SIEMENS ENGINEERING RESEARCH AND DEVELOPMENT
(COURSE CODE: 57R3)

COURSE DESCRIPTION: In the Engineering Research and Development course, the capstone experience in the Siemens Engineering program, students are challenged to form teams to identify, research, and create a unique solution to an existing problem. Teams will gauge market interest in their proposed solution and will be responsible for developing and documenting the research as it applies to the creation of a prototype solution to their identified problem. Student teams design a business model for creation of the product and apply lean design concepts to the development of a plan of manufacture. Teams explore concepts of lean manufacturing and statistical process control (SPC) and how Six Sigma is used to keep waste to a minimum and maximize profits. At the end of the course students present the results of their research, prototype development, business plan and how they were able to optimize the process of manufacturing.

OBJECTIVE: Given the necessary equipment, supplies, and facilities, the student will complete all of the following core standards successfully.

COURSE CREDIT:	1 (120 hours) Carnegie unit
PREREQUISITE:	Siemens Mechatronics and the Internet of Things (Iot)
RECOMMENDED GRADE LEVELS:	11, 12

A. SAFETY

Engineers know the academic subject matter, including safety as required for proficiency within their area. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Review school safety policies and procedures.
2. Review classroom safety rules and procedures.
3. Review safety procedures for using equipment in the classroom.
4. Identify major causes of work-related accidents in office environments.
5. Demonstrate safety skills in an office/work environment.

B. STUDENT ORGANIZATIONS

Engineers know the academic subject matter, including professional development, required for proficiency within their area. The following accountability criteria are essential for students in he Siemens Engineering program of study.

1. Identify the purpose and goals of a Career and Technology Student Organization (CTSO).
2. Explain how CTSOs are integral parts of specific clusters, majors, and/or courses.
3. Explain the benefits and responsibilities of being a member of a CTSO.

4. List leadership opportunities that are available to students through participation in CTSO conferences, competitions, community service, philanthropy, and other activities.
5. Explain how participation in CTSOs can promote lifelong benefits in other professional and civic organizations.

C. TECHNOLOGY KNOWLEDGE

Engineers know the academic subject matter, including the ethical use of technology. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Demonstrate proficiency and skills associated with the use of technologies that are common to a specific occupation.
2. Identify proper netiquette when using e-mail, social media, and other technologies for communication purposes.
3. Identify potential abuse and unethical uses of laptops, tablets, computers, and/or networks.
4. Explain the consequences of social, illegal, and unethical uses of technology (e.g., piracy; cyberbullying; illegal downloading; licensing infringement; inappropriate uses of software, hardware, and mobile devices in the work environment).
5. Discuss legal issues and the terms of use related to copyright laws, fair use laws, and ethics pertaining to downloading of images, Creative Commons, photographs, documents, video, sounds, music, trademarks, and other elements for personal use.
6. Describe ethical and legal practices of safeguarding the confidentiality of business-related information.
7. Describe possible threats to a laptop, tablet, computer, and/or network and methods of avoiding attacks.

D. PERSONAL QUALITIES AND EMPLOYABILITY SKILLS

Engineers know the academic subject matter, including positive work practices and interpersonal skills. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Demonstrate creativity and innovation.
2. Demonstrate critical thinking and problem-solving skills.
3. Demonstrate initiative and self-direction.
4. Demonstrate integrity.
5. Demonstrate work ethic.
6. Demonstrate conflict resolution skills.
7. Demonstrate listening and speaking skills.
8. Demonstrate respect for diversity.
9. Demonstrate customer service orientation.
10. Demonstrate teamwork.

E. PROFESSIONAL KNOWLEDGE

Engineers know the academic subject matter, including positive work practices and interpersonal skills. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Demonstrate global or "big picture" thinking.
2. Demonstrate career and life management skills and goal-making.
3. Demonstrate continuous learning and adaptability skills to changing job requirements.
4. Demonstrate time and resource management skills.
5. Demonstrates information literacy skills.
6. Demonstrates information security skills.
7. Demonstrates information technology skills.
8. Demonstrates knowledge and use of job-specific tools and technologies.
9. Demonstrate job-specific mathematics skills.
10. Demonstrates professionalism in the workplace.
11. Demonstrate reading and writing skills.
12. Demonstrates workplace safety.

F. DEVELOPING AND DOCUMENTING IDEAS

Engineers apply the skills for developing and documenting ideas. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Apply concepts of intellectual property rights in the selection and documentation of an original idea.
2. Document original ideas in such a way they can prove original work in the development of the idea.
3. Design research to inform decisions made in the development of intellectual property.
4. Document original research to analyze, apprise and revise investigations used in the research.
5. Analyze methods of protecting intellectual property to create a plan for protecting the creation and manufacturing of a product.
6. Apply divergent and convergent thinking to provide fresh ideas in the creation process.
7. Create and maintain an Engineering Notebook for research, prototype creation, documentation, and daily reflections.
8. Apply engineering design and problem solving as an iterative process incorporating science, mathematics, and engineering to optimally convert resources to meet a design solution.
9. Communicate design solutions utilizing effective technical writing skills including correct spelling, proper grammar, and accurate technical vocabulary.
10. Prepare a quantitative plan for the successful completion of a project.
11. Assume leadership responsibility for collaborative team actions and decisions related to the successful completion of a project.
12. Evaluate the needs and costs of resources necessary for the completion of a project.

13. Prepare and communicate model documentation to include such details as product analysis, size, materials, assembly details, schematics, program design, installation, and service requirements.

G. ENTREPRENEURSHIP AND BUSINESS

Engineers apply entrepreneurial and business skills in engineering design and development. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Apply the concepts of lean startup to a plan to create a new venture or introduce a new product on behalf of an existing company.
2. Research and create a business plan for the creation of a new product.
3. Design a feasibility study to gain insights to judge demand for a new product idea.
4. Create a marketing plan for introducing and promoting demand for a new product.
5. Critique issues with a business plan to identify and implement changes to better respond to public demand.
6. Research and categorize the activities that a business conducts to make discoveries that can either lead to the development of new products or procedures, or to improve existing products or procedures.
7. Research and evaluate the new approaches of rapid development and deployment of products that saves time and is more efficient.
8. Review and evaluate the benefits of a plan for an assembly line or work cell.
9. Create a strategy to increase efficiency and decrease waste by receiving inventory just in time for the production process to reduce costs and reduce use of natural resources.
10. Create a management plan including quality planning, quality control, quality assurance, and quality improvement for an advanced manufacturing environment.
11. During the creation of their business plan student teams will apply the concepts of lean manufacturing to create a dynamic growing enterprise creating high quality products.

H. LEAN DESIGN

Engineers apply lean design skills. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Apply the concepts of design for quality to optimize the design of a new product or innovation to an existing one.
2. Analyze results from a feasibility study in the creation of the design of a product to better meet the needs of potential customers.
3. Apply Concurrent engineering to the design of a product to allow for faster development and production.
4. Conduct failure analysis to identify issues and solutions necessary in the creation of a successful product.
5. Create a cradle-to-cradle plan in order to plan for eventual disassembly and resource recovery of a product.

6. After customer surveys teams revisit those surveyed to critique how effective their designs were in meeting the needs of their customers.
7. As a component of their testing protocol teams incorporate customer input to formulate improvements to better serve their customers in the future.
8. Teams analyze how well their product design met the needs identified by customers as a component of the marketing plan.
9. Teams design automated systems to statistically analyze components parts of their product design to gauge the accuracy of manufacture, how well their selected materials and design perform and how attractive to various consumers.

I. DESIGN FOR MANUFACTURING

Engineers apply proficient skills for manufacturing design. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Apply the principles of design for manufacturing, enabling the efficient and effective production of products.
2. Develop a logical argument for organizing the tools, machines, and labor necessary to produce finished goods from raw materials.
3. Create a strategy to increase efficiency and decrease waste by receiving goods only as they are needed in the production process, thereby reducing inventory costs and reducing the impact of water and other natural resource consumption.
4. Create a plan for protecting the safety, health and welfare of people engaged in the manufacturing environment.
5. Create technical drawings having proper dimensional tolerances and limits necessary for components to fit as designed.
6. Teams analyze their designs to identify stresses and forces applied to the parts and then select the material used in the printing process and how the layers are applied to create the strongest part that is easy to print.
7. Understand and apply Statistical Process Control (SPC) to acquire quality control.
8. Research and apply knowledge of material properties to product design and development.

J. DESIGN FOR ASSEMBLY

Engineers apply proficient skills for designing and maintaining assembly systems. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Apply engineering design of components to assure alignment for assembly.
2. Create a management plan that includes quality planning, quality control, quality assurance, and quality improvement for an advanced manufacturing environment.
3. Research, construct, and evaluate a plan for an assembly line or work cell.

K. LEAN MANUFACTURING

Engineers apply proficient skills for lean manufacturing. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Analyze a product design and select the most appropriate type of manufacturing and design a method of producing and assembling the necessary parts.
2. Synthesize information about customer demand and design a manufacturing method to produce the necessary components efficiently.
3. Investigate value, value stream, flow, pull (customer orders) and elimination of waste and perfection to design an appropriately sized function to produce parts and maximize profits.
4. Teams critique the use of additive manufacturing for components of their designs with the goal of supplying components just when they are needed against other methods of manufacturing those components to realize savings and providing an uninterrupted flow of parts to the manufacturing process just when it is needed.
5. Teams create a plan for manufacturing their product using lean principles to allow people working on the products to give input on all aspects of the process with the goal of improving efficiency of the process.
6. Apply Just-In-Time principles to streamline a production process and eliminate waste.
7. Create a process map for the product to streamline the process and effectively improve the flow.
8. Teams analyze their manufacturing process to create a plan to use AI to help improve the accuracy of the manufacturing process.
9. Apply various techniques to lower work-in progress, needed floor space, travel distances and inventory buildup enabling a savings on the space necessary to produce products.
10. Design a data collection system to collect and analyze information about the production of processes necessary.
11. Use appropriate instruments accurately to make precision measurements required by plan specification to achieve required dimensions, shapes, location of centers, parallel surfaces, and other component attributes.
12. Understand and apply Statistical Process Control (SPC) to better inform the six-sigma analysis of a product.
13. Create a plan for protecting the safety, health and welfare of people engaged in the manufacturing environment.
14. Use appropriate instruments accurately to make precision measurements required by plan specification to achieve required dimensions, shapes, location of centers, parallel surfaces, and other component attributes.

L. REVERSE ENGINEERING

Engineers apply proficient skills for reverse engineering. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Apply design principles which include the accommodation for disassembly and resource recovery.
2. Research and apply current business practices that lead to new product development or improvement of products or procedures including the use of rapid development and deployment to be faster to market.
3. Analyze the design attributes of an existing product by disassembling it into its parts, use precision measurement tools to create sketches & drawings of the parts, identify the materials and processes used in manufacturing, and create a new and improved design.
4. Utilize convergent modeling to capture data and rapidly create new parts to fit existing scans.
5. Collaborate with teams to combine models and parametrically create solutions.
6. Utilize rapid prototyping/additive manufacturing to create highly complex parts designed in a CAD system.

M. ELECTRICAL AND CONTROL SYSTEMS

Engineers apply proficient skills for designing electrical and control systems. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Design and analyze an electrical system to efficiently convert, transform, and transmit electricity to where it is needed.
2. Create, read, and analyze schematics and provide a concise summary for documentation purposes.
3. Research and specify electrical devices necessary to provide needed power.
4. Apply machine control systems, sensory feedback, and information processing to increase efficiency.
5. Teams discuss the sensors necessary to gather data to guide the automation programming to be self-correcting, improving quality and limiting downtime.
6. Use flow charts and state diagrams to apply logic in the design of control programs.
7. Apply machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.
8. Teams design programming to allow automation to be creative in applying algorithms to effectively control the manufacturing process with negligible human intervention.
9. Use flow charts and diagrams to apply logic in the design of control programs.
10. Design and analyze the application of machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.
11. Teams create PID controls for their automation to allow the program to continually update the algorithms to produce consistent results.
12. Apply the principles of programming in the design of a control system to solve control issues.
13. Apply flow charts and state diagrams to solutions of design problems.
14. Create programming to control systems with minimal human interaction.
15. Create user interfaces that display appropriate information to track functioning of systems.
16. Select and apply appropriate execution structures in the design of control systems.

17. Design programming to acquire and process data for the control of systems.
18. Design a system using sensors to monitor changes and use that data to inform changes to the system.
19. Apply Boolean logic in the design of a system that monitors inputs.
20. Create programs to initialize, calibrate, and monitor system parameters.
21. Select and apply appropriate sensors to obtain data about system performance.
22. Design a system of elements that manages power to accomplish a task involving defined movement.
23. Design a control system to vary the speed and performance of a motor by utilizing feedback from the system to gain the most efficiency possible.
24. Formulate a system to utilize data collection and analysis to maintain and improve product quality and provide adequate confidence that the product will satisfy design requirements.
25. Design and analyze the application of machine control systems, sensory feedback, and information processing to increase efficiency.
26. Create programs to initialize, calibrate and monitor system parameters.
27. Design a system using sensors to monitor changes and use that data to inform changes to the system
28. Create a system to measure and record data about a process.
29. Design electrical and other circuits to condition signals from sensors used in monitoring systems.
30. Specify hardware needed to create a system to acquire needed data.
31. Apply different types of data in the correct format to inform control systems.

N. MANUFACTURING AND AUTOMATION TECHNOLOGY

Engineers apply proficient skills in manufacturing and automation technology. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Apply Cartesian Coordinates to create toolpaths for machine tools.
2. Research and apply proper cutting tool speeds, feeds, and directions for manufacturing.
3. Create simple Numeric Control (NC) part programs using a text editor or a CAM package.
4. Analyze NC part program files to identify and correct errors.
5. Analyze part geometry to select appropriate cutting tools and fixturing devices needed to create a part using a CNC machine.
6. Edit the tool library of a CNC machine program to establish tool offset values.
7. Design and prepare 3D models with appropriate units for use in toolpath generation.
8. Setup a CAM package by editing the material and tool libraries.
9. Generate tool paths from a CAD program and edit NC part program files to identify and correct errors.
10. Design, construct, and operate a multi-axis robot for use in an industrial application.
11. Design and create the wiring diagrams for controlling the motion of a robotic arm.
12. Apply the degrees of freedom to describe arm movement used in the programming of the arm.

13. Integrate a robotic arm into an automated work cell for moving and manipulating components.
14. Design and create grippers and other end effectors for custom use in an automated setting.
15. Create a system utilizing sensors to allow a robotic arm to make decisions based upon sensor input.
16. Design a system involving the integration of machines, machine tools, specialized dies, jigs, fixtures, and instruments used in production creating needed parts to make jigs, fixtures, alignment and drill guides, gauges, and other manufacturing and assembly tools with a rapid prototyping/additive manufacturing device.
17. Develop a logical argument for selecting the automation to control tools, machines, and labor necessary to produce finished goods from raw materials.
18. Research and apply knowledge of material properties to product design and development.

O. HUMAN MACHINE INTERFACE (HMI)

Engineers apply proficient skills for designing and implementing a human machine interface. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Design the visual displays to obtain and display data from a process controlled by a PLC.
2. Create a system to visualize and remotely control a work cell.
3. Create a communication system to monitor and automatically capture data on demand for storage in a database.
4. Design a system to remotely monitor and display real time machine parameters to allow for changes and updates to the operating parameters.

P. PNEUMATICS DESIGN AND CONTROL

Engineers apply proficient skills for constructing and operating pneumatics systems. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Construct systems that efficiently utilize a fluid (liquid or gas) under pressure to generate, transmit, and control power.
2. Design an integrated system of machines, machine tools, jigs, fixtures, instruments, and control programs to produce needed parts.
3. Identify systems, sub-systems, and typical components of an automated manufacturing operation.
4. Apply the necessary safety precautions associated with a fully automated system.

Q. INTERNET OF THINGS (IOT)

Engineers apply proficient skills for designing and implementing a network of IoT devices. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Analyze different types of network setups to select the most appropriate for specific tasks.
2. Compare network operating systems to specify the most appropriate system for data networks.
3. Synthesize applications for use in gathering, analyzing, and display in information environments.
4. Design and implement a program for device security.
5. Evaluate various connectivity options for protocols for communication in the design stage of an automated workcell.
6. Create a method to collect, store, analyze, and display sensor data.
7. Secure the elements of an IoT connected device.
8. Teams critique their manufacturing system to identify areas that must be defended against cyber-attacks and design a system to provide the security necessary to protect the operation while allowing data transfer between elements of the system and specific operators.

R. CAREER AWARENESS AND DEVELOPMENT

Engineers acquire the career development skills necessary for success. The following accountability criteria are essential for students in the Siemens Engineering program of study.

1. Develop awareness of career opportunities related to each curriculum project.
2. Critique career connections described in each curriculum project engagement scenario.

Academic Standards and Indicators