem.

Definition

Generation should include explanations of at least three solutions and may include sketches, lists, flowcharts, and/or multimedia elements.

Process/Skill Questions

- What are the benefits of generating multiple solutions?
- How can sketches and other graphic displays aid the ideation process?
- What are the benefits of having multiple perspectives in a team?
- Where can ideas originate?

ITEEA National Standards

9. Engineering Design

TSA Competitive Events

Engineering Design

Task Number 84

Sketch the solutions to the design problem.

Definition

Sketches of the solutions may be

- freehand
- isometric
- orthographic/multi-view
- computer-aided/generated.

Sketches may also be in schematics or block diagrams.

Process/Skill Questions

- What are the benefits of sketching to the design process?
- What advantages does sketching have over computer generation?

- What is the purpose of a block diagram?
- What technical skills are necessary for making effective sketches?

ITEEA National Standards

9. Engineering Design

TSA Competitive Events

Engineering Design

Task Number 85

Evaluate the constraints and criteria of each solution to the design problem.

Definition

Evaluation should include constraints and criteria related to

- ethical and legal issues
- environmental effects
- societal effects
- sustainability
- cost and budget
- manufacturability (e.g., scaling up)
- time requirements and limitations
- resources needed, including their availability.

Process/Skill Questions

- Why should one analyze the constraints and criteria of the various solutions?
- What might be the consequences of not analyzing the constraints and criteria?
- Why is sustainability an important issue?
- How do constraints and criteria change due to time limitations?

ITEEA National Standards

9. Engineering Design

TSA Competitive Events

Engineering Design

Task Number 86

Explain the application of quality control and the importance of regulatory agencies to the manufacture of biomedical products.

Definition

Explanation should include

- regulatory agencies (e.g., Food and Drug Administration [FDA], U.S. Department of Agriculture [USDA], Federal Communications Commission [FCC], OSHA)
- quality requirements and standards (e.g., Good Laboratory Practices [GLP], Good Manufacturing Practices [GMP], International Standards Organization [ISO])
- distinguishing between quality assurance and quality control
- application of quality control to biomedical products.

Process/Skill Questions

- Why are regulatory agencies such as FDA, USDA, FCC, and OSHA concerned with biomedical products?
- What is the difference between quality control and quality assurance?
- What are the origins of the guidelines for GLP and GMP?

ITEEA National Standards

11. Apply the Design Process

6. The Role of Society in the Development and Use of Technology

TSA Competitive Events

Engineering Design

Essays on Technology

Extemporaneous Speech

Task Number 87

Justify an optimal solution to the design problem.

Definition

Justification should include

- explaining the meaning of the term *optimal solution*
- comparing all known aspects of the proposed solutions
- explaining reasons one solution may be the best
- explaining how a decision matrix is used to choose the optimal solution.

Process/Skill Questions

- What are trade-offs?
- How do trade-offs affect the decision-making process?
- How can the optimal solution among multiple solutions be determined?
- Why is selecting the optimal solution not a guarantee of success in solving the design problem?

ITEEA National Standards

11. Apply the Design Process

TSA Competitive Events

Engineering Design

Task Number 88

Determine the objectives for a biomedical engineering test of the solution to the design problem.

Definition

Determination of objectives should include

- explaining what the test must do to be considered a success
- predicting the expected results of the test.

Process/Skill Questions

- Why is it imperative to determine the objectives for a biomedical engineering test before conducting the test?
- How can one state objectives so that success or failure is definitive?
- Why should one predict the results of the test? Why is this important?
- Where can one find standard testing procedures?
- What concerns should be addressed when using animals or humans in testing?

ITEEA National Standards

10. The Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving

TSA Competitive Events

Engineering Design

Task Number 89

Create a prototype for the chosen solution to the design problem, using appropriate materials and processes (e.g., 3D rapid prototyping).

Definition

Creation should include

- explaining the importance of creating a prototype and benchmark
- identifying standard methods for creating a prototype and benchmark
- listing the materials and processes required
- describing why each material and process is needed
- using computer software to model
- constructing the prototype so that it demonstrates the effectiveness of the solution.

Process/Skill Questions

- What is the purpose of constructing a model or prototype for the chosen solution? What can it show?
- What are the common limitations of modeling and prototyping?
- How can one determine which materials and processes are needed for the construction of the model or prototype? How would the availability of materials guide this determination?

ITEEA National Standards

10. The Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving

TSA Competitive Events

Biotechnology Design

Computer-Aided Design (CAD), Engineering

Engineering Design

Task Number 90

Test the solution to the design problem.

Definition

Testing should include

- using mathematical, conceptual, and/or physical modeling, simulating, and optimizing
- recording what the test will show or accomplish
- evaluating whether the prototype meets the criteria
- researching other tests that cannot be conducted in the classroom.

Process/Skill Questions

- How do the criteria dictate the structure of the testing process?
- What should one do if a test fails?
- Why is repeated testing necessary?

ITEEA National Standards

13. Assess the Impact of Products and Systems

TSA Competitive Events

Engineering Design

Task Number 91

Evaluate test results.

Definition

Evaluation should include

- interpreting the data to determine whether the test results are repeatable and reliable
- determining the degree to which the solution meets the design criteria
- weighing the advantages and disadvantages of the solution, including costs, time and resources required, plausibility, ethical considerations, and effects.

Process/Skill Questions

- Why is it important to know whether the test results demonstrated by the model are repeatable and reliable?
- Why is it important to consider the disadvantages of the solution before attempting to implement it, even when the disadvantages are greatly outweighed by the advantages?
- How does one determine the true cost of the solution? What are the factors affecting cost?
- What is the difference between efficiency and effectiveness?
- How are data and results validated?
- Why is it important to consider how a solution might affect the environment?
- Why is it crucial to consider the ethics surrounding the potential solution?
- What criteria might one use to determine the degree to which the solution meets the objective stated in the design brief?

ITEEA National Standards

13. Assess the Impact of Products and Systems

TSA Competitive Events

Engineering Design

Task Number 92

Formulate an improved solution to the design problem.

Definition

Formulating should include

- revisiting the solutions proposed
- proposing an improved solution(s), based on data acquired
- justifying how the improved solution better meets the criteria
- testing the improved solution.

Process/Skill Questions

- Why should one revisit the solutions proposed when formulating an alternate solution to the problem?
- How might the data acquired in the test influence the formulation of an alternate solution?
- What factors might help justify an alternate solution as optimal?

ITEEA National Standards

9. Engineering Design

TSA Competitive Events

Engineering Design

Task Number 93

Prepare the final project report.

Definition

Preparation should include

- abstract
- introduction

- research questions and/or hypothesis
- methods and materials
- obstacles encountered and solutions found in the process
- results
- conclusions
- appendices (e.g., raw data, sketches, notes, surveys)
- citations of references used.

Process/Skill Questions

- What is an abstract? What is its purpose?
- What elements belong in an abstract?
- Why should one include appendices in a report?
- What is the importance of choosing one's references carefully and citing them properly?
- Why is it important to include enough detail in a report to ensure replication?

ITEEA National Standards

9. Engineering Design

TSA Competitive Events

Engineering Design

Task Number 94

Present the final project report.

Definition

Presentation should include

- statement of the engineering-design problem
- graphical representations and visual aids (e.g., diagrams, sketches, photos, videos, models, prototypes)
- presentation of the design
- justification for the design
- results
- evaluation of solution
- final results based on initial expectations and degree of success in meeting the requirements of the proposal.

Process/Skill Questions

- What are the benefits of incorporating graphical and/or visual representations of a solution into one's presentation?
- What makes a presentation effective and persuasive?
- How can the quality of a presentation affect the acceptance of a solution?
- Why is it important to know the audience when preparing a presentation?

ITEEA National Standards

9. Engineering Design

TSA Competitive Events

Engineering Design

Extemporaneous Speech

Prepared Presentation

SOL Correlation by Task

39	Describe biomedical engineering.	English: 11.3, 12.3 History and Social Science: VUS.8
40	Define terms related to biomedical engineering.	English: 11.3, 12.3 History and Social Science: VUS.8
41	Relate biomedical engineering milestones to the current historical context.	English: 11.5, 12.5 History and Social Science: VUS.8
42	Explain the nature and manufacturing of biomaterials.	English: 11.1, 11.5, 12.1, 12.5 History and Social Science: VUS.8, VUS.14, WG.17, WHII.14
43	Demonstrate laboratory safety.	Science: BIO.1, CH.1
44	Describe sociocultural effects of biomedical engineering.	English: 11.5, 12.5 History and Social Science: VUS.14, WG.17, WHII.14
45	Practice the engineering design process to solve biomedical problems.	English: 11.3, 11.8, 12.3, 12.8

		History and Social Science: WHII.4 Mathematics: AFDA.8, COM.1, PS.8*, PS.10* Science: BIO.1, CH.1, PH.1
46	Analyze data generated from lab activities.	English: 11.5, 12.5 History and Social Science: WHII.4 Mathematics: AFDA.1, AFDA.3, AFDA.4, AFDA.5, AFDA.7, AFDA.8, AII.3, AII.7, AII.9, AII.10, AII.11, MA.1, MA.2, MA.3, MA.4, MA.5, PS.5, PS.1*, PS.17, PS.18, PS.19, PS.2*, PS.20, PS.3*, PS.4*, PS.7* Science: BIO.1, CH.1, PH.2
47	Identify postsecondary opportunities related to biomedical engineering.	English: 11.5, 11.8, 12.8 History and Social Science: VUS.1, VUS.14, WG.1, WG.17, WHI.1, WHII.1, WHII.14
48	Apply mathematics and science in cell and tissue engineering and regenerative medicine.	History and Social Science: WHII.4 Mathematics: DM.4, DM.1*, DM.2*, DM.3*,M.9*, MA.7, MA.10, MA.11, PS.10*
49	Produce cellular models and simulations.	History and Social Science: WHII.4 Mathematics: T.3, COM.1, COM.2, COM.5, COM.7, COM.9, MA.7, MA.10, MA.11
50	Explain techniques of cellular and tissue engineering.	English: 11.1, 12.1
51	Explain techniques of genetic engineering.	English: 11.1, 11.3, 12.1, 12.3 Mathematics: MA.7 Science: BIO.5
52	Perform experiments related to cell function.	Mathematics: AFDA.8, PS.8*, PS.10*
53	Design a solution for a regenerative medicine problem.	History and Social Science: WHII.4 Mathematics: AFDA.8, PS.1*, PS.2*, PS.3*, PS.4*, PS.10*
54	Describe bioinformatics as a database technology.	English: 11.1, 12.1 History and Social Science: VUS.14, WG.7, WHII.14

		Mathematics: COM.7
55	Apply mathematics and science in imaging and instrumentation.	Mathematics: MA.7, MA.10, MA.11, PS.5, PS.1*, PS.18, PS.19, PS.2*, PS.20, PS.3*, PS.4*, PS.7*, PS.10*
56	Produce models and simulations of bioinstruments.	Mathematics: T.3, MA.1, MA.3, MA.5
57	Analyze images and biosignals.	English: 11.1, 12.1 Mathematics: T.3, AII.11, PS.5, PS.6, PS.1*, PS.2*, PS.3*, PS.4*
58	Perform experiments using basic biosensors.	History and Social Science: WHII.4 Mathematics: AFDA.7, AII.11, PS.5, PS.6, PS.1*, PS.2*, PS.3*, PS.4*
59	Design solutions requiring creation of a bioinstrument.	English: 11.1, 11.3, 11.8, 12.1, 12.3, 12.8 History and Social Science: WHII.4 Mathematics: T.3, AII.11, MA.1, MA.3, MA.5, PS.5, PS.6, PS.1*, PS.2*, PS.3*, PS.4*
60	Compare the mechanisms of medical imaging technologies.	English: 11.1, 12.1 History and Social Science: VUS.14, WG.17, WHII.14 Mathematics: G.14
61	Analyze the design of biomedical instruments and devices.	English: 11.1, 11.5, 12.1, 12.5 Mathematics: PS.5, PS.6, PS.1*, PS.2*, PS.3*, PS.4*, PS.7*, PS.10*
62	Identify the role of computational modeling in bioinstrumentation.	English: 11.1, 12.1 Mathematics: T.3, AII.7, AII.9, AII.10, COM.1, MA.1, MA.2, MA.3, MA.4, MA.7, MA.10, MA.11
63	Apply mathematics and science in biomechanics.	Mathematics: T.9, AII.10, MA.7, MA.8, MA.9, MA.10
64	Apply scientific principles to biomaterials for biocompatibility.	History and Social Science: WHII.4
65	Use models and simulations in biomechanics.	Mathematics: T.9, AII.10, MA.7, MA.8, MA.9, MA.10
66	Perform experiments related to biomaterials and biomechanics.	Mathematics: AFDA.3, AII.9, AII.10, AII.11, COM.1, COM.7, MA.7, PS.5, PS.6, PS.1*, PS.2*, PS.3*, PS.4*, PS.7*, PS.8*, PS.10*
67	Design solutions to a biomechanics problem.	English: 11.3, 11.5, 12.3, 12.5

		History and Social Science: WHII.4 Mathematics: AII.11, COM.1, MA.1, MA.3, MA.5, PS.5, PS.6, PS.1*, PS.2*, PS.3*, PS.4*
68	Analyze the design of implants.	
69	Explain concepts related to disability and rehabilitation.	English: 11.1, 12.1 History and Social Science: VUS.13, VUS.14, WG.17, WHII.14
70	Explain the different areas of rehabilitation engineering.	English: 11.1, 12.1 History and Social Science: VUS.14, WG.17, WHII.14
71	Examine the design of assistive technologies.	History and Social Science: VUS.14, WG.17, WHII.14
72	Examine the design of prosthetics.	History and Social Science: VUS.14, WG.17, WHII.14
73	Examine the design of rehabilitative devices.	History and Social Science: VUS.14, WG.17, WHII.14
74	Synthesize biomedical engineering concepts to produce solutions.	English: 11.5, 12.5 History and Social Science: VUS.14, WG.17, WHII.14
75	Describe the effects of human factors.	English: 11.1, 12.1 History and Social Science: VUS.14, WG.17, WHII.14
76	Produce models and simulations for rehabilitation.	History and Social Science: WHII.4 Mathematics: T.9, AII.11, MA.7, PS.5, PS.6, PS.1*, PS.2*, PS.3*, PS.4*, PS.10*
77	Perform experiments to determine rehabilitation need.	English: 11.8, 12.8 History and Social Science: WHII.4 Mathematics: PS.5, PS.6, PS.1*, PS.2*, PS.3*, PS.4*, PS.10*
78	Design solutions for a rehabilitation problem.	English: 11.1, 11.3, 12.1, 12.3 History and Social Science: WHII.4 Mathematics: G.14, T.9, COM.1
79	Document the design process.	English: 11.6, 12.6 History and Social Science: WHII.4

		Mathematics: G.3, G.14, PS.7*, PS.9* Science: PH.1
80	Define a biomedical engineering design problem.	English: 11.3, 11.5, 12.3, 12.5 History and Social Science: WHII.4 Mathematics: COM.1
81	Identify the constraints and criteria of the design problem.	History and Social Science: WHII.4 Mathematics: COM.1, COM.3 Science: PH.1, PH.4
82	Research potential solutions to the design problem.	History and Social Science: WHII.4 Science: PH.1, PH.4
83	Generate multiple solutions to the design problem.	History and Social Science: WHII.4 Mathematics: COM.7 Science: PH.1, PH.4
84	Sketch the solutions to the design problem.	History and Social Science: WHII.4 Mathematics: G.14 Science: PH.1, PH.4
85	Evaluate the constraints and criteria of each solution to the design problem.	History and Social Science: WG.2, WHII.4 Science: PH.1, PH.4
86	Explain the application of quality control and the importance of regulatory agencies to the manufacture of biomedical products.	History and Social Science: VUS.13, VUS.14, WG.17, WHII.14
87	Justify an optimal solution to the design problem.	History and Social Science: WHII.4 Mathematics: DM.4, DM.2*, DM.3*
88	Determine the objectives for a biomedical engineering test of the solution to the design problem.	History and Social Science: WHII.4
89	Create a prototype for the chosen solution to the design problem, using appropriate materials and processes (e.g., 3D rapid prototyping).	History and Social Science: WHII.4
90	Test the solution to the design problem.	History and Social Science: WHII.4

		Mathematics: PS.10* Science: PH.1, PH.4
91	Evaluate test results.	History and Social Science: WHII.4 Mathematics: PS.5, PS.1*, PS.13, PS.2*, PS.20, PS.3*, PS.4*, PS.7*, PS.16* Science: PH.1, PH.4
92	Formulate an improved solution to the design problem.	History and Social Science: WHII.4 Mathematics: PS.10* Science: PH.1, PH.4
93	Prepare the final project report.	History and Social Science: WHII.4 Mathematics: PS.8*, PS.10*
94	Present the final project report.	History and Social Science: WHII.4 Mathematics: COM.7, COM.12

Appendix: Credentials, Course Sequences, and Career Cluster Information

Industry Credentials: Only apply to 36-week courses

- College and Work Readiness Assessment (CWRA+)
- National Career Readiness Certificate Assessment
- Workplace Readiness Skills for the Commonwealth Examination

Concentration sequences: *A combination of this course and those below, equivalent to two 36-week courses, is a concentration sequence. Students wishing to complete a specialization may take additional courses based on their career pathways. A program completer is a student who has met the requirements for a CTE concentration sequence and all other requirements for high school graduation or an approved alternative education program.*

- Biotechnology Foundations in Agricultural and Environmental Science (8085/36 weeks)
- Biotechnology Foundations in Health and Medical Sciences (8344/36 weeks)
- Biotechnology Foundations in Technology Education (8468/36 weeks)
- Engineering Explorations I (8450/36 weeks)
- Engineering Practicum IV (8453/36 weeks)

Career Cluster: Agriculture, Food and Natural Resources	
Pathway	**Occupations**
Animal Systems	**Animal Geneticist** **Animal Scientist**
Food Products and Processing Systems	**Food Scientist**
Natural Resources Systems	**Microbiologist**
Plant Systems	**Botanist** **Plant Breeder/ Geneticist**
Power, Structural, and Technical Systems	**Agricultural Engineer**

Career Cluster: Health Science	
Pathway	**Occupations**
Biotechnology Research and Development	**Biochemist** **Cell Biologist** **Medical, Clinical Laboratory Technician** **Research Assistant**
Health Informatics	**Bioinformatics Technician**
Support Services	**Medical, Clinical Laboratory Technologist**
Therapeutic Services	**Physician** **Surgeon**

Career Cluster: Science, Technology, Engineering and Mathematics	
Pathway	**Occupations**
Engineering and Technology	**Agricultural Engineer** **Biomedical Engineer** **Chemical Engineer** **Human Factors Engineer** **Industrial Engineer** **Industrial Engineering Technician**
Science and Mathematics	**Biologist** **Botanist** **Environmental Scientist** **Microbiologists** **Plant Breeder and Geneticist**