2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #52726

Designing Introductory Engineering Projects to Teach Teamwork and Problem-Solving

Dr. Atheer Almasri, West Virginia University

Dr. Almasri is currently a teaching assistant professor in the Fundamentals of Engineering Program (FEP) at the Statler College of Engineering, West Virginia University. He has been serving in this position since 2020. Before joining West Virginia University, he worked as an assistant professor of Chemical Engineering at Imam University for 10 years. Dr. Almasri holds a bachelor's degree in Chemical Engineering, as well as master's and Ph.D. degrees in Materials Engineering.

Dr. Lizzie Santiago, West Virginia University

Dr. Lizzie Santiago is a Professor and the Director of the Fundamentals of Engineering Program in the Benjamin M. Statler College of Engineering and Mineral Resources at West Virginia University. She holds a Ph.D. in Chemical Engineering and has completed postdoctoral training in neural tissue engineering and molecular neurosciences.

Dr. Robin A.M. Hensel, West Virginia University

Robin A. M. Hensel, Ed.D., is a Teaching Professor in the Benjamin M. Statler College of Engineering and Mineral Resources at West Virginia University and an ASEE Fellow Member. As a mathematician and computer systems analyst, she collaborated in engineering teams to support energy research before entering higher education, where she taught mathematics, statistics, computer science, and engineering courses, secured over $5.5M to support STEM education research, led program development efforts, and served in several administrative roles. She has been recognized for her teaching, advising, service, and research through various awards.

Ms. Susie A. Huggins, West Virginia University

Susie A. Huggins supports the Fundamentals of Engineering Program in the Benjamin M. Statler College of Engineering and Mineral Resources at West Virginia University, where she supports faculty efforts in designing and implementing first-year engineering courses. Her work focuses on supporting the development of project-based learning experiences that foster collaboration, critical thinking, and problem-solving skills among first-year engineering students. Her professional interests align with the development of structured, low-cost, and engaging design projects that introduce students to the engineering design process while supporting teamwork and technical communication. Huggins has experience supporting hands-on, student-centered learning initiatives and assessment strategies, including the use of rubrics, peer evaluation, and project-based outcomes to measure student engagement and learning. She is currently pursuing a Ph.D. in Curriculum and Instruction at West Virginia University, with research focused on Appalachian kindergarten teachers' perceptions of STEM education. Her broader experience includes leadership in K–12 after-school programming, adult literacy initiatives, and STEM outreach efforts. She is a member of the American Society for Engineering Education and the Society of Women Engineers.

Dr. Todd R Hamrick, West Virginia University

Dr. Todd Hamrick, Ph.D. is aTeaching Professor in the Fundamentals of Engineering Program at West Virginia University Statler College of Engineering and Mineral Resources, a position he has held since 2011.

Dr. Akua B. Oppong-Anane, West Virginia University

Akua Oppong-Anane is an Teaching Assistant Professor at West Virginia University. She holds a Bachelor's degree in Chemical Engineering, a Master's degree in Chemistry and a Ph.D. in Environmental Engineering Sciences. Her research areas are in groundwater contamination at landfill sites, advising and retention of first year engineering students.

Dr. Carter Hulcher, West Virginia University

Dr. Hulcher is a Teaching Assistant Professor in the Fundamentals of Engineering Program in the Benjamin M. Statler College of Engineering and Mineral Resources at West Virginia University in Morgantown, WV. He has been in his current role at WVU since 2020. Dr. Hulcher holds degrees in Civil Engineering, as well as Mathematics.

Gia Huy Pham, West Virginia University

Shaping Engineers from Day One:
Project-Based Learning for Collaboration and Critical Thinking

This complete evidence-based practice paper focuses on how to design and implement effective engineering projects that promote teamwork, creativity, and problem-solving in a first-year engineering course. Developing meaningful and achievable design projects is central to introducing students to the engineering design process while building technical and professional skills essential for future coursework and career success. Creating a successful project for an introductory-level engineering course requires balancing complexity, available resources, cost, student enjoyment, and alignment with the ABET learning outcomes.

A series of hands-on projects was developed and tested to meet certain criteria. Each project was designed to be low-cost, time-efficient, and feasible for first-year students while still providing opportunities to apply fundamental concepts in design. The development process considered multiple factors and deliverables, including material availability, safety, and the ability to assess both technical writing and teamwork skills.

The methodology used to create these projects involved defining measurable learning objectives and creating individual & team writing and testing activities to refine project scope and evaluation criteria. Assessment tools such as rubrics, peer & self-evaluations, and individual and team project testing were employed to measure student learning and engagement.

The purpose of this study is to examine how diverse project experiences at an introductory level can strengthen teamwork competencies and problem-solving skills. Specifically, this paper addresses one main research question: how can first-year engineering projects be structured intentionally to teach teamwork skills and problem-solving? Findings from classroom implementation provide evidence-based recommendations for designing and integrating projects into foundational engineering courses to prepare students more effectively for advanced coursework and professional practice.

1. Introduction

One of the core courses in the Statler College of Engineering & Mineral Resources at West Virginia University is Engineering Problem Solving -1 (ENGR 101). All engineering and computer science students must complete this course before progressing into their majors. Traditionally, (ENGR 101) covers topics such as teamwork, project management, meetings, technical writing, engineering design process, engineering ethics, estimation, and engineering problem solving using Microsoft Excel. A central component of the course is an engineering design project.

These topics are intentionally chosen because teamwork and problem-solving are important skills for success in engineering education and professional practice. In first-year engineering courses, hands-on design projects provide a powerful platform for students to develop these skills in a collaborative, engaging, and authentic learning environment [1]. However, designing such projects requires careful attention to complexity, cost, feasibility, time constraints, and alignment with learning objectives.

For this reason, the first topic covered in (ENGR 101) is teamwork and the importance of collaboration in engineering design. The second major topic is engineering design and the stages of the design process. All course projects are intentionally designed to reinforce teamwork, problem solving, the design process, and technical communication.

Building on this course structure, this paper focuses on how to design introductory engineering projects that effectively teach teamwork and problem-solving. It presents a series of tested hands-on projects, describes the motivations behind them, outlines key logistics and design methodologies, and examines their impact on student engagement and team collaboration.

Understanding the current course structure requires consideration of its 20-year evolution through a process of continuous assessment and improvement. When a university-wide first-year seminar became mandatory, the student success and career exploration components were removed from Engineering 101, resulting in a revised two-credit course focused primarily on design and technical skill development. Early iterations featured three distinct team-based design projects per semester, each with a separate technical report, targeting introductory design and teamwork, data analysis with Excel, and a broader socially motivated challenge. Although pedagogically well intentioned, this fast-paced model limited sustained team development and reflection while creating significant workload pressures for students and instructors.

Over time, targeted enhancements were introduced to strengthen learning outcomes, including integrated information-literacy modules developed with engineering librarians [2–6], cross-disciplinary collaborations with mathematics faculty linking theory and design application [7], discipline-specific first-year projects, and a comprehensive technical writing guide. While each initiative addressed important objectives, their cumulative effect increased cognitive load, compressed instructional time, and restricted opportunities to incorporate additional essential content, such as engineering ethics. While team reconstitution for distinct projects fostered student networking, it had the unintended consequence of constraining meaningful teamwork, reflection, and project management development, often resulting in superficial design and writing outcomes and limited proficiency with analytical tools such as Excel. Incremental adjustments, such as reducing the number of projects, expanding laboratory experiences, and increasing in-class project time, provided partial relief but did not fully resolve the tension between content breadth and deep, sustained learning.

Through ongoing evaluation and continuous improvement, the course was redesigned approximately three years ago to address the imbalance between breadth and depth. Recognizing that excessive content coverage limited meaningful learning, the structure was streamlined to center on a single, comprehensive design project per semester. This refined model retains the strongest elements of prior iterations while prioritizing iteration, feedback, and revision, core components of the engineering design process, resulting in improved student engagement, reduced overload, and stronger design and communication outcomes.

In the resulting current model, students are introduced to the project early in the semester, and the project includes multiple deliverables distributed across the entire semester. Some deliverables are completed individually, while others are completed in teams. This structure is intentionally designed to promote teamwork and systematic problem solving.

The earliest deliverables are individual based. For example, each student completes an individual background research summary related to the project so that all students build a basic understanding of the design problem and can meaningfully contribute to team discussions. Each student also develops and tests an individual design. This ensures that every student has technical experience to bring into team decision-making and later technical writing of the report. After this individual work, team-based deliverables begin with the first progress report, in which teams write the initial sections of their technical report, including the introduction, problem statement, and background. Instructors grade this report and provide feedback that students use to improve their work in the next phase. Next, teams give their first presentation, using their individual designs, research, and decision tables to explain how they plan to move toward a final team design. All team meetings are formally documented using standardized meeting agenda and meeting minutes templates. Students are expected to prepare agendas in advance to outline discussion topics, goals, and action items, ensuring meetings are organized and focused. Meeting minutes are submitted afterward to record decisions, assigned tasks, and follow-up items, providing a clear record of team progress and accountability. In addition, teams are required to develop a team charter, a project charter, a work breakdown structure, and a Gantt chart to reinforce planning, coordination, and effective teamwork throughout the project.

Students, then, are given time to build and test their final team design and prepare a technical poster presentation with an elevator pitch for the end of the semester. The second progress report expands upon the first by adding methods and materials, results, discussion, and conclusions with future recommendations. This report is graded with detailed feedback and returned to students. The final project deliverable is a complete technical report that incorporates all feedback from the second progress report.

Alongside these technical and design activities, students complete peer and self-evaluation surveys at the middle and end of the semester to assess their own contributions and those of their teammates.

This streamlined approach retains the most effective elements of prior iterations while prioritizing iteration, feedback, and revision (core components of the engineering design process), resulting in improved student engagement, reduced overload, and stronger design and communication outcomes.

2. Literature Review

2.1 Project-Based Learning in First-Year Engineering

Project-Based Learning (PBL) has been widely adopted in first-year engineering programs as an effective instructional approach for increasing student engagement, strengthening design quality, and supporting persistence in engineering pathways. By emphasizing active learning, real-world problem solving, and structured collaboration, PBL fosters deeper conceptual understanding while improving students' communication and teamwork skills [8]. In engineering education, hands-on design projects serve as a primary mechanism for introducing the engineering design process, contextualizing foundational concepts, and promoting meaningful engagement creating the basis for revising and refining ideas, generating concepts and facilitating problem solving [9]. Each iteration of PBL helps lead to stronger, more thoughtfully developed design solutions.

Multiple studies demonstrate that first-year design courses positively impact student retention and motivation. Knight, Sullivan, and Carlson found that students who participated in a team-based, hands-on design course were significantly more likely to remain in engineering compared to peers in traditional lecture-based formats [10]. Similarly, Tiwari, Nair, and Barua in [11] reported improved retention rates and reduced time to graduation for students enrolled in multidisciplinary, project-based first year engineering courses. These findings support the use of structured design experiences early in the curriculum to foster student commitment and success.

Beyond retention, PBL has been shown to enhance students' self-efficacy, problem-solving ability, and interest in engineering [12]. By engaging students in authentic engineering tasks, first-year design projects help bridge the gap between theoretical coursework and professional practice, reinforcing the relevance of engineering education and promoting long-term persistence in the field.

2.2 Teaching Teamwork in Engineering Education

Teamwork is a central component of engineering practice, yet research consistently shows that students do not automatically develop effective teamwork skills simply by working in groups [13]. Without explicit instruction, many student teams experience challenges such as unequal workload distribution, poor communication, conflict avoidance, and social loafing. As a result, scholars emphasize that teamwork must be intentionally taught, structured, and assessed in engineering courses [14].

[13] applied team effectiveness theory from industrial and organizational psychology to engineering student teams and found that explicit instruction in team processes, roles, and accountability significantly improves collaboration and outcomes. Similarly, Salas, Sims & Burke [15] identified key components of effective team training, including clear goals, structured communication, shared mental models, and feedback mechanisms - elements that can be intentionally embedded into coursework.

Engineering education research further supports the use of tools such as team charters, peer evaluations, role assignments, and meeting documentation to improve team functioning [16]. These structures promote accountability, clarify expectations, and encourage equitable participation. Courses that incorporate such strategies tend to report higher student satisfaction, stronger team performance, and reduced interpersonal conflict [14]. Collectively, this literature underscores the importance of designing team-based projects that explicitly teach collaboration rather than assuming it will emerge organically.

2.3 Scaffolding and Individual-to-Team Progression

Scaffolding is a well-established instructional strategy that supports learners as they move from novice to more expert levels of performance. Rooted in [17], the concept of the Zone of Proximal Development, scaffolding involves providing structured support early in the learning process and gradually removing that support as learners gain competence. In engineering education, scaffolding is particularly important in first-year courses, where students often have limited prior exposure to design, fabrication, and technical problem-solving.

Research indicates that unguided or minimally guided instruction is less effective for novice learners, particularly in complex domains such as engineering design [18]. Instead, structured progression - from simpler individual tasks to more complex collaborative challenges - leads to improved learning outcomes, confidence, and performance [19]. Similarly, [9] emphasizes that effective design education requires guided engagement with iterative design processes rather than open-ended exploration alone.

The transition from individual work to team-based design is a particularly powerful form of scaffolding. [20] found that novice designers often struggle with problem framing, idea generation, and evaluation compared to experts. By first engaging students in individual design and testing, instructors can help students develop foundational skills and confidence before entering team-based design phases. This approach reduces reliance on dominant teammates, mitigates social loafing, and increases the likelihood that all students contribute meaningfully to team discussions and decisions.

2.4 Engineering Problem-Solving and Design Thinking

Engineering problem-solving involves complex, ill-structured challenges that require iterative reasoning, trade-off analysis, and evidence-based decision making [21]. Unlike well-structured textbook problems, design problems require students to define constraints, generate alternatives, evaluate competing solutions, and revise designs based on testing and feedback. These processes reflect core components of engineering design thinking [9].

Research comparing novice and expert engineers highlights significant differences in how problems are approached. [20] found that expert engineers spend more time problem scoping, engage in broader information gathering, and iterate more frequently than novices. Similarly, [22] describes “designedly ways of knowing,” emphasizing the importance of iteration, reflection, and synthesis in professional design practice. These findings suggest that first-year engineering courses should explicitly model and reinforce these behaviors rather than focusing solely on final products.

Project-based learning environments provide a natural context for developing these skills by engaging students in authentic design challenges that require iterative testing and refinement [9], [21]. When students are required to document design decisions, justify trade-offs, and revise solutions based on performance data, they begin to adopt the cognitive habits of practicing engineers. Structured design cycles, multiple deliverables, and feedback loops further support the development of engineering problem-solving competence.

2.5 Assessment, Reflection, and Peer Evaluation

Assessment plays a critical role in shaping student learning and behavior in team-based, project-centered courses. Traditional summative assessments alone are insufficient for capturing the complexity of teamwork, design thinking, and professional skill development [23]. Instead, researchers advocate for a combination of formative feedback, performance-based assessment, and reflective practices to support deeper learning.

Peer and self-assessment are widely recognized as effective tools for promoting accountability, reflection, and metacognitive awareness [16, 24]. When students evaluate their own contributions and those of their teammates, they become more aware of teamwork dynamics, communication challenges, and leadership behaviors. These processes also provide instructors with valuable data for diagnosing dysfunctional teams and intervening when necessary. Recent research further highlights the role of reflection and psychological safety in effective teamwork. [25] found that structured reflection combined with peer evaluation promotes more accurate self-assessment, stronger team cohesion, and improved collaboration. Rubric-based assessment and staged feedback have also been shown to enhance learning by clarifying expectations and supporting iterative improvement [23].

In design-based engineering courses, multi-stage deliverables - such as progress reports, proof-of-concept demonstrations, and revised final submissions - function as both assessment tools and instructional scaffolds [9]. These approaches align assessment with authentic engineering practice, where designs evolve through cycles of testing, feedback, and refinement rather than through single, high-stakes submissions.

3. Project Design and Development

Designing an engineering project for a course is challenging, and it becomes even more difficult in an introductory engineering class. At this level, projects must demonstrate core engineering principles to students who are often recent high school graduates with limited technical background. It is therefore essential to balance project complexity by making the project meaningful but not overwhelming.

For this reason, each project was designed to be low-cost, time-efficient, and feasible for students who are still learning fundamental engineering concepts. Another key consideration is the availability of resources, including what students can reasonably access and what the college or department can afford to provide. Managing the overall cost of the project is critical, along with ensuring material accessibility and safety.

In addition, projects should actively engage students and be enjoyable, since motivation and interest strongly influence learning [26]. The goal is to challenge students to think critically, work collaboratively, and apply the engineering design process from brainstorming through testing and evaluation. Each project, therefore, includes both individual and team deliverables, such as design reports, prototypes, and reflection assignments, allowing instructors to assess technical understanding as well as teamwork and communication skills.

Most importantly, every project must align clearly with the course learning outcomes. Each time a new project is considered, all of these factors, and often more, must be carefully evaluated. As a result, a series of hands-on engineering projects was developed for first-year students, including:

- **Horizontal and Vertical Wind Turbines**: The objective of this project was to design, evaluate, and build a wind turbine that can generate enough electrical power to light one or more LEDs. Students must build the wind turbine entirely from scratch using readily available, non-edible, off-the-shelf materials; no kits or pre-made blades are allowed. The turbine must be free-standing, water and weather-resistant, and able to withstand different wind speeds without losing structural integrity. The maximum blade radius is 1.5 feet. Each student first creates an individual design that can generate enough power to light a red LED (about 2–2.2 V, 20 mA). Then, as a team, they improve the design so it can light a green LED (about 3–3.2 V, 20 mA).

- **Simple Crane Design:** This project requires students to design, build, and demonstrate a manually operated crane that can lift objects from the ground and place them into a container located 1.25 meters high. The crane can be of any type (such as stationery or telescopic) but must operate without motors, electricity, magnets, or human support during lifting. The crane must be stable, balanced, and free-standing, with only its base, outriggers, or counterweights touching the ground. It must lift items delicately without damaging them, using a single hook that cannot be changed during testing. Students first build an individual crane within a $30 budget, then develop a team version within a $40 budget, using mostly low-cost or free materials. Materials specifically designed for lifting objects are not allowed, and the crane must successfully lift all assigned items either together or one at a time.

- **Medical Supply Drop Device**: This project requires students to design and build a medical supply drop device that is reliable, safe, easy to use, and at a low cost. The device must protect fragile items, including glass medicine vials, and a $400 data acquisition unit with an accelerometer, during an aerial drop. Students must build the device from scratch using non-edible, readily available or 3D-printed materials; no kits or pre-made containers are allowed. The container must be waterproof or water-resistant, easy to open and close with reusable closures, and allow quick insertion and removal of the payload. The individual design uses one egg in a container no larger than 6 inches in any dimension, while the final team design must protect four eggs in a container no larger than 12 inches. The device must be released freely without tethers or zip lines, but may include a built-in system to slow the fall. It should land within one foot of the target drop location and keep all content unbroken and the container intact after impact.

- **Ultimate Boat Design**: The objective of this project is to design, build, and demonstrate a functional boat that remains stable in water while applying basic engineering principles. The project has two phases: an Individual Design Phase, where each student creates a boat within 20 cm × 20 cm × 20 cm, and a Team Design Phase, where teams collaborate on a boat to be tested around week 12, with a minimum length and width of 25 cm and a maximum overall size of 40 cm × 40 cm × 40 cm. Budgets are $30 per student and $40 per team, and students are encouraged to use free or low-cost materials while documenting market prices for any donated items. Additionally, the stability requirement differed between the individual and team designs, with the individual design expected to support 5 wind corks, compared to 35 corks for the team design. The boat must have its own propulsion system, cannot be manually pushed or remotely controlled, and cannot use parts from old boats or toys.

Chemical propulsion is prohibited, and the testing pool must remain undamaged. Designs must demonstrate stability, balance, and functionality, reflect diverse materials and fabrication skills, and show creativity and effort, as hastily assembled boats are discouraged. Some components may be 3D printed, and additional constraints may be added during the project.

- **Solar-Powered Car Design**: This project challenges students to design, build, and test a solar-powered car that is fast, lightweight, low-cost, and able to travel efficiently in a straight line while carrying small weighted "passengers." The project has two phases: an Individual Design Phase, where each student builds a car within a 20 cm × 20 cm size limit and tests it around week 6, and a Team Design Phase, where teams create a larger car (up to 40 cm × 40 cm) tested around week 11 that must also travel over gravel while carrying more weight. Budgets are limited to $30 per student and $35 per team, with encouragement to use free or low-cost materials and document their market value. The car must be powered only by solar energy with no batteries or other power sources, cannot be pushed or remotely controlled, and cannot use parts from toy cars or old projects. Designs must show strength, stability, and fabrication skills using multiple materials, with limited 3D printing allowed, and should demonstrate creativity, effort, and aesthetic quality.

- **Solar Oven Design**: This project requires students to design, build, and test a solar-powered cooking device that uses only solar energy to heat water. In the individual phase, the cooker must heat 20 ml of water, and in the team phase, it must heat 60 ml. Designs must be functional, efficient at collecting and retaining heat, safe, portable, and built from low-cost, lightweight materials. Budgets are limited to $30 per student and $40 per team, with encouragement to use free or low-cost materials while documenting their market value. The cooker must operate only on solar energy; no electricity, fuel, or preheating; and during testing, a halogen lamp or sunlight is used as the heat source. Once testing begins, no manual adjustments are allowed. The design must be hand-built, demonstrate fabrication skills using a variety of materials, and cannot be purchased as a finished product. Limited 3D printing is allowed for specific parts, but the entire cooker cannot be 3D-printed. Designs should be neat, creative, and show meaningful modification of any pre-made items, and additional constraints may be added as the project progresses.

While these projects illustrate the overall design philosophy, the structure of the course itself has also evolved. Traditionally, as described in the introduction, the course included three projects per semester. Later, the structure was changed to two projects per semester. However, this model revealed several problems. Some students relied heavily on their teammates to build, fabricate, test the design, and even complete much of the technical writing [27, 28].

To address these issues, the course was redesigned to include only one project per semester. Instead of reducing learning opportunities, the project was divided into multiple deliverables to preserve the same educational goals of the earlier two- and three-project models and to ensure that course learning outcomes were still met. An individual design component was added so that every student must build and test a personal version of the design. In addition, the technical report was divided into three stages: Progress Report 1, Progress Report 2, and the Final Technical Report.

As a result, this structure ensures that students cannot rely solely on their teammates. They are required to build, test, and learn from their own designs. Students also receive feedback during Progress Reports 1 and 2, which they apply to later versions of the same report, allowing real iterative improvement. Despite these improvements, the instructional team observed recurring problems with procrastination and last-minute building of the design project. To reduce this, two new deliverables were introduced: the Individual Proof of Concept and the Team Proof of Concept. These ensure that students build early prototypes at least one week before final testing. Beyond student behavior, project success also depends on strong instructor planning. Each semester, the course coordinator proposes several project ideas to the teaching team. Project selection is currently guided by a collaborative but flexible review process rather than a formal rubric. Each semester, the teaching team engages in structured discussion to balance several key considerations, including available laboratory capabilities, anticipated student workload, safety, and logistical feasibility. During these discussions, the team evaluates whether existing lab resources are sufficient or whether limited additional materials would be required, while intentionally avoiding projects that would necessitate excessive or impractical purchases.

The team also considers project viability from the student perspective, including whether the scope and complexity are appropriate for first-year students, whether the project can be completed within the available time, and whether it would impose unreasonable financial or logistical burdens on students. Student interest and engagement are discussed qualitatively based on prior experience with similar projects and observed student feedback.

While this process is not currently captured in a formal checklist or scoring rubric, it is informed by recurring themes - such as cost, feasibility, complexity, and engagement - that emerged from iterative course refinement over multiple semesters. These themes implicitly guide project selection and align with the broader course design philosophy presented in this paper. In future iterations, this process could be formalized into an explicit project-evaluation framework, which would allow for more systematic comparison across potential projects and clearer alignment with institutional constraints.

The team then agrees on a project title after considering resources, logistics, student enjoyment, and learning value. Once a project is selected, the project handout is drafted with all deliverables and deadlines. It goes through multiple revisions before being finalized and shared with students on the first day of the semester. Training on tools applicable to the student design project is also provided through the student-focused makerspace and university-level fabrication service center. This facility offers instruction on MIG welding, CNC routing, CNC plasma cutting, circuit board manufacturing, laser training, and general tool operation. Students are encouraged to complete their training session prior to starting their individual design projects.

In summary, the methodology for designing and evaluating these projects involved several key steps:

1. Defining Learning Objectives – Each project was aligned with measurable learning outcomes related to teamwork, design thinking, problem-solving, and communication.
2. Integrating Individual-to-Team Progression – Projects were structured to begin with individual design and testing phases, followed by team-based development, allowing

students to build confidence independently before collaborating, which enhances teamwork and problem-solving effectiveness.
3. Establishing Assessment Tools – Rubrics were created to assess design quality, teamwork, communication, and creativity.
4. Implementing Peer and Self-Evaluations – Students completed the peer and self-evaluation forms to evaluate team performance, collaboration, and their own contributions.
5. Refining Project Scope – Feedback from students and instructors was used to continuously improve project clarity, fairness, and alignment with course objectives.

By following this structured approach, the projects ensure consistency across sections while maintaining flexibility for instructors to adapt based on class size, available materials, or lab conditions.

4. Assessment and Evaluation

The project and all of its deliverables are prepared in advance and shared with students on the first day of class. Students receive clear instructions for each project deliverable, including what is required, how it should be completed, the due date, and the grading rubric for every assignment.

Student learning was assessed using a combination of quantitative and qualitative measures:
- **Rubric-Based Grading:** For every deliverable, rubrics were used to evaluate design innovation, functionality, technical writing, communication, and teamwork. Rubrics provide clear criteria and performance levels, which promote consistency, transparency, and alignment with intended learning outcomes across sections and instructors.
- **Peer and Self Assessments:** Students completed structured peer and self-evaluation forms at multiple points during the semester. These assessments encouraged reflection on individual and team contributions, promoted student accountability, and provided supplementary data to inform grade decisions and diagnose team dynamics.
- **Team Testing and Reports:** Teams presented and tested their final designs in real or recorded videos (online students), demonstrating how they solved practical constraints such as material limitations, structural performance, or functional requirements. This form of performance-based assessment captures authentic problem solving and application of design principles.
- **Instructor Observations:** Faculty monitored team collaboration, engagement, and iterative design behavior during class and lab sessions. Instructor observations helped identify teams needing additional guidance, provided context for rubric scores, and supported formative feedback throughout the project process.

These assessment methods provided insight into how students interacted, managed tasks, and communicated ideas within diverse teams.

5. Discussion

The intentional structure of the project - beginning with individual work and transitioning into team-based design - had a clear impact on both teamwork development and engineering problem-solving skills. Prior research shows that first-year students often struggle to contribute meaningfully to teams when they lack individual technical confidence [13]. By requiring every student to complete an individual background study and individual prototype before joining a team, this course design ensured that all students entered teams with ideas, data, and hands-on experience. This reduced social loafing and increased equitable participation, a pattern strongly supported in teamwork literature.

The staged progression from individual to team deliverables also supported cognitive and social development. Educational research shows that scaffolding - moving from simpler individual tasks to more complex collaborative tasks - improves learning and confidence. In this course, early individual design tasks built foundational problem-solving skills, while later team phases required students to negotiate ideas, compare alternatives using decision tables, and justify choices through evidence. These activities reflect core engineering problem-solving processes: defining constraints, generating alternatives, evaluating trade-offs, and iterating based on testing results [9].

Assessment of engineering Design thinking and learning

Student development in engineering design thinking was assessed using a rubric-based evaluation across sequential deliverables, including the individual design, proof-of-concept submissions, progress reports, and final technical report. These rubrics evaluated problem definition, idea generation, decision-making, testing, iteration, and justification of design choices.

Across implementations, rubric results showed consistent improvement from early to later deliverables. In particular, scores in problem framing, justification of design decisions, and incorporation of experimental feedback increased from Progress Report 1 to the Final Report, indicating improved engagement with the engineering design cycle. The inclusion of structured individual design and proof-of-concept deliverables also resulted in more complete and functional final prototypes compared to earlier course iterations that did not include these staged requirements. These results suggest that structured scaffolding of the design process improves both learning outcomes and the quality of student design work.

Interdependence is further reinforced through team-level deliverables such as a unified design rationale, shared experimental testing, and collective performance during competition events. Success in these outcomes depends on effective collaboration, division of labor, and mutual accountability, rather than parallel individual contributions. Thus, although the physical artifact is larger, the primary increase in complexity lies in the cognitive, analytical, and coordination demands placed on teams, which intentionally support interdependent teamwork.

The requirement to document teamwork through agendas, meeting minutes, team charters, and project management tools (Work Breakdown Structure (WBS) and Gantt charts) significantly strengthened professional skills. Studies show that explicit instruction in team processes - rather than assuming students will “learn teamwork naturally” - leads to stronger collaboration and fewer conflicts [13]. In this course, agendas improved meeting focus, minutes increased accountability, and project planning tools reduced last-minute work. Together, these structures trained students to approach teamwork as an engineering process rather than a casual group activity.

Assessment of teamwork development

Teamwork effectiveness was assessed using peer evaluation surveys, self-assessment instruments, and instructor review of team artifacts, including meeting agendas, meeting minutes, team charters, WBS, and Gantt charts. Peer evaluation instruments were aligned with teamwork constructs such as accountability, interdependence, communication, contribution, and conflict management.

Mid-semester and end-of-semester peer evaluation results showed improvements in perceived accountability and communication consistency. Teams that consistently used structured agendas and meeting minutes demonstrated higher task completion rates and clearer division of responsibilities. Instructor review of team artifacts confirmed that teams with consistent documentation showed stronger follow-through on assigned tasks and better coordination of deliverables compared to teams with incomplete documentation.

Qualitative peer evaluation comments also indicated improvements in communication climate and psychological safety, particularly in later stages of the project. Students increasingly reported comfort in sharing ideas, raising concerns, and participating in decision-making after the introduction of structured team charters and defined roles.

Accountability was assessed primarily through instructor observations and review of the submitted meeting artifacts. Teams were required to submit formal meeting agendas and minutes for every team meeting. Instructors checked these documents to see whether discussion topics, goals, assigned tasks, and follow-up items were clearly recorded and acted upon. When tasks listed in the agendas were completed on time and documented in subsequent minutes or deliverables, this provided evidence that students were following through on responsibilities.

Allowing teams to set their own milestone deadlines could provide valuable insight into higher-level skills such as planning, time management, and collective decision-making. In the current implementation, instructor-mandated milestones ensure consistency across sections and prevent last-minute work, which is particularly important for first-year students who may lack experience estimating task durations.

Iteration, feedback, and learning cycles

Iteration through multiple report stages and proof-of-concept deadlines had a strong impact on engineering problem solving. Engineering education research emphasizes that iteration and feedback are central to authentic design learning [9] Progress Reports 1 and 2, combined with instructor feedback, allowed students to revise designs and technical writing based on evidence rather than guesswork. The addition of Individual and Team Proof of Concept deliverables reduced procrastination and encouraged early testing.

Rubric comparisons across deliverables showed that students increasingly incorporated instructor feedback into subsequent submissions within the same project context, particularly between Progress Report 1, Progress Report 2, and the Final Report.

Although formal assessment data from this implementation are not available, qualitative observations suggest positive outcomes. Specifically, the final individual designs produced by students consistently demonstrate improvement over their initial proof-of-concept designs, as well as over individual designs developed in earlier semesters before the introduction of the proof-of-concept requirement. These observations suggest that incorporating an explicit proof-of-concept phase promotes iterative learning and enables students to benefit from early instructor feedback on intermediate deliverables.

Similar trends have been observed in students' technical writing. Dividing the technical report into three staged submissions appears to be more effective than requiring a single comprehensive report for one project and then applying instructor feedback to a subsequent, unrelated project. In the revised structure, students are able to immediately incorporate feedback within the same project context, leading to noticeable improvements in report quality. These conclusions are based on consistent observations reported by instructors; however, they are not yet supported by systematic quantitative assessment data.

An additional indirect benefit of this implementation is a reduction in team-related issues, as students complete individual components of the project prior to team formation and are therefore better prepared to contribute meaningfully to team discussions. Nevertheless, some team challenges persist due to factors unrelated to project structure, such as differences in work habits, communication styles, or levels of engagement.

Psychological safety/teamwork climate

One challenge in implementing this approach is ensuring that each phase of the design project is meaningfully distinct. This may require variations in factors such as project scale, the specific component or item being tested, or selected secondary design requirements to differentiate one phase from another. Without such intentional differences, there is a risk that students may simply replicate earlier designs with minimal modification, resulting in limited learning gains across successive project deliverables.

Additional challenges include the increased instructional effort required to develop, coordinate, and assess multiple phased deliverables within a single project. Managing timelines across phases can be difficult, particularly in large-enrollment courses, as delays in early phases may cascade into later stages. Providing timely and consistent feedback at each phase also places greater demands on instructional staff, but it is essential for supporting iterative improvement.

Furthermore, students may initially struggle with the iterative nature of the process, especially if they are accustomed to viewing design as a linear activity rather than a cyclical one. Some students may focus on meeting minimum requirements at each phase rather than engaging deeply with design refinement.

Students completed structured evaluation forms at multiple points during the semester, focusing on specific behaviors such as participation in meetings, contribution to design and testing, communication, and collaboration. An open-ended question was included in the survey allowing students to provide comments: “You may make comments about your rating of this member if you wish.” This encouraged thoughtful reflection and provided instructors with qualitative insights to support team development. Peer and self-evaluations further strengthened teamwork and reflection. Reflection is a key component of experiential learning and engineering design [25]. By evaluating themselves and teammates mid-semester and at the end, students became more aware of communication issues, unequal workload, and leadership challenges. These evaluations also provided instructors with data to intervene early in dysfunctional teams, supporting healthier collaboration.

In this course, hands-on design projects likely contribute positively to student retention. Research on project-based engineering courses shows that participation in hands-on, collaborative design activities in first-year programs is associated with higher retention rates compared with students who do not take such courses. For example, a study of a first-year, team-based design/build course found significant gains in retention through multiple semesters, especially for students from groups traditionally underrepresented in engineering [10]. Another study showed that first-year hands-on, multidisciplinary projects increased retention and even improved graduation rates, as students were better able to plan their academic paths and feel committed to the major [11]. Teams that communicated regularly and divided responsibilities effectively showed higher design performance and reported greater satisfaction with teamwork. In contrast, teams that struggled with communication or time management often produced incomplete or less creative solutions.

Overall, the redesigned project structure addressed the research questions by showing how engineering projects can be intentionally designed to teach teamwork and problem-solving, and by demonstrating the impact of these projects on team performance and problem-solving skills. The new structure of a single comprehensive project, individual-to-team progression, iterative deliverables, formal teamwork documentation, and multiple assessment methods created a learning environment that strongly supports teamwork and engineering problem-solving. The approach aligns with best practices in project-based and active learning, which consistently show positive effects on student engagement, retention, and skill development in engineering education. Beyond retention data, research indicates that project-based learning improves students’ self-efficacy [12], interest, and effort regulation, all of which are linked with persistence in engineering. These courses help students build confidence and relevant skills early, which can reduce attrition by making the engineering curriculum feel more engaging, relevant, and achievable.

6. Conclusions and Recommendations

Our solution is intentionally designed to address institutional needs that are not fully met by existing first-year engineering experience models. While many such courses share common design parameters - such as introduction to the engineering design process, teamwork, and professional skills - our approach is differentiated by its tight alignment with our institution’s student demographics, resource constraints, and retention goals.

Specifically, this course was developed to support a large cohort of first-year students entering multiple engineering disciplines with widely varying levels of preparation. Unlike more traditional first-year programs that emphasize discipline-specific exposure or a single semester-long design project, our approach integrates multiple low-stakes, iterative design challenges that explicitly scaffold engineering thinking, reflection, and skill development across the semester. This structure allows students to repeatedly engage with the design process while receiving targeted feedback, which is particularly beneficial for students who are undecided, first-generation, or underprepared.

What is novel in our implementation is not the inclusion of individual pedagogical components - many of which are well established in the literature, but rather the way these components are deliberately combined and sequenced to address institutional priorities. In particular, the emphasis on repeatability, ease of implementation at scale, and consistency across course sections differentiates this model from others that rely heavily on instructor autonomy or resource-intensive projects. This design enables both scalability and sustainability while maintaining a consistent student experience, which is critical for our institution. Taken together, the innovation of this work lies in the intentional alignment between pedagogical design, institutional context, and implementation of constraints, rather than in any single instructional element in isolation.

The project structure was intentionally scaffolded to support students in the gradual development of both technical and teamwork skills, recognizing that first-year engineering students often have limited prior experience in these areas. The initial phase required each student to write a background summary of the technical aspects of the project and to create and test an individual design prototype. This step served multiple purposes: it built technical competence, encouraged independent problem-solving, and ensured that each student had hands-on experience with the engineering design process. By engaging with the project individually, students gained confidence in their abilities, developed familiarity with materials and tools, and generated ideas that could later contribute meaningfully to team discussions.

Once students have completed their individual prototypes, they transition to team-based projects that leverage the knowledge and experience gained from their personal designs. This shift from individual to teamwork provided a structured framework for teamwork development. Teams were required to synthesize diverse design concepts, discuss design decisions, and coordinate fabrication and testing tasks. The collaborative phase emphasized communication, delegation, and shared accountability, allowing students to apply problem-solving skills in a realistic engineering context.

Throughout the semester, the project was broken into iterative deliverables, including progress reports, proof-of-concept demonstrations, and final technical reports. These staged submissions functioned as built-in scaffolds, providing students with clear expectations, ongoing feedback, and opportunities to reflect on and refine their work. Instructor and peer feedback at each stage guided students toward higher-quality designs and more effective collaboration while maintaining autonomy in decision-making.

By gradually transferring responsibility from instructor-guided support to independent student performance, the scaffolding structure enabled students to tackle increasingly complex tasks by the end of the semester. This approach not only strengthened technical skills and design proficiency but also reinforced essential professional competencies, such as teamwork, project management, and iterative problem-solving, preparing students for subsequent engineering coursework and real-world engineering challenges.

References

[1] H. Nguyen, L. Wu, G.N. Washington, K.Y. Lim and C. Fischer. Collaboration Patterns and Design Practices in First-Year Project-Based Engineering. Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line. doi: 10.18260/1-2—3429.

[2] R. A. Hensel, O. Brown, and M. L. Strife, "Engineering an information literacy program for first-year engineering students," in *Proc. 2012 ASEE Annual Conf. & Exposition*, San Antonio, TX, USA, Jun. 2012, doi: 10.18260/1-2--21292.

[3] M. L. Strife, R. A. M. Hensel, and M. G. Armour-Gemmen, "Integrating information literacy in engineering: Librarians/faculty," in *Proc. 2012 ASEE Annual Conf. & Exposition*, San Antonio, TX, USA, Jun. 2012, doi: 10.18260/1-2--21556.

[4] M. L. Strife, M. G. Armour-Gemmen, and R. A. Hensel, "Re-tooling information instruction delivery and assessment for the freshman engineering class: The good, the bad, and the ugly," in *Proc. 2013 ASEE Annual Conf. & Exposition*, Atlanta, GA, USA, Jun. 2013, doi: 10.18260/1-2--22406.

[5] M. G. Armour-Gemmen, R. A. Hensel, and M. L. Strife, "The 360° of information fluency delivery to freshman engineering students," in *Proc. 2014 ASEE Annual Conf. & Exposition*, Indianapolis, IN, USA, Jun. 2014, doi: 10.18260/1-2--23118.

[6] M. G. Armour-Gemmen, C. Pickens, R. A. Hensel, M. L. Strife, and M. Jalalifard, "Jazzing up next-gen librarians for freshman engineering instruction delivery," in *Proc. 2016 ASEE Annual Conf. & Exposition*, New Orleans, LA, USA, Jun. 2016, doi: 10.18260/p.25504.

[7] A. Lowery, S. Kane, V. Kane, R. Hensel, and G. Ganser, "Joint math–engineering projects to facilitate calculus success in first-year students," in Proc. 2010 ASEE Annual Conf. & Exposition, Louisville, KY, USA, Jun. 2010, doi: 10.18260/1-2--16865.

[8] M. J. Prince and R. M. Felder, "Inductive teaching and learning methods: Definitions, comparisons, and research bases," *Journal of Engineering Education*, vol. 95, no. 2, pp. 123–138, 2006, doi: 10.1002/j.2168-9830.2006.tb00884.x.

[9] C. L. Dym, A. M. Agogino, O. Eris, D. D. Frey, and L. J. Leifer, "Engineering design thinking, teaching, and learning," *Journal of Engineering Education*, vol. 94, no. 1, pp. 103–120, 2005, doi: 10.1002/j.2168-9830.2005.tb00832.x.

[10] D. W. Knight, J. F. Sullivan, and L. E. Carlson, "Staying in engineering: Effects of a hands-on, team-based, first-year projects course on student retention," in *Proc. 2003 ASEE Annual Conf. & Exposition*, 2003, doi: 10.18260/1-2--11855.

[11] B. Tiwari, P. Nair, and S. Barua, "Effectiveness of freshman-level multidisciplinary hands-on projects in increasing student retention rate and reducing graduation time for engineering students in a public comprehensive university," in *Proc. 2018 ASEE Annual Conf. & Exposition*, 2018, doi: 10.18260/1-2--30360.

[12] N. A. Brake and J. C. Curry, "The impact of one-credit introductory engineering courses on engineering self-efficacy: Seminar vs. project-based," in *Proc. 2016 ASEE Annual Conf. & Exposition*, 2016, doi: 10.18260/p.26176.

[13] M. Borrego, J. Karlin, L. D. McNair, and K. Beddoes, "Team effectiveness theory from industrial and organizational psychology applied to engineering student project teams," Journal of Engineering Education, vol. 102, no. 4, pp. 472–512, 2013, doi: 10.1002/jee.20023.

[14] B. A. Oakley, R. M. Felder, R. Brent, and I. H. Elhajj, "Turning student groups into effective teams," *Journal of Student-Centered Learning*, vol. 2, no. 1, pp. 9–34, 2004.

[15] E. Salas, D. E. Sims, and C. S. Burke, "Is there a 'big five' in teamwork?" Small Group Research, vol. 36, no. 5, pp. 555–599, 2005, doi: 10.1177/1046496405277134.

[16] M. L. Loughry, M. W. Ohland, and D. D. Moore, "Development of a theory-based assessment of team member effectiveness," Educational and Psychological Measurement, vol. 67, no. 3, pp. 505–524, 2007, doi: 10.1177/0013164406292085.

[17] L. S. Vygotsky, Mind in Society: The Development of Higher Psychological Processes. Cambridge, MA: Harvard University Press, 1978.

[18] P. A. Kirschner, J. Sweller, and R. E. Clark, "Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching," Educational Psychologist, vol. 41, no. 2, pp. 75–86, 2006, doi: 10.1207/s15326985ep4102_1.

[19] C. M. Reigeluth, Ed., Instructional-Design Theories and Models: A New Paradigm of Instructional Theory, vol. 2. Mahwah, NJ: Lawrence Erlbaum Associates, 1999.

[20] C. J. Atman, R. S. Adams, M. E. Cardella, J. Turns, S. Mosborg, and J. Saleem, "Engineering design processes: A comparison of students and expert practitioners," Journal of Engineering Education, vol. 96, no. 4, pp. 359–379, 2007, doi: 10.1002/j.2168-9830.2007.tb00945.x.

[21] D. H. Jonassen, "Engineers as problem solvers," in Cambridge Handbook of Engineering Education Research, A. Johri and B. M. Olds, Eds. Cambridge, UK: Cambridge University Press, 2014, pp. 103–118, doi: 10.1017/CBO9781139013451.009.

[22] N. Cross, *Designerly Ways of Knowing*. Basel, Switzerland: Birkhäuser, 2008.

[23] D. Boud, R. Cohen, and J. Sampson, Peer Learning in Higher Education: Learning from and with Each Other, 2nd ed. Abingdon, UK: Routledge, 2014.

[24] F. Dochy, M. Segers, and D. Sluijsmans, "The use of self-, peer and co-assessment in higher education: A review," *Studies in Higher Education*, vol. 24, no. 3, pp. 331–350, 1999, doi: 10.1080/03075079912331379935.

[25] S. C. Shah-Fairbank, J. Woo, K. Lamb, and J. Cho, “Students’ teamwork assessment based on reflection, peer evaluations, and psychological safety,” in Proc. 2021 ASEE Virtual Annual Conf. & Exposition, 2021, doi: 10.18260/1-2--37774.
[26] H. Zheng, Z. Ye, X. Bai et al., “The effect of enjoyment on the achievement of learning goals in college students’ online classes: a moderated mediation model,” Humanities and Social Sciences Communications, 2026, doi: 10.1057/s41599-026-06563-y.
[27] P. Aggarwal and C. L. O’Brien, “Social loafing on group projects: Structural antecedents and effect on student satisfaction,” Journal of Marketing Education, vol. 30, no. 3, pp. 255–264, Dec. 2008, doi: 10.1177/0273475308322281.
[28] R. Tucker and N. Abbasi, “Bad attitudes: Why design students dislike teamwork,” Journal of Learning Design, vol. 9, no. 1, pp. 1–20, Apr. 2016, doi: 10.5204/jld.v9i1.227.

Appendix

An example of the list of project deliverables sheet.

ENGR 101 - FALL 2023
SIMPLE CRANE DESIGN PROJECT
PROJECT DELIVERABLES DUE DATES

Deliverable	Due Date*	Individual or Team Submission	Project Grade Breakdown
Background Research Summary *If the individual background summary is not submitted by the deadline, you will be disqualified from your group and receive a zero for the remaining project deliverables.*	Sunday (Sep. 10, 11:59 PM)	Individual	5 %
Design Proposal *If the individual design proposal is not submitted by the deadline, you will be disqualified from your group and receive a zero for the remaining project deliverables.*	Friday (Sep. 15, 11:59 PM)	Individual	5%
Progress Report 1	Sunday (Sep. 24, 11:59 PM)	Team	10 %
Individual Design Demonstration *If the individual design demonstration is not tested by the deadline, you will be disqualified from your group and receive a zero for the remaining project deliverables.*	In class during the week of Sep. 25-29, but the calculations file should be uploaded to eCampus by Sunday, Oct. 1 (11:59 PM)	Individual	10%
PowerPoint Slides & Oral Presentation	In-class Monday (Oct. 2) and Wednesday (Oct. 4), but the slides should be uploaded to eCampus by Sunday, Oct. 1 (11:59 PM)	Team	10 %
Peer & Self Evaluation 1	Sunday (Oct. 8, 11:59 PM)	Individual	5%
Team Design Demonstration	Out-of-class time Week of Oct. 16, but the calculations file should be uploaded to eCampus by Sunday, Oct. 22 (11:59 PM)	Team	10 %
Progress Report 2	Sunday (Oct. 29, 11:59 PM)	Team	10 %
Final Technical Report	Sunday (Nov. 12, 11:59 PM)	Team	10 %
Technical Poster & Elevator Pitch	In class during the week of Dec. 4, but the Poster should be uploaded to eCampus on Sunday (Dec. 3, 11:59 PM)	Team	10 %
Final Technical Report Resubmission	Thursday (Dec. 7, 11:59 PM)	Team	10 %
Peer & Self Evaluation 2	Thursday (Dec. 7, 11:59 PM)	Individual	5 %

* Please note that the instructor retains the right to make adjustments to the due dates as necessary.

An example of a project handout.

ENGR 101 - SPRING 2025
The Ultimate Solar-Powered Car Design Challenge
Innovation, Construction, and Performance

INTRODUCTION

As a new engineer in the early stages of your career, you have joined EcoDrive on a three-month training period. **EcoDrive Innovations** is a forward-thinking engineering firm specializing in sustainable transportation solutions, focusing on renewable energy sources to power vehicles of the future. At EcoDrive, we pride ourselves on pushing the boundaries of innovation and prioritizing environmental responsibility.

During this training period, you will be tasked with developing a project that showcases your creativity, engineering knowledge, and problem-solving abilities. Specifically, you are responsible for designing, building, and testing a solar-powered car, representing our company's commitment to eco-friendly solutions.

This project will help you develop the mindset and skills to think and work like an engineer. You will be assigned a project along with teammates to collaborate with, and you will have the opportunity to build your project management abilities. To successfully carry out the project, you will need to establish a solid foundation on the topic by thoroughly researching and reviewing a variety of resources.

Your performance on this project will determine the outcome of your training. At the end of the three months, your supervisor will evaluate the quality of your design. This includes assessing its functionality, innovation, sustainability, and overall performance. *Based on this assessment, your supervisor will make a critical decision: to either extend a job offer for a full-time engineering role or terminate the training period without further employment.*

This opportunity is both a challenge and a test of your abilities. Success will lead to a rewarding career at EcoDrive Innovations, where you will contribute to cutting-edge projects that drive a positive impact on the environment. Failure, however, means parting ways with the company. With this high-stakes project, you can demonstrate your value as a member of EcoDrive and establish yourself as a skilled engineer.

Approach this project with focus, commitment, and enthusiasm—EcoDrive Innovations is looking for engineers who are ready to make a meaningful difference.

OBJECTIVE

The main goal of this project is to design, construct, and demonstrate a functional solar-powered car that is fast, lightweight, cost-effective, and capable of moving efficiently in a *straight line* on a flat surface while carrying four passengers (represented by small Stainless Steel cubes - 30 g each - 2 X 2 X 2 cm). Your design should apply engineering principles focused on energy efficiency and sustainability.

LEARNING OBJECTIVES

As a freshly graduated engineer, this project will not only test your technical skills but also develop your ability to manage complex engineering tasks from start to finish. Your main objective is to design, build, and test a fully functional solar-powered car that aligns with EcoDrive Innovations' standards of sustainability and innovation. However, technical design alone is only part of the equation. To succeed, you will need to learn and apply essential project management skills that will guide you in organizing, tracking, and executing your project effectively.

Throughout the project, you will be required to use various project management tools such as:

1. **Team Charter**: Define the project's purpose, establish goals, assign roles, and set expectations. Even if working individually, creating a Team Charter will help you clarify your responsibilities and identify your project's scope and goals.
2. **Project Charter**: Outline the key objectives, stakeholders, deliverables, and constraints. The Project Charter serves as a guiding document to ensure that your work remains aligned with EcoDrive's mission and project expectations.
3. **Work Breakdown Structure (WBS)**: Break down the project into smaller, manageable tasks to organize and sequence the steps required to complete your solar-powered car. This will help you plan and allocate resources efficiently, avoid missed deadlines, and prevent unnecessary obstacles.
4. **Gantt Chart**: Track your project's timeline by creating a Gantt Chart that maps out each task, identifies dependencies, and allocates deadlines. This tool will help you maintain a clear picture of your progress, ensuring you stay on track to meet your goals and complete the project on time.

Mastering these project management tools will not only help you manage your time and resources efficiently but also demonstrate to your supervisor that you have the organizational and leadership skills necessary to succeed as an engineer. Following this structured approach will guide you through each phase, ensuring you have a well-planned path to deliver a high-quality, innovative solar-powered car design that meets EcoDrive's standards.

DESIGN RESTRICTIONS AND CONSTRAINTS

- **Project Phases:**
  - <u>Individual Design Testing</u>: Each student will design a solar-powered car to be tested around the 6th week. Car dimensions must not exceed 20 cm × 20 cm. However, the height can be any dimension; any design exceeding these dimensions will be disqualified. If the individual design testing is not tested by the deadline, you will be disqualified from your group and receive a zero for the remaining project deliverables.
  - <u>Team Design Testing</u>: Do not begin this design until you have completed the Individual Design Testing Phase. We want to incorporate the evaluation results from individual designs into the team design. During the Team Design Phase, teams will collaborate to create a single design, which will be tested around the 11th week. The team car must measure at least 25 cm in both length and width, with no specific height limit, as long as the length and the width dimensions do not exceed 40 cm × 40 cm. The new design must be able to pass over a floor filled with gravel with 8 passengers.
- **Budget:**

Each student's design budget is limited to $30. Team designs should not exceed $35 per team. Students are encouraged to use available "free" materials, such as repurposed cardboard, plastic bottles, or old electronic components. If you obtain free materials, research and document their market prices to reflect the actual cost of the design. This is your project, and it is your responsibility to find the best and most cost-effective vendor. Be innovative and think creatively when sourcing materials.

- **Propulsion System:**

The car MUST be powered solely by solar energy without battery storage, requiring a focus on optimizing design for sunlight availability. The propulsion system MUST not include any other power source. Additionally, the car cannot be pushed manually during testing.

- **Remote Control:**

The car CANNOT be controlled remotely; no remote control devices are allowed.

- **Repurposed Parts:**

The car MUST NOT use parts/components from pre-existing toy cars (such as tires) or old projects.

- **Design Durability:**

The car MUST demonstrate strength and stability during operation and can move on a flat, straight path.

- **Fabrication Skills:**

The car should not consist of only a single material; students MUST use a variety of materials and construction techniques to showcase building and fabrication skills. While 3D printing is allowed for specific components, the entire car may not be 3D-printed. The car cannot be constructed using pre-made items such as Tupperware, cans, or boxes as the primary structural components. The project intends to showcase fabrication skills, which means students are expected to actively engage in building the car from scratch. This includes demonstrating techniques such as cutting, shaping, joining, and adhering materials to create a unique and functional design.

- **Aesthetic Appeal:**

The car should reflect time, effort, and creativity, with an emphasis on aesthetics. Designs hastily assembled are discouraged.

- **Additional Requirements:**

Additional constraints may be added as the project progresses.

GRADING CRITERIA

Projects will be evaluated based on criteria such as creativity, originality, repeatability, ease of operation, and adherence to budget constraints. Key grading criteria include:

- **Speed Test** (25%)

Objective: Measure how quickly the car can travel a 2.50-meter distance under solar power.
Scoring: The fastest ***successful functional working car*** (with passengers) in the class receives the highest score in this criterion. If the car does not move, your grade for this criterion will be a zero. Nobody would buy a car that does not move.

- **Weight Test** (25%)

Objective: Measure how much the car weighs.
Scoring: The lightest ***successful functional working car*** (with no passengers) in the class achieves the highest score in this criterion. If the car does not move, your grade for this criterion will be a zero. Nobody would buy a car that does not move.

- **Cost** (25%)

Objective: Calculate the total cost of your car. If you obtained materials for free, research and include their market prices to reflect the actual cost. This is your project, and it’s your responsibility to find the best and most cost-effective vendor. Be innovative and think creatively when sourcing materials.

Scoring: The lowest ***successful functional working car*** design cost in the class achieves the highest score in this criterion. Your cost will be compared to the budget of the project. If the car does not move, your grade for this criterion will be a zero. Nobody buys a car that does not move, even if it is cheap.

- **Fabrication Skills** (15%)

Objective: Award points for a ***successful functional working car*** design. The car MUST not consist of only a single material; students MUST use a variety of materials and construction techniques to showcase building and fabrication skills. While 3D printing is allowed for specific components, the entire car may not be 3D-printed.

Scoring: Your instructor will evaluate your fabrication skills. If the car does not move, your grade for this criterion will be a zero. Nobody buys a car that does not move.

- **Aesthetics** (10%)

Objective: Award points for aesthetically pleasing, ***successful functional working car*** design and for demonstrating effort and time spent on the creation.

Scoring: Your instructor will evaluate the visual appeal. If the car does not move, your grade for this criterion will be a zero. Nobody buys a car that does not move, even if it looks nice.

An example of the individual background summary prompt.

BACKGROUND RESEARCH SUMMARY – INDIVIDUAL ASSIGNMENT

Content and Settings Submissions (37) Student Activity

Instructions

Print

Note: *If the individual background summary is not submitted by the deadline, you will be disqualified from your group and receive a zero for the remaining project deliverables.*

The purpose of this assignment is to help you learn about solar-powered cooking technologies so you can design an effective device. **ENGR 101 is not a course about building solar cookers**—it's about learning to think and work like an engineer. Please note that we will not cover the detailed steps of building solar cookers during class. Therefore, you are expected to take initiative, treat this as a real engineering project, and begin developing your own understanding of the solar cooking field. Use every available resource—readings, videos, and research—to prepare for your design.

For this assignment, each student must write a **Background Research Summary** covering the following three key areas:

- **Principles of Solar Energy and Heat Transfer**

Use this research to understand how solar energy can be harnessed and transferred efficiently for *cooking applications*.

- **Types and Designs of Solar Cookers**

Explore various existing solar cooker designs (e.g., box cookers, parabolic cookers, panel cookers) and their advantages or limitations to help guide your own design choices.

- **Materials for Solar Cooker Construction**

Investigate materials that are efficient, durable, and cost-effective for building solar cooking devices.

The knowledge gained from your research will directly inform and support your engineering design decisions.

The research summary must follow the **IEEE format** for in-text citations and reference lists. Use **only reliable sources** from the **WVU library database**, such as peer-reviewed journal articles, books, conference proceedings, patents, and reports from government agencies or professional associations. **Websites of any kind are not permitted.**

The Background Research Summary may be written as:

- One comprehensive paragraph that integrates all three topics, **OR**
- Three shorter paragraphs, each focusing on one of the following:
    a. Principles of Solar Energy and Heat Transfer
    b. Types and Designs of Solar Cookers
    c. Materials for Solar Cooker Construction

The BACKGROUND RESEARCH SUMMARY:

- Must be submitted as a WORD file (Template is attached), using 12-point Times New Roman font and double line spacing. NO PDF FILES.

An example of the list of project deliverables sheet.

ENGR 101 - FALL 2025
PROJECT DELIVERABLES*

* Please note that the instructor retains the right to make adjustments to the due dates as necessary.

Deliverable	Due Date	Project Grade Breakdown
Background Research Summary – Individual Assignment	Sunday - September 14, 11:59 PM	10%
Individual Proof of Concept – Individual Assignment	The Individual Proof of Concept Demonstration will take place outside of class during the week of September 22–25. The testing results file must be uploaded to eCampus by Sunday, September 28, at 11:59 PM.	5%
Progress Report 1 – Team Assignment	Sunday - September 28, 11:59 PM.	10%
Individual Design Demonstration – Individual Assignment	The Individual Design Demonstration will take place in class on Monday, September 29, and Wednesday, October 1. The testing results file must be uploaded to eCampus by Sunday, October 5, at 11:59 PM.	10%
PowerPoint Slides & Oral Presentation – Team Assignment	The PowerPoint slides must be uploaded to eCampus by Sunday, October 5, at 11:59 PM. The Oral Presentations will take place in class on Monday, October 6, and Wednesday, October 8.	10%
Peer & Self Evaluation 1 – Individual Assignment	Tuesday - October 14, 11:59 PM.	5%
Team Proof of Concept – Team Assignment	The Team Proof of Concept Demonstration will take place outside of class during the week of October 27-30. The testing results file must be uploaded to eCampus by Sunday, November 2, at 11:59 PM.	3%
Team Design Demonstration – Team Assignment	The Team Design Demonstration will take place outside of class during the week of November 3. The testing results file must be uploaded to eCampus by Sunday, November 9, at 11:59 PM.	7%
Progress Report 2 – Team Assignment	Sunday - November 16, 11:59 PM.	15%
Technical Poster & Elevator Pitch – Team Assignment	The poster must be uploaded to eCampus by Sunday, December 7, at 11:59 PM. The elevator pitch presentations will take place in class on Monday, December 8, and Wednesday, December 10.	10%
Final Technical Report – Team Assignment	Thursday - December 11, 11:59 PM.	10%
Peer & Self Evaluation 2 – Individual Assignment	Thursday - December 11, 11:59 PM.	5%

An example of the rubric of the background research summary.

Criteria	Not Present	Below Expectations	Good	Very Good	Excellent
Front Matter **10%** of total grade	**0%** • Front Matter is not present.	**25%** • Cover page is present, but many items in the cover page are missing such as the (Title, author names, client name, class info., WVU affiliations, or date submitted).	**60%** • Cover page is present, but few items in the cover page are missing such as the (Title, author names, client name, class info., WVU affiliations, or date submitted).	**80%** • Cover page is present, but one item in the cover page is missing such as the (Title, author names, client name, class info., WVU affiliations, or date submitted).	**100%** • Cover page is present AND all items in the cover page are present such as the (Title, author names, client name, class info., WVU affiliations, or date submitted)..
Introduction **20%** of total grade	**0%** • Introduction section is not present.	**25%** • Very little information is provided and/or information is incorrect.	**60%** • The introduction describes the purpose or need but not clearly.	**80%** • The introduction describes the purpose or need.	**100%** • The introduction precisely describes the purpose or need.
Problem Statement **20%** of total grade	**0%** • Problem statement is not present.	**25%** • Very little information is provided and/or information is incorrect.	**60%** • The problem statement is not properly stated.	**80%** • The problem statement doesn't clearly state the problem to be solved.	**100%** • The problem Statement states the problem to be solved.
Background **20%** of total grade	**0%** • Background section is not present.	**25%** • Very little information is provided and/or information is incorrect.	**60%** • The background doesn't summarize relevant topical literature and previous research.	**80%** • The background summarizes relevant some topical literature and previous research.	**100%** • The background summarizes relevant topical literature and previous research.
References **20%** of total grade	**0%** • Reference list is not present.	**25%** • Reference list is present, but citations' formats are incorrect and do not follow IEEE format or the entire list is not present.	**60%** • Reference list is present, but citations' formats are generally correct but more than 6 not in the correct IEEE format.	**80%** • Reference list is present, but citations' formats are very correct but less than 6 not in the correct IEEE format.	**100%** • Reference list is present, but citations' formats are correct and all of them are in the correct IEEE format.

An example of peer and self-evaluation.

Categories	Novice: 0 or 1 point	Emerging : 2 pts	Proficient: 3 points	Superior: 4 points
Responsibility	Frequently failed to complete tasks on time	Sometimes failed to complete tasks on time	Was responsible and completed most tasks on time	Exceeded our expectations on timely completion of tasks and follow up
Quality of Work	Quality of work often failed to meet our expectations	Quality of work sometimes failed to meet our expectations	Quality of work met our expectations	Quality of work frequently exceeding our expectations
Cooperation	Uncooperative or unwilling to listen to and support others to achieve group goals	Cooperative, but occasionally unwilling to listen to or support colleagues	Consistently listened to others' ideas and worked cooperatively to achieve goals	Consistently listened to others; willing to sacrifice personal interests to achieve our goals
Leadership	Passive in respect to goal setting, initiating tasks and resolving problems	Was supportive but displayed little initiative in moving the team towards its goals	Showed initiative in helping the team solve problems and achieve its goals	Was a positive force in looking ahead and supporting other team members to achieve its goals
Overall Assessment	I'd refuse to work with this member again	I'd be reluctant to work with this member again	I'd be pleased to work with this member again	I'd actively seek to work with this member again

An example of a rubric for how the design was graded.

Criteria	Poor	Average	Excellent
Thermal Performance **40%** of total grade	**20%** Little or no temperature gain; fails to demonstrate heating capability.	**70%** Some temperature increase observed; partial success in heating or cooking.	**100%** Device demonstrates clear and measurable temperature gain; successfully heats, cooks, or sterilizes.
Align with goals			
Reliability **20%** of total grade	**20%** Stop functioning during testing.	**70%** Shows inconsistent performance.	**100%** Consistently performs well over time without failing.
Align with goals			
Design & Construction **20%** of total grade	**20%** Poor construction; fragile or uses prohibited unmodified containers (e.g., Tupperware).	**70%** Some variety in materials; moderately durable but may show flaws in structure.	**100%** Uses diverse, appropriate materials; well-constructed and durable.
Align with goals			
Aesthetic Appeal **10%** of total grade	**20%** Minimal effort in appearance; lacks visual organization.	**70%** Design is functional with some thought to appearance.	**100%** Design shows creativity and professionalism; visually well-presented.
Align with goals			
Cost Efficiency **10%** of total grade	**20%** Expensive or wasteful materials used; significantly over budget or no documentation provided.	**70%** Materials are reasonable; documentation is incomplete or project is slightly over budget.	**100%** Uses low-cost or repurposed materials wisely; material costs are well-documented and the project stays under budget.
Align with goals			

An example of how a technical report feedback.

1 Introduction

The task of building a 40 x 40 x 40-centimeter boat to carry 15 wine corks across a 3-meter pool has been assigned. The wine corks are representative of passengers on a larger scale on said boat, along with anything else considered load bearing. The goal of the project was to create a boat that is as efficient and stable as it can be while maintaining cost efficiency. In this report, the research and thought process that went into the creation of the boat will be shown.

- State the Purpose: You mention the task of building a boat, but the specific purpose or objective of the document could be clearer (e.g., designing for stability and cost efficiency).

- Provide Context: You briefly mention wine corks as passengers, but more context on why this project matters or its practical application could engage the reader more effectively.

- Outline the Scope: The scope of the report is hinted at but not fully explained. It would be good to briefly mention what aspects of the boat design will be covered (e.g., materials, construction methods, testing).

- Engage the Reader: The introduction could be more engaging by adding fact or hook, such as highlighting the challenge of balancing stability and cost.

- Be Concise: The introduction is mostly concise but could be streamlined a bit further.