

STEM showcase

SECOND LOOK

This feature shines a spotlight on breakthrough best practices, clever methodologies, and game-changing approaches by returning them to the public eye.

Integrated Secondary Education Engineering Curriculum at West Michigan Aviation Academy

BY BRYAN FORNEY AND JAKE VERSCHUEREN

West Michigan Aviation Academy (WMAA) is a tuition-free public charter high school located on the campus of the Gerald R. Ford International Airport in Grand Rapids, MI. The WMAA vision is to provide an aviation- and STEM-focused high school experience, where character and leadership development are integral to a comprehensive, well-rounded education that inspires personal growth and ignites a passion for learning. Through a curriculum rich in aviation and STEM subjects, WMAA offers students a unique opportunity to focus on high-growth career fields. This approach better prepares WMAA students to pursue higher education, technical degrees, or enter the workforce in their chosen field.

The WMAA Engineering Department exists to introduce students to a range of STEM opportunities, offering courses in engineering, biomedical science, and computer science. The Engineering Department is guided by the core principles of integrity, ingenuity, and innovation with the goal of ensuring every WMAA student is equipped with an understanding of how to analyze and solve complex problems as an engineer would. Additionally, the Engineering Department endeavors to present many STEM-related career opportunities to students and provide them with a realistic understanding of what studying and working in these fields requires. Students choosing to take engineering electives during their junior and senior years will work toward mastery of the core disciplinary standards and technology and engineering practices delineated in *Standards for Technological and Engineering Literacy: The Role of Technology and Engineering in STEM Education* (STEL; ITEEA, 2020). The engineering electives explore a wide range of technology and engineering con-

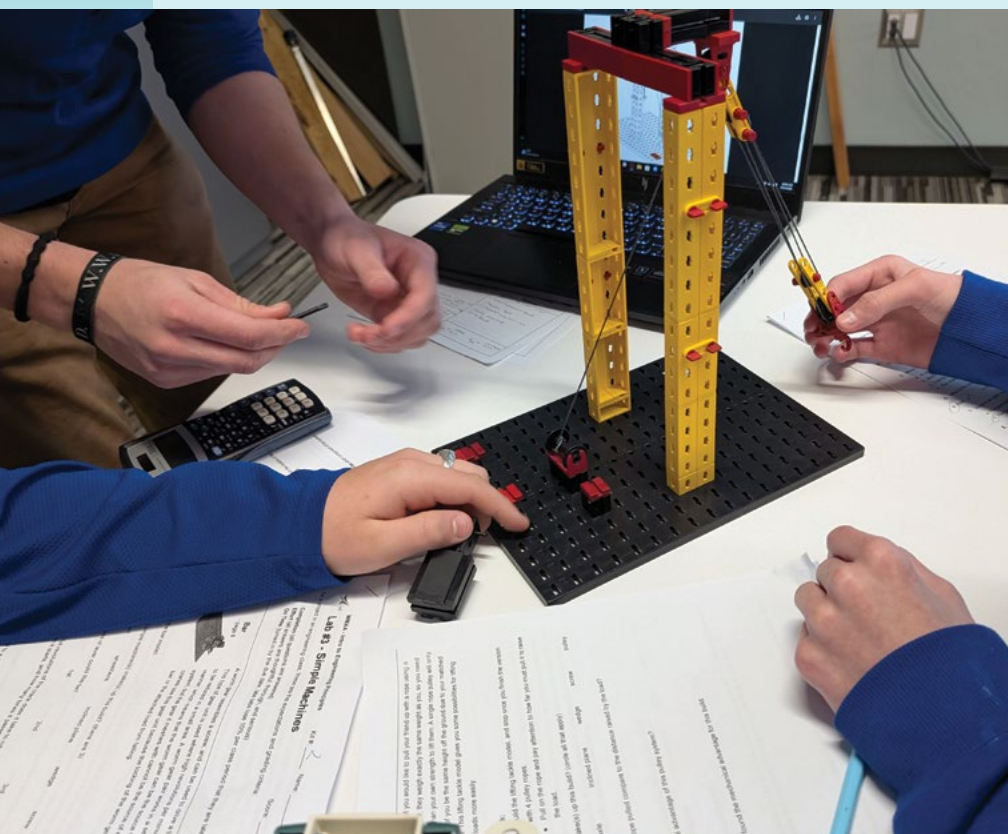


Figure 2. Students working on Junkyard War.

texts, allowing students to focus on the disciplines that best align with their interests.

The core of engineering instruction at WMAA is the Engineering Design Process (EDP). The version of the process used at WMAA has six steps: Empathize, Define, Ideate, Prototype, Test, and Go Public, as shown in Figure 1. To emphasize the iterative nature of engineering design, there is a loop in the model labeled Optimize. The Optimize loop is composed of the Ideate, Prototype, and Test steps, which are repeated until the solution is optimized or a resource constraint is encountered. Every engineering course taught by the Engineering Department is grounded in the EDP.

WMAA sophomores take two semester-long engineering courses that fulfill the Visual Performing and

Applied Arts credit requirement of the Michigan Merit Curriculum. These courses also form the foundation of engineering knowledge for all WMAA students and help them determine if they want to explore engineering more deeply through the wide range of STEM courses offered at WMAA.

The first of these is Introduction to Engineering Principles, a lab- and project-based course integrating science, technology, design, and mathematics concepts to introduce students to fundamental principles of engineering. Students work in collaborative teams on projects to develop understanding and skills in work, energy, simple machines, mechanics, structures and mechanical design. Students learn the EDP and exercise it through a series of activities called Junkyard Wars (Figure 2).

Each Junkyard War poses a design challenge narrow enough in scope to be solved in a few class periods, but with few enough constraints that a wide range of solutions are potentially effective. Junkyard War design challenges typically happen at the end of units, so students can put newfound content knowledge into practice. To assist students in becoming comfortable with the EDP, groups are provided with a simplified engineering notebook to record their work in each of the six steps of the process. An example of a Junkyard War EDP format is provided in Figure 3 (page 42). By the end of Introduction to Engineering Principles, students are well-versed in the fundamental functions of each step of the EDP. They also make connections between relevant math and science concepts and explore how they are the essential tools for engineering.

The partner course is Robotics, Automation & Manufacturing (RAM), which provides students with tools and techniques to better equip them to apply math and science through use of the EDP to solve problems. This project-based course introduces electronics, sensors, programming, additive manufacturing, computer-aided drafting, and robotics. The two courses do not need to be taken in a particular order, but a student who has completed both courses is well-versed in principles, processes, and techniques to practice the EDP and has a novice to apprentice level of understanding of each of the core disciplinary standards.

Sophomores at WMAA are encouraged to explore as many contexts as possible to consider multiple potential career fields. The Engineering and Aviation Departments each offer a variety of quarter-long exploratory courses from which students can choose. WMAA sophomores take four quarter-long electives. The



Figure 1. Engineering Design Process.

course options cover a wide range of topics such as robotics, drafting, biomedical sciences, computer science, and a wide range of aviation topics. Each of these classes exposes students to different contexts in which to apply the core disciplines and engineering practices.

In their junior year, WMAA students have many elective options. Students can choose to focus on engineering, biomedical sciences, computer science, private pilot flight, aviation maintenance, or unmanned aerial systems. All courses associated with these tracks are elective courses in addition to standard high school core requirements and provide deeper understanding of the core disciplinary standards within the associated contexts.

Students who choose to continue in engineering and dive deeper into the EDP will enroll in Aerospace Engineering, which introduces aerodynamics, performance, structures, and astrodynamics. It is a project-based course that builds on the foundation of the EDP where students learn to analyze requirements, research existing solutions, and apply modern 3D-modeling software and manufacturing equipment to design, build, test, and optimize aerospace systems. With these tools in hand, students achieve a deeper understanding of the EDP and demonstrate this, in part, by formatting their own engineering notebooks and practicing more advanced work done in each step of the EDP. Sophomores are expected to test prototypes against one or two project requirements. Junior students in Aerospace Engineering are taught how to turn requirements into design specifications and write test plans to evaluate performance objectively. The projects are more complex, have tighter constraints, require simulations to evaluate multiple prototypes, and are evaluated against competing performance criteria. For example,

the Aerospace Truss project, shown in Figure 4, requires students to evaluate the performance of multiple materials and design, build, and test a truss that carries the maximum load at the lowest possible truss weight and cost. This project introduces the idea of research and development costs spread across a production run and requires students to evaluate their designs using algebraic truss analysis, load-versus-deformation analysis (Hooke's Law), and computer simulations. By the end of this course, students have

a very deep understanding of the standards and practices within the contexts associated with mechanical and aerospace engineering.

Senior year electives in the Engineering Department are capstone courses that provide opportunities for students to truly master the standards and practices. The capstone that follows Aerospace Engineering is called Engineering Design and Development. This course begins with introducing project management concepts and adding the final design tools to the EDP. These



Figure 4. Aerospace truss project.



Figure 5. WMAA Engineering Showcase.

new tools are practiced through an autonomous robotics design project through the fall. Near the end of the first semester, students begin identifying a problem to solve. As the semester comes to a close, student design teams must select a problem, develop a problem statement, and present it to a panel of faculty and administrators acting as potential investors from whom the students need support for the project. The students exercise the EDP throughout the second semester as they develop a solution to their problem with the support of a mentor from industry or a local university. Throughout the project, the students must maintain a complete engineering notebook and produce a portfolio to summarize all their work. The projects culminate in a formal poster presentation called the Engineering Showcase (Figure 5). This is an opportunity for the students to truly practice the Go Public step as they present to industry professionals and potential employers, as well as their family and friends.

To understand how growth in the EDP is developed, it is helpful to review how one step of the EDP is approached at each grade level. Figure 6 (page 45) illustrates how

these skills are scaffolded and evolve as the students progress through the different levels of engineering coursework. Throughout this progression, the focus of the Ideate step is to consider as many solutions to the problem statement as possible and then identify which concepts will likely be most successful and should be taken to prototype. The tools shown in the figure assist students to do this at every grade level. As students gain more experience with the EDP, have a deeper understanding of the science and math from their core classes, and receive more complex challenges, additional engineering tools are provided to assist them in making the ideation process more flexible and powerful. Representative Ideate student work is presented in Figure 7 (page 45). A similar progression in the complexity of the EDP can be found in every step as students progress through the sequence of engineering courses at WMAA.

The Engineering Department at WMAA is dedicated to providing students with the opportunity to explore many facets of engineering while learning how engineers solve problems. All students are required to take the first year of engineering

courses, providing them with a thorough foundation in the *STEL* standards. Those students who choose to pursue the upper-level elective courses gain a deeper understanding of the EDP and the tools used by engineers. By the end of their senior year, members of the Engineering Design and Development course are extremely well prepared to enter undergraduate engineering programs.



Bryan Forney is the Engineering Department Leader at West Michigan Aviation Academy in Grand Rapids, MI. He can be reached via email at bforney@westmichiganaviation.org.



Jake Verschueren is an engineering teacher at West Michigan Aviation Academy in Grand Rapids, MI. He can be reached via email at jverschueren@westmichiganaviation.org.



Scaffolding the EDP for 10th-12th Grade Engineers

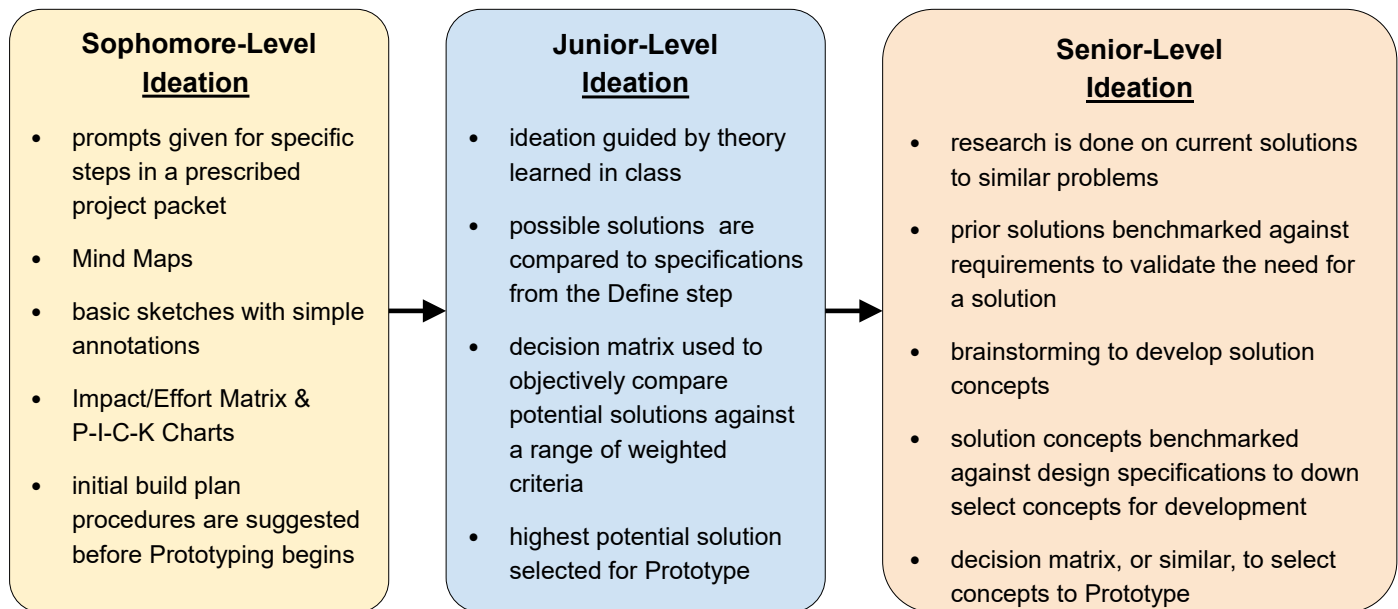


Figure 6. Scaffolding the EDP for 10th-12th Grade Engineers.

Student Work by Grade Level – Ideate Step

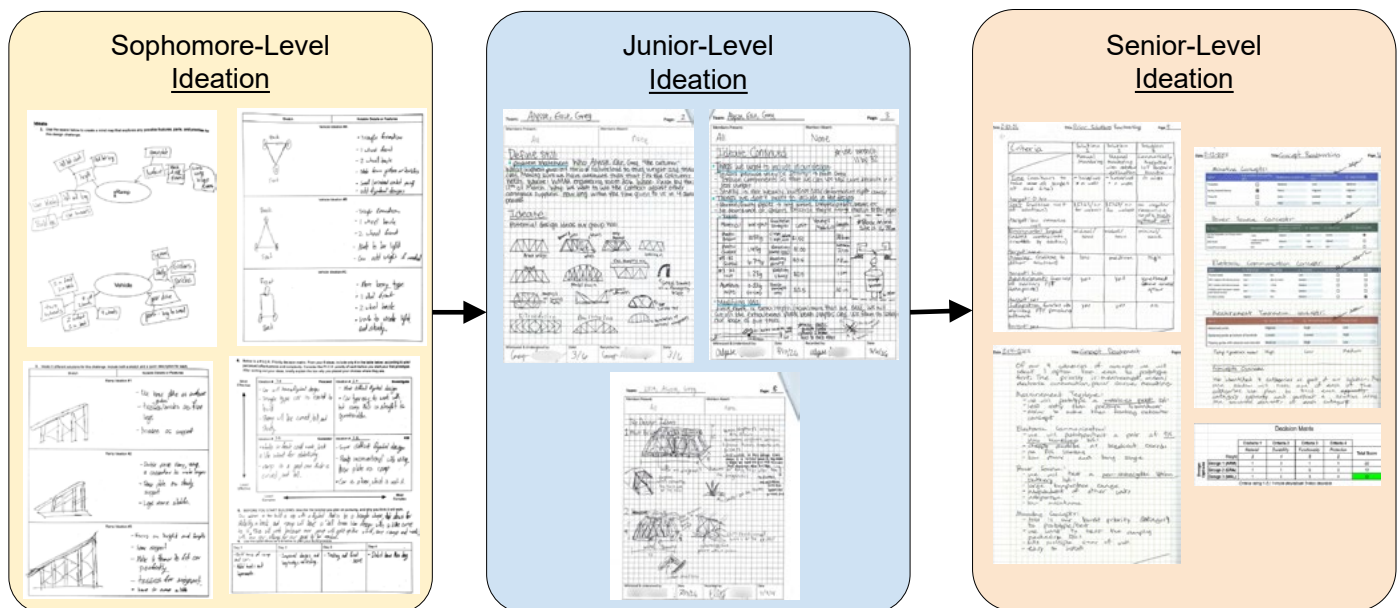


Figure 7. Student Work by Grade Level – Ideate Step.