

Rethinking Assessment for the 21st Century: Project-Based Learning

The mission of Caltech is “to expand human knowledge and benefit society through research integrated with education”. How are we integrating research into our educational experiences for students?

What is project-based learning?

Students gain knowledge and skills by working for an extended period to investigate and respond to an authentic, engaging, and complex question, problem, or challenge. PBL centers on student-driven inquiry, collaboration, and the creation of a public product that addresses real-world issues.

Key Principles of Project-Based Learning:

- **Driving Question/Problem:** The project is anchored in an open-ended, engaging question or problem.
- **Sustained Inquiry:** Students engage in an extended, in-depth process of asking questions, finding resources, and applying information.
- **Authenticity:** Projects feel real, often connecting to the community or professional world.
- **Student Voice & Choice:** Students have ownership of their learning, including decisions about how to work and what to create.
- **Reflection & Iteration:** Students and teachers reflect on the learning, while also engaging in a process of revision to improve their work.
- **Public Product:** Students share their final results with an audience beyond the classroom.

How to implement project-based learning in your course:

1. **Define your learning objectives:** What do you want students to be able to do by the end of your course? Articulate these in specific, measurable terms (for you and the students).
2. **Select a Problem:** Choose a real-world, messy, or complex issue. Alternatively, develop a menu of problems that students can choose from.
3. **Create a Driving Question:** Spark curiosity with a compelling question.
4. **Plan the Process:** Map out the inquiry, resources, and timeline. Connect your learning objectives to skills and knowledge your students will need to complete the objectives, and determine which of these skills students already have, are already developing, or will be new. Cluster these skills together logically and develop a course structure that teaches them.
5. **Facilitate & Scaffold:** Guide students through research, acting as a facilitator rather than a lecturer.
6. **Assess Continuously:** Use formative assessments, peer, and self-evaluation throughout.
7. **Public Presentation:** Have students present their work to an audience.

Some sample project ideas:

Engineering & Technology

- **Assistive Technology Design:** Engineering students can design and prototype devices to aid individuals with disabilities, such as building a **hydraulic robotic arm** or fitness-trackers.
- **Sustainable Infrastructure:** Teams can use physics and structural engineering principles to design a **model bridge** or a **tiny house** that meets specific client needs and environmental constraints.
- **Autonomous Systems:** Students may build a **miniature self-driving car** or a color-detecting Mars rover, requiring integration of electronics, mechanical design, and programming (often using Python).
- **Renewable Energy Solutions:** Design and test functional **wind turbines** or **solar-powered vehicles**, optimizing for electricity generation or performance under varying conditions.

Biological & Life Sciences

- **Epidemiological Modeling:** Math and biology students can collaborate to create models that help local policymakers understand and control the **spread of infectious diseases**.

- **Water Security & Quality:** Investigate local water sources to determine safety, or design **nanotechnology solutions** for cleaning up ocean oil spills.
- **Genetics & Evolution Studies:** Conduct multi-generational experiments with fast-growing plants (like *Wisconsin Fast Plants*) to recreate and analyze **Mendelian genetics** or natural selection.
- **Biodiversity Assessment:** Use acoustic technology or DNA analysis (e.g., **DNA profiling**) to monitor wildlife in local ecosystems or the rainforest.

Computer Science & Data Science

- **AI & Machine Learning Applications:** Build a **facial recognition system** using neural networks or develop an app that solves a specific community problem.
- **Simulation & Expert Systems:** Create advanced computer simulations or expert systems to model complex physical or biological phenomena.
- **Interactive Data Visualization:** Design interactive hands-on exhibits or websites that use real-world scientific data to teach STEM concepts to the public.

Interdisciplinary STEM Projects

- **Urban Ecosystem Planning:** Students research and design **soilless (hydroponic) farming** solutions to improve local food security and sustainability.
- **Climate Action:** Analyze a campus or local building to propose specific redesigns that significantly **reduce carbon emissions**.
- **Industry Case Studies:** Many universities partner with industry to have students solve **multimedia case studies** in optics, photonics, or advanced manufacturing, comparing student solutions to those used by actual companies.