SREB | High Schools That Work

Advanced Career

Integrated Production Technologies

Course 3: Mechatronic Systems for Advanced Production
Syllabus

College or Career?...Why Not Both?

Advanced Career (AC)

A multi-state consortium to develop curricula, assessments, instructional materials, and teacher/counselor/leader training to provide more students with relevant and challenging career-technical courses

Course Syllabus
Integrated Production Technologies
Course 3: Mechatronic Systems for Advanced Production

Course Description

Students will design cost-effective work cells incorporating automation and robotics to improve quality of final products. The advanced production in this course depends on the use and coordination of information, automation, network systems, vision and sensing systems. Students will design and create mechatronic systems and automated tooling to accomplish these advanced tasks. Students produce authentic documentation about their cyber-mechanical systems and the integration with data to control and monitor processes.

Instructional Philosophy

The Mechatronic Systems for Advanced Production course requires AC students to engage in authentic projects they might encounter in the workplace. Students complete a variety of challenging projects designed to prepare them for employment and a variety of options for training and college after high school. To complete challenging work-related projects, students participate in a variety of learning activities that require the use of technology, software, and academic skills such as reading, writing, mathematics, and science that are essential to success in design and production and many other high-demand careers.

Students read technical texts in the design and production field to acquire background information; they frequently consult supporting documents to complete the project assignment. Students maintain and use an Engineering Notebook to keep track of notes, design and production vocabulary, citations, reflections, and project notes gained from background reading and class work. At the end of each project, students develop a written explanatory/informative or argumentative document in a format used by manufacturing professionals to communicate their work to others.

In this information-centered economy, the ability to read the technical documents of the field is an essential skill. Success in the modern economy demands that students be able to read these dense technical materials, write about what they had learned, and present their findings orally to various stakeholders. AC views literacy as a fundamental skill for the 21st century that allows students to apply the varied technical skills that drive the AC curriculum.

Students apply knowledge of scientific information and processes as appropriate to complete each project. They also apply algebra and statistical concepts (e.g., data collection, data analysis, and descriptive statistics) learned in high school mathematics courses. At the conclusion of each project, individual students and their teams make an oral presentation to an audience of one or more professionals in engineering, design and production, or other related fields.

AC students take responsibility for their own learning, demonstrating autonomy and innovation in solving problems posed by the AC Integrated Production Technologies projects. Individual students and student teams take ownership of the project, but teachers provide instruction as needed on learning skills that increase self-reliance and teamwork. As the student and the team progress through the projects, the teacher gives students additional voice and choice on how to complete the project. Serving as facilitators, teachers ask insightful questions that cause students to reflect on their work. They also teach mini-lessons on necessary technical skills that students have been unable to learn independently (e.g., reading strategies for managing difficult reading assignments, writing skills, and mathematics and/ or science concepts). Under the guidance of a skilled teacher-facilitator who knows how to ask the right questions to lead students to find answers on their own, teams increase their independent research and project work. The teacher-facilitator provides criteria to ensure quality work and supports students who need extra help to achieve the high-quality performance expected in AC courses.

To ensure success as a postsecondary student, employee, business owner, or entrepreneur, AC Integrated Production Technologies students must meet high expectations regarding quality of work and personal behavior. Students arrive at class on time with all necessary materials. They redo major assignments until they meet the high-quality AC standards. They sometimes require before- or after-school tutoring and extra-help sessions. Since AC courses include rigorous work, students can expect to complete homework and out-of-class project assignments.

AC students work in teams and complete individual assignments related to the team's work. Like teams in the workplace, AC Integrated Production Technologies team members are collectively and individually responsible for the success of a project and for ensuring that each team member masters related academic and technical content and demonstrates the 21st-century skills of teamwork, critical thinking, and problem solving. Students evaluate their work and that of others, using scoring guides provided by the AC teacher.

AC Integrated Production Technologies students frequently use technology. In Course 3, students use a variety of computer software for design, testing, and creating products using advanced technologies. They learn about input and output control and visualization software (e.g., Solid Edge). Students use Cloud or Internet-based applications such as social media, texting, and electronic survey instruments. They use electronic media to interview professionals in the design and production field, participate in virtual field trips, and use digital cameras and/or recorders and related software.

AC students interact with design and production experts. As appropriate, students participate in field trips and/or interact with professionals. Community experts serve as guest speakers, project mentors, and authentic audience members to provide feedback at the conclusion of each project. Teachers coach students in the behavior and expectations of design and production professionals. Students exhibit professional standards of dress and behavior.

This course requires AC students to adhere to safety and quality standards expected on the job. Students complete class activities, projects, and problems by using the planning and thinking methods of design and production professionals. Throughout the project, the teacher checks for understanding through Engineering Notebook entries, questioning, and work reviews. Students use self-evaluation and peer-evaluation scoring guides throughout a project. As in the workplace, students revise work until it meets quality standards, and they follow all safety requirements.

Students complete an end-of-project exam, final products/deliverables, a professionally written report on their work, and an oral presentation at the end of each project. Mirroring final products, presentations, or certification exams in the workplace, students do not revise or redo these final assessments. These serve as a means for assessing the academic, technical, and technology knowledge and skills students acquire through each project. At the completion of Course 3, teachers administer an End-of-Course Assessment to each student. A team consisting of high school and college academic and technical teachers and design and production professionals developed the assessment to ascertain mastery of essential academic, technical, and 21st-century knowledge and skills. The assessment is similar to employer certification exams. Students read, interpret, paraphrase, summarize, and analyze technical materials; answer technical, mathematics, and science questions; and complete mathematics problems.

Course Goals

Students in Advanced Career (AC) Integrated Production Technologies Course 3 do the following:

- Use terminology of the field.
- Research design and production technical texts, journal articles, and related documents.
- Use the Engineering Design Process.
- Use design and production concepts to solve problems.
- Relate manufacturing to societal principles, including economic implications.
- Use design and production tools to make decisions and solve problems.
- Apply project management principles.
- Gain information on how the American manufacturing industry works.
- Use appropriate and effective research skills.
- Use best practices to design and implement research studies.
- Use science practices to design investigations.
- Demonstrate proficiency in word processing, spreadsheets/databases, and presentation software.
- Communicate information, including descriptive mathematics, to audiences.

Major Projects/Problems and Assignments

Major projects for Course 3 include the following

Project 1: Design and Test a Furniture Coating Process

Essential Question (EQ): How can we create a furniture finish process that mitigates environmental impact?

Student teams are challenged to develop a furniture finish coating process that both balances the need for volatile organic compound (VOC) limited finishes and the need for efficient application in a manufacturing setting to limit total VOC use. Students learn the basics of mixtures and how subtle changes in the composition of coatings may have a pronounced effect on the final products in terms of finish performance, application methods, and sustainability.

Project 2: Sensor-Guided Overhead Crane

Essential Question (EQ): How can we design a program to control a multi-axis motor-driven crane?

Students assume leadership roles of software engineering groups that create software to operate a sensor-controlled overhead crane. The software program must identify objects, pick up the objects, and then move the objects to new locations without collisions. In turn, students demonstrate an understanding of automation and control of motor-driven overhead cranes using sensors, ability to write software algorithms to control motor-driven cranes, and research skills to determine appropriate algorithms for controlled movement and to meet the goal of safely operating cranes.

Project 3: Tool Dispensing System

Essential Question (EQ): How can we design a "secure" tool dispensing system for advanced manufacturing environments?

This project requires students to develop an integrated tool crib dispensing system using multiple sensors, a programmable user interface, and an Internet communications module. Automated tool crib systems are essential to reducing the time required for machine setup, maintaining personal accountability for key tools, and reducing theft and loss in production environments.

Project 4: Electro-mechanical Lockout/Tagout System

Essential Question (EQ): How can we design and implement an improved Lockout/Tagout device to reduce the risks of injury when performing maintenance on production equipment?

This project requires students to design, develop, and successfully demonstrate a new electro-mechanical interlocking device, or “Lockout/Tagout" (LOTO) device, that produces an electronic signal (such as a LED beacon) that turns on when the LOTO device is locked. The device ensures and communicates that all energy has been removed or disconnected from a piece of equipment before maintenance procedures begin, thereby reducing the risk of injury to maintenance workers.

Project 5: Bottle-filling Machine

Essential Question (EQ): How can we automate, improve, and statistically monitor a bottle-filling process?

Students integrate sensors and actuators to improve the quality and increase the throughput of a bottle-filling machine. The project pushes students to think critically about how to dispense two different color fluids reliably into bottles. The machine they design must read the label on the empty bottle, calculate the appropriate quantities, and then dispense the right mixture of colored fluids at the correct volume, while controlling a motor-driven conveyor belt that moves the empty bottles to the filling station and moves the full bottles to the end of the conveyor where students pick them up. Students use control chart methodology to first characterize the quality of the system and then apply improvements based on experience.

Engineering Notebook

Each student maintains an Engineering Notebook for each project, either an electronic notebook or a paper version. Students take notes, define terms, develop project plans, and write reflections in their notebooks. Teachers check the notebooks periodically to measure understanding; to help students manage the work; and to determine the need for additional teaching, clarification, or practice.

Career Investigations

Each project contains a career component that allows students to explore design and production, manufacturing, engineering, or related careers and the skills associated with success, including educational requirements.

Instructional Delivery Plan

AC curricula, including the Integrated Production Technologies curriculum, use the project-based learning (PBL) method. Teachers introduce each project with an entry event to give students an overview of the problem and to develop interest. Subsequently, students work in teacher-assigned teams to determine what they need to know and do to solve the problem. They develop a team calendar and a work plan to record team expectations and methods of collaboration. As students become proficient in PBL, the teams have greater autonomy or independence. If teachers see a need for additional technical or academic knowledge and skills for students to complete the project, they provide instruction in the form of mini-workshops for teams that are ready for the information or whole-class instruction on the topic.

Teachers using PBL serve as facilitators rather than disseminators of information to students. **Frequently, teachers answer students' questions with more questions, challenging them to think for themselves or to conduct research rather than rely on the teacher for answers.** AC Integrated Production Technologies students may need to use tutorials or other resources to learn software rather than rely on the teacher for instruction. Mini-workshops, some whole-class instruction, and independent learning are reflections of the world of work, where professionals use all three methods to learn new skills. Employees in high-skill jobs seldom do their work by using skills based on categories such as reading, writing, mathematics, or science. Instead, workers, business owners, and entrepreneurs integrate various skill sets to solve complex problems. That is why AC projects require students to use academic skills such as reading, writing, mathematics, and science to solve technical or career-related problems. Occasionally, students work with other teachers to obtain answers to academic questions or with industry experts to find project-related information.

AC teachers use "just-in-time" instruction, for example, to teach mathematics concepts needed by students to complete project assignments. This method assembles students into small groups or pairs (i.e., different from their project teams) to learn mathematics skills. After the instruction, project teams use the new skills to create a product or solve a problem.

All AC projects require each student to prepare a final written product, using formats similar to those in the career area. If students complete research, participate in learning activities, and keep good notes in an Engineering Notebook, they find it easier to produce the final product. All AC projects include an oral presentation to an authentic audience of professionals in the field. Audience members use rubrics or scoring guides to evaluate the technical and oral aspects of the presentation and to provide feedback to the teams.

To complete a project, students work both independently and with a team. **Individual members ensure that all team members demonstrate understanding of the concepts and procedures used in solving the problem.** The teacher assigns a group grade for the project based on the team's work and an individual grade based on the Engineering Notebook, a student's individual paper, independent work, a student's individual portion of the oral presentation, and end-of-project and course exam.

Weekly extra-help sessions after regular class hours provide support for individual students and teams. AC Integrated Production Technologies teachers frequently review the work of individuals and teams. They review Engineering Notebooks weekly to monitor progress and provide suggestions to help individuals and teams redirect their energies, as needed. A teacher may recommend or require an extra-help session. Because AC is an advanced program, students expect frequent homework and out-of-class assignments to complete projects. AC teachers may use the "flipped classroom" approach that allows students to view online videos of teacher-led demonstrations or homework explanations outside of class so that more class time is available for students' collaborative work.

Extra-help sessions may include the following:

- Reteaching to small groups of students during class time
- Tutoring or extra help outside of regular class time
- Redoing assignments as homework
- Tutoring by subject-area teachers in reading, writing, mathematics, and science

Assessment Plan

AC courses include two types of assessment—formative and summative. Teachers use formative assessments to determine the need for additional instruction. Typically, teachers do not score formative assessments until students demonstrate mastery of knowledge and skills. Students use formative assessments (e.g., checklists, rubrics, and peer or teacher feedback) to determine what or how to improve. Students usually redo formative assessments until the work reaches the high standards expected of AC students. Students sometimes redo work after class hours, during extra-help sessions or homework, to avoid slowing the pace of the team or the class.

Summative assessments measure how well students have mastered academic, technical, technology, and 21st-century standards at the end of an assignment, a project, or a major assessment, such as an end-of-project or end-of-course exam. Students ordinarily do not redo summative assessments (e.g., oral presentations to authentic audiences, final products, and end-of-project or end-of-course exams). The assessment plan for the AC Integrated Production Technologies course includes five components:

1. **Engineering Notebook:** Students maintain an electronic portfolio or a written notebook for each project. The purposes are to document the investigative process and research; to develop organization skills necessary for success in continuing education, the workplace, and in completing the written product at the end of the project; to write daily reflections on new insights; to practice the inquiry process for group and individual questions; and to use the notebook as a study guide. AC teachers use the notebooks as formative assessment to check for student understanding and to reteach as needed. The AC teacher supplies a rubric and a due date for the notebooks.

   An Engineering Notebook contains the following types of work used by a student to complete a project:

   - Daily and weekly reflections;
   - Essential technical vocabulary;
   - Notes from technical readings, interviews, and field experiences;
   - Practice mathematics problems;
   - Science lab reports;
   - Career investigations; and
   - Other assignments completed during the project.

2. **21st-Century Skills:** The 21st-century skills are the personal skills necessary to compete in a global economy that demands innovation by workers, business owners, and entrepreneurs. Competition in the modern economy requires an understanding of global awareness; financial, economic, business, and entrepreneurial literacy; and civic, health, and environmental literacy. AC courses include a variety of tools and strategies to enable students to use these skills. Teachers assess students' understanding and application of 21st-century skills by rating how they 1) take responsibility; 2) help the team; 3) respect others; 4) make and follow agreements; 5) organize work; and 6) build teamwork. They also assess how students participate in classroom and lab activities and adhere to lab safety rules. When assignments require students to interact with community experts, academic teachers, or other adult mentors, the teacher observes and scores

the student’s ability to communicate in a professional manner. The AC Integrated Production Technologies teacher grades 21st-century skills through observation, peer- and self- evaluation, and Engineering Notebook entries.

3. **Project Academic and Technical Tasks:** Evaluation includes the demonstration of academic tasks, such as solving mathematics problems, applying science concepts, reading technical and academic materials, writing information/explanatory or argumentative texts, and making oral presentations to a specific audience. In most projects, approximately 50 percent of the tasks involve application of academic knowledge and skills; approximately 50 percent demonstrate mastery of technical skills and use of technology and software. Tasks in most Integrated Production Technologies projects include a blend of academic, technical, technology and 21st-century skills. AC teachers evaluate students' demonstrations of understanding, reasons, processes, and procedures. AC students demonstrate quality, creativity, and efficiency of work resulting in solid design and performance of project deliverables.

4. **End-of-Project Assessment:** Each project includes an End-of-Project Assessment designed to assess whether or not each student mastered the academic and technical content required to complete the project. In other words, can each student actually read and comprehend the technical materials? Can each student actually do the mathematics to complete the project? Can each student demonstrate understanding of the science concepts underpinning the project? Can each student demonstrate mastery of technical content knowledge and the knowledge and skills to use the technology and software needed to complete the project? The End-of-Project Assessment is designed to ensure that one student on the team did not do all of the reading, mathematics, and academic applications while others watched. The assessment includes multiple-choice questions, mathematics problems, science questions, and constructed-response questions that require students to write clearly for a specific audience and demonstrate the ability to respond to a specific work-related problem. AC students read technical materials and demonstrate understanding of the technical text. The exams include questions related to 21st-century skills, such as developing a work plan, researching possible solutions, and working together with peers and experts. Because the End-of-Project Assessments may build on the knowledge and skills of prior projects, they may contain questions from previous projects. Fifty percent of the End-of-Project Assessment questions relate to technical and technology content; 50 percent relate to academic and 21st-century skills. Some questions overlap into both categories.

5. **End-of-Course Assessment:** AC courses include a rigorous, comprehensive national End-of-Course Assessment to assess technical, academic, and 21st-century skills. This is a final assessment of whether or not students have retained the understanding and skills acquired through several projects they have completed. It is recommended that the final assessment represent 30 percent of a student's grade; however, this is a decision each school must make. AC students should take this assessment seriously because it is expected that it will be used by some states as the basis for awarding an industry certification, academic credit, or dual credit for high school and college.

   The End-of-Course Assessment mirrors employer certification exams; college-readiness exams for mathematics, science, and language arts; and authentic workplace scenarios and technical questions. Approximately 50 percent of the End-of-Course Assessment consists of items related to literacy, mathematics, and science; approximately 50 percent relates to technical knowledge applied through the course. Some items may address the habits of mind and behavior that are fundamental to 21st-century skills.

Grading Protocol

Project Grade: Teachers determine individual grades by assessing students' mastery of knowledge and skills based on a list of project deliverables, rubrics, scoring guides, and project exams. Three assessment components make up the project grade. The teacher calculates the grade by dividing the number of points earned by the number of points possible. The following table contains three project assessment components with the corresponding weight relative to the project grade.

Table 1. Project Grade Distribution

Project technical and academic tasks, including the final project product and written report	40%
21st-century skills assessments and the Engineering Notebook	20%
End-of-Project Assessment	40%

Six- or Nine-Weeks Grade: The teacher determines the grade for each six- or nine-week grading period by calculating grades from projects completed during the period. If required by the district, teachers create an end-of-grading period exam, which counts as 20 percent of the grade. Students accumulate points in each of the three assessment components from all projects completed during the grading period. The teacher divides the total accumulated points by the total number of points available during the grading period. The following table shows the five components making up the six- or nine-weeks grade and the end-of-grading period exam, along with the weight of each in relation to the grading period grade.

Table 2. Nine-Week Grade Distribution

Technical and academic grades from completed projects and written products	40%
21st-century skills assessments from all completed projects and the Engineering Notebook	20%
End-of-Project Assessments	40%

Final Course Grade: District policy determines the final grades for completion of the AC Integrated Production Technologies course. Averaging the grades from each grading period might account for 70 percent of a student's final grade, and the End-of-Course Assessment could account for 30 percent.

Sample Advanced Career (AC) Integrated Production Technologies Program of Study

This career area program of study is a source of information as you develop your own personal learning plan. This plan lists coursework suggested to meet the demands of high-wage, high-skill, and high-demand jobs. Your personal learning plan needs to meet high school graduation requirements as well as entrance requirements for a variety of postsecondary options, including college and work.

	7-8th Grades	Grade 9	Grade 10	Grade 11	Grade 12	Postsecondary
Language Arts	Language Arts 8	College Preparatory Language Arts 9	College Preparatory Language Arts 10	College Preparatory Language Arts 11	College Preparatory Language Arts 12 AP English	Articulation/Dual Credit transcripted post-secondary courses may be taken/moved to the secondary level for articulation/dual credit purposes. Post-secondary plans of study need to meet learner's career needs required for degrees, licensure or certification. In the first years, postsecondary coursework may include: English Composition Technical Writing Speech Algebra Statistics Psychology Sociology Organic Chemistry Microbiology Ethics and Legal Issues
Mathematics	Algebra I Pre-Algebra	Algebra I/Geometry	Geometry Algebra II	Algebra II Trigonometry Pre-Calculus	Trigonometry/AP Calculus AP Statistics	
Science	Science 8	Biology	Physics Physical Science	AP Chemistry Chemistry	AP Anatomy and Physiology/Anatomy & Physiology	
Social Studies	Social Studies 8	State History Geography/ Civics	U. S. History	World History	Economics/ Entrepreneurship	
Career-Technical	Career Exploratory Computer Applications	AC Integrated Production Technologies 1: Advanced Technology for Design and Production	AC Integrated Production Technologies 2: Systems of Advanced Technology	AC Integrated Production Technologies 3: Mechatronic Systems for Advanced Production	AC Integrated Production Technologies 4: Design for the Production of Advanced Products	
Academic Electives		Speech World Language I	Psychology Physical Education World Language II	Fine Arts		
Intervention	Summer Bridge Program for Mathematics or Language Arts	Double-Dosing of Mathematics or Language Arts*	Catch-Up Courses	Catch-Up Courses	Senior Transition Course for Mathematics or Language Arts**	

* For students entering grade nine at less than grade-level proficiency in mathematics and/or English/language arts

** For students in grade 12 not yet college- or career-ready in mathematics and/or literacy