ASSESSMENT GUIDE

for

ENGINEERING DESIGN PROJECTS

ProjectEngin™

HOW TO ASSESS ENGINEERING DESIGN AND OTHER PROJECTS

Guidelines and Resources

Whenever you use active and project-based learning approaches, assessment becomes more challenging. When you intentionally focus on skills such as creativity, collaboration, and critical thinking, in addition to curricular content, developing a meaningful way to assess learning may seem close to impossible. Couple all of that with the disconnect between forward-thinking teaching and high-stakes, standardized testing programs and it can easily deflate the atmosphere in any room of once enthusiastic educators.

So how do you manage assessment in a less structured setting? Designing assessments that truly reflect and monitor learning is always a challenge and it becomes even more challenging when you are dealing with project-based learning. We encourage educators to do it one step at a time. Keep the assessments you have and think about ways to modify or add to them. Make use of some real-time in-class formative performance assessment first – it minimizes your work outside of class and solidifies your role as a guide in classroom projects. Involve your students in the development of assessments by brainstorming what they think truly reflects what they know and how well they have learned.

It helps to keep four questions in mind before you even move onto the question of how to assess.

1. **What do you want to assess?**
2. **When do you want to assess?**
3. **Who will you assess?**
4. **Why do you want to assess?**

In traditional forms of assessment, the answers to those questions is often content, final product, individuals, and "for a grade". And even when there is a change in the delivery of a lesson or unit, those things are still significant components of assessment.

What to assess in Engineering Design Projects

Things change a bit when you start to use a more skills-oriented project-based approach. There are more to components to assess, more points where you can include assessments and generally, a change in the design of the assessment.

TRADITIONAL VS PBL ASSESSMENT

	Traditional Curriculum Unit	**Engineering Design Challenge (Project-based Learning)**
WHAT	Content	Skills
WHEN	Product	Process
WHO	Individual	Group
WHY	For a grade; often mostly summative	Measure of learning; increased formative information

Using the Engineering Design Process to frame projects and activities can help you to develop formative and summative assessments at key points. It also provides a way to value and assess the process more than the final product. Because Engineering Design challenges and projects are active learning tasks that ask you to apply what you know to solve problems, they are performance assessments. So ,in many ways, there is no reason for having to think of assessment as being a separate task or assignment that students need to complete. Following the process of analyzing and understanding a problem, considering multiple solutions, and prototyping, testing, and modifying one possible choice provides ongoing evidence of creativity, collaboration, communication, critical and systems thinking. There is assessment built into the steps of the project. You just need to know how to look for it and how to categorize and analyze it.

The following table lists characteristics of Engineering Design projects that make them a little more challenging to assess. It is helpful to keep them in mind as you develop assessments. Resources that can help you develop assessments for each step are also given

Engineering Design Projects – What and How to Assess

Characteristics of Engineering Design Projects	Impact on Assessment ***Resources and Suggestions***
Student-led learning	Ongoing formation of ideas and concepts requires ongoing formative assessment and checkpoints; providing summary of key concept understandings provides framework for concept-based summative assessment.
Systems thinking, impacts, connections	Assessment of complexity and connections is challenging. Standards-based rubrics and concept maps may be helpful. A Structure for Assessing Systems Thinking also provides some standards.
Multiple solutions/no one right answer	Contrary to traditional summative assessments. The project should provide evidence of learning through application of concept; makes it an *authentic* assessment. Constructed scenarios that involve evaluation or ranking of possible solutions against constraints, criteria, and user needs allow for assessment of both process and product understanding. Scenarios focused on meeting constraints due to curricular concepts (i.e., restrictions due to gravity, environment, etc.) can allow for assessment of concept understanding.
Skills AND content rich	Process should always matter more than product; rubric-based assessment of skills probably most effective; student self-assessment also valuable. Buck Institute rubrics (PBLWorks)for creativity, collaboration, presentation, and critical thinking are excellent starting points. Traditional assessments of content can be used as checkpoints or individual assessments.
Group work	Group should function as team; evaluating collaboration can be challenging – peer and self-assessment summative assessments can be helpful; ongoing teacher observations can provide formative assessments. The Eberly Center at Carnegie Mellon University has some good guidelines for assessing group work.
Process-oriented	This is where much of the learning happens. Need documentation of the process for both formative and summative assessment; value of the Engineering Notebook; periodic group "check-ins"; daily observations; single-point rubric focused on EDP for self and formative assessment.
Real world; messy problems	Summative assessment requires a focus on connections, rationale for decisions; critical thinking and creativity are paramount as well as understanding of key concepts and identification of "need to know"; Buck Institute rubrics (above) extremely helpful. For generalized assessment of critical thinking and problem-solving skills, a hypothetical design challenge or an actual case-study example (older students) can be useful.

An Engineering Design challenge supports the development and mastery of content knowledge through application. It requires students to solve a somewhat messy problem by following a process. And it connects your classroom to the real world. This is contrast to practices that teach to a test, units that follow a highly linear progression, and the student perception that the end-goal of learning is the coveted “A”. Students need to know that learning is not test-taking. They need authentic challenges that go beyond an arbitrary test, requiring them to apply and find out what they need to know. And we need to assess much more than what they know.

Project-based learning has far more layers than direct instruction, so it makes sense that there are more ways to think about and structure assessment. We typically look at balancing three main areas:

- **Content and Skills**
- **Product and Process**
- **Individual and Group**

In traditional instruction and assessment, the focus is on content, product, and individual. You may already have effective methods to provide both formative and summative assessment for all of those. Most of the teachers we work with find that the challenges lie in developing assessments that focus on the aspects that are hallmarks of project-based learning – skills, process, and collaborative group work. It is worth looking at the categories above in order to structure project assessments to complement what you already use.

Content and Skills

Content assessment can range from more traditional quiz/test formats to performance tasks. Because most Engineering Design projects are done in groups, it can be difficult to assess content understanding for individual students. This is one area where a version of the tests or quizzes you may have previously used can be helpful. Keep in mind the standards you are following and don’t drill down to the smallest fact. An assessment that checks for general understanding as a background for the project insures that all students have a reasonable starting point. Most of the teachers we work with will use a quiz on key concepts at this point, with a provision for retakes if needed. Additional evidence of content understanding can be a required component of the final presentation and it can also be part of the required documentation in the Engineering Notebook, making the connection between concepts and design decisions. Most teachers find that it is easier to make assessment of content understanding a component of the individual grade for the project.

Assessing skills is a challenge. Unlike content, there are no clear boundaries or discrete checkpoints; our mastery of skills generally follows an often non-linear continuum. Rubrics are generally the most effective form of skills assessment. As mentioned in the last blog posting, the Buck Institute has some great resources and rubrics on its PBLWorks website. Student self-assessment of improvement in terms of the 4 C's is also helpful. The Department of Defense's Education Activity program has created a good compilation of rubrics for both teacher and student assessment of 21st century skills. The document also has some good resources and references.

Most teachers are comfortable assessing collaboration, communication, and critical thinking. Assessment of creativity is often a bigger challenge. In our view, it should be strictly formative and geared toward feedback. There should also be a high degree of student involvement in understanding (perhaps even designing) and employing the rubric or feedback form. As Ken Robinson points out in his book, *Out of Our Minds,* far from being an innate gift, creativity can be taught but doing so presents assessment challenges. "The educational value of creative work lies as much in the process of conceptual development, as in the creation of the final product. Assessment needs to take this into account…" (Robinson, 2011). This brings us to a consideration of product versus process.

Product and Process

Traditional assessments typically focus on the product. A multiple-choice test shows little about the thought process that lead to the answer, or final product. Artifacts such as papers and presentations are often assessed in their final form with little focus on the research or editing process. But there is an enormous amount of critical thinking and creativity inherent in constructing and revising those artifacts. One of the benefits of using the Engineering Design

Process to frame projects is that various steps in the process highlight skills as well as content development.

In our experience, putting more weight on the final product in assessments has a “beauty contest” effect. Students are more likely to take a “hands-on” approach, skipping over much of the “minds-on” learning that you hoped to promote. A physical prototype will look better, go faster, or fly higher but much of the development will be occur in a trial-and-error method to see what works. A focus on the process will enable you to stress the need for planning, research, decision-making, and connections to curricular concepts. An Engineering Notebook that allows students to document the decisions and connections that are part of the process. It can be used as formative and summative document to assess the group’s work as they move toward a solution. We strongly believe that much of the transferable learning is in the process and we suggest that you consider making your assessment of how well it was employed at least 65% of the final project grade. As educators, we are all aware that we cannot keep up with the explosion in knowledge. Developing a way to think about and use that knowledge is a lifelong skill that should be one of the key learning goals in our classrooms.

Individual and Group

This is typically the most *challenged* part of any project assessment. There can be pushback from both students and parents, particularly those used to high marks on the individual assessments that make up most recorded grades. It is important that you have a clear explanation, identifiable guidelines, and as much transparency as possible. It makes sense to have a group component to assessment since the work was done collaboratively and, in most cases, the project was designed to make it necessary to have a team approach to successfully complete it. But you need to be attentive to the fact that group dynamics are rarely perfect in a classroom environment. Student contributions and commitment will vary. Some of your assessments, such as those relating to content understanding and creativity, will necessarily be of individual progress and achievements. In my own practice, I generally kept the individual component of the final project grade at anywhere from 30-35%. That gives most students a sense of control while stressing that the work of the entire group is key.

That individual component of the grade can be made up of content assessments, peer review, and your own observations of time-on-task along with any student self-assessment of skills. The group grade can be based on the final product and presentation (product), the Engineering Design Notebook (process) and your assessment of the group's use of the Engineering Design Process and their problem-solving skills. You may also want to add a group self-assessment as well. Just be sure you have made all your assessment components and guidelines clear and reasonably weighted based on the project tasks and the learning goals. In the third part of this series, rubrics and milestones for formative and summative assessments will be provided. Start thinking about how you want to structure the components of what you assess. Keep some of what you already use to assess content, products, and individuals while considering how to add consideration of skills, process, and collaborative efforts. If your students are going to be ready for a future that demands innovation and collaboration, that needs to be part of your classroom today.

Create a Vision to Guide Your Assessment Choices

Every project has some unique assessment needs and challenges, but it helps to keep a few core principles in mind. I typically follow these percentages guidelines for most projects;

Process / Product	65% / 35%
Group / Individual	70% / 30%
Skills / Content	60% / 40%

My reasons are based on my overall approach to education and what I hope to help young people learn; how you design your assessments should reflect your vision. I believe that a problem-solving process has far more value than any one product. It can be and often is (as reported by students) a method that finds a way into lots of other projects and disciplines.

Current and future jobs require a team approach due to the shear complexity of many factors affecting them, so collaboration is a critical skill. Assessment that highlights group work is important if we hope to teach collaborative skills. And content can be found everywhere, but the skills needed to apply and to master new ideas need to be learned and practiced. Think about what it is important for your students to learn and develop assessment guidelines that will support those goals. Setting percentages such as those above provides a landing spot for the various assessments you will employ. You can employ both formative and summative assessments in line with guidelines you have set, or you can focus on defining a grade based on summative assessments based on the percentages you have in place. Depending on your school norms and where you are on the assessment spectrum, your percentages may be different than those above. Keep the idea of incremental change in mind and make adjustments when you and your students are ready.

How to Assess

Most project-based learning practitioners make use of rubrics for formative and summative assessment. The three that we most commonly used are a peer assessment rubric, a single-point rubric, and an analytic rubric that covers the various components and skills that make up the Engineering Design Process. These can be found in the Resources section. They can be used as both formative and summative assessment components depending on your needs. In addition to these rubrics, more content and project or skills-specific rubrics can be used to highlight important learning objectives. You can also find a terrific compilation of rubrics and information on Kathy Schrock's website. In our work, we are increasingly using single-point rubrics for student and group self-assessment at the middle school level. Some of the teachers we work with use content assessments that are similar to the ones they have traditionally used. They feel this gives them additional feedback about the effectiveness of the project in developing understanding.

When to Assess

As noted, before, the project your students are working on is an assessment. It is a performance task that challenges them to think critically and creatively while working together to apply their knowledge to solve a problem. That sounds great, but it can be overwhelming to assess in a way that allows you to make sense of the degree of learning and to generate a fair grade. Since our work focuses on using the Engineering Design Process as a framework for projects, we use key points in the process for formative and summative assessments.

The teachers we work with at ProjectEngin like the idea of thinking of the Engineering Design Process as having three or four phases, rather than being a cycle of multiple steps. It makes it possible to insert small summative assessment measurements at the end of each of those phases if you choose to. This might be an important consideration if you are working on a lengthy project and there are pressures (student, administrative, or parental) to report progress in terms of some grades. In other words, there should be evidence of problem definition before moving onto the divergent thinking phase of generating multiple solutions. An evaluation of effective brainstorming and some planning should precede the building phase. The principal summative evaluation is at the end of the project when students provide evidence of process (Engineering Notebook or ENB), a product (a prototype), and the ability to present their work. A table of *Assessment Points in the Engineering Design Process* can be found in the Resources section. The summarizes where different assessments can be made throughout the process. Please note that the steps and assessment points correlate closely with the Engineering Design Disciplinary Core Ideas, Performance Expectations, and Practices specified in the Next Generation Science Standards.

By keeping the idea that the Engineering Design Process always frames the project in the foreground, you can develop an assessment model that is ongoing and focused on both skills and content. The framework of the Engineering Design Process (EDP) enables you to identify and highlight the skills needed to solve a problem and it can be used to do the same for your students. Making the EDP the organizing core of your projects gives both you and your students the opportunity to focus on increased mastery of skills as you move through multiple challenges.

In summary, the answer to the questions of who, why, what, and when to assess is to do it throughout the project and to do it with student involvement. Specified criteria for success and connections to the full spectrum of the learning experience are more effective than a "cover the material, take a test approach". Time for feedback, reflection, and modification is critical if we hope to develop lifelong learners. And remember that part of modeling never-ending learning is to continually assess and modify the assessments to align with the skills and ideas that you hope students will learn. Change your assessment approach slowly, following your sense of where the real learning is happening in your projects.

RESOURCES AND RUBRICS

Assessment Points in the Engineering Design Process

EDP STEP		Assessment Focus	Assessment Format	Group or Individual	Formative or Summative
Problem Definition	Know End-User	Systems thinking/impacts	Discussions with group	Group	Formative ***Summative at end of this phase***
	Constraints Criteria	Limiting design Space	ENB documents	Group	Formative ***Summative at end of this phase***
	Background Concepts	Curricular concepts	Quiz/conventional assessment	Individual	Formative; re-check at end of project for Summative assessment if desired
Explore Multiple Options	Research Previous/Possible Solutions	Overview of approaches; background knowledge	Worksheet/ENB form	Individual (by "job" on team)	Either – teacher discretion depending on complexity of project
	Brainstorm	Quantity, variety; creativity	Forms, documents in ENB	Group	(ENB)
	Fit ideas to constraints and criteria – choose prototype	Critical thinking; organizing	Forms, documents in ENB; ***Initial Design Plan***	Group	***Summative – acts as entrance ticket to building***
Building	Planning	Critical thinking; organizing	Forms, documents in ENB; ***Materials List***	Group	(ENB)
	Building	Ongoing progress; collaboration	In-class performance	Group	Formative
Optimizing	Testing	Critical thinking/relevant curricular concepts/data analysis	Testing procedure and results document/ results and data analysis	Group	(ENB)
	Modifying	Critical thinking/systems thinking/justification	Documentation in ENB	Group	(ENB)
Communicating Results	Final Notebook/Final Design Summary	Evidence of following a process	Entire Engineering Notebook	Group	***Summative***
	Finished Prototype	Ability to apply ideas and concepts	Prototype	Group	***Summative - with reasonable degree of completion***
	Presentation	Ability to communicate and explain process and product	Power Point/ Report/Pitch	Group with designated individual contributions	***Summative***

Notes:

ENB – Engineering Notebook designed to document the steps of the process. It can be used for periodic formative checks throughout the project and for a summative evaluation at the conclusion of the project.

Formative assessment can be done at various points in the process. Inserting quick checks of concepts, understanding of criteria and constraints, consideration of various options, planning and building, developing and implementing tests, making modifications, and optimizing a prototype can provide formative steps in mastering the process.

Engineering Design Process Rubric

	Exceeding Expectations	Meeting Expectations	Approaching Expectations	Not Meeting Expectations
Define the Problem	Shows a clear understanding of the problem(s) to be solved Rephrases the problem clearly and precisely	Shows a basic understanding of the problem(s) to be solved Rephrases the problem clearly	Shows limited understanding of the problem(s) to be solved Rephrases the problem with limited clarity	Lacks understanding of the problem(s) to be solved Does not rephrase the problem
Delimit the Problem	Identifies and clearly defines all the criteria Specifies all the constraints with detail	Identifies most of the criteria Specifies most of the constraints	Identifies minimal criteria Identifies minimal constraints	Identifies criteria that are irrelevant Identifies constraints that are irrelevant
Generate Solutions	Generates an extensive list of possible solutions and thoroughly documents all ideas (list or diagrams)	Generates several possible solutions and documents ideas (list or diagrams)	Generates a single possible solution and documents the idea	Generates an idea(s) that is unreasonable and/or does not document ideas
Prototype/ Test	Prototype meets the task criteria in insightful ways The model or prototype is constructed with care, neat, attractive and follows plans accurately	Prototype meets the task criteria The model or prototype is constructed with care but may be missing details	Prototype meets the task criteria to a limited extent The model or prototype is messy and/or missing details	Prototype does not meet the task criteria The model or prototype is incomplete
Modify/ Optimize	Significant improvements are made to the design based on prototype testing and evaluation Evidence of modification, testing and optimization are thoroughly documented	Some improvements are made to the design based on prototype testing and evaluation Evidence of modification, testing and optimization are documented	Minor improvements are made based on testing and evaluation results Evidence of modification, testing or optimization is incomplete	Improvement based on testing and evaluation is not evident Evidence of modification, testing or optimization is missing
Communicate Results	Provides thorough documentation for all steps of the Engineering Design Process Team presents a well thought out solution to the problem and includes a rationale for their solution Team shows a clear understanding of the related science concepts and design process	Provides documentation for all steps of the Engineering Design Process Team presents a well thought out solution to the problem Team shows a basic understanding of the related science concepts and design process	Provides documentation for some steps of the Engineering Design Process but does not include all steps Team presents a simple solution to the problem Team shows little understanding of the related science concepts and design process	Provides little documentation for the steps of the Engineering Design Process Team presents a solution that does not solve the problem Team lacks understanding of the related science concepts and design process

Evaluating How Well We Engineer

What we can do better	Goal	Got it! (√)	What we did that was awesome!
	Know the Problem: We understand the end-user; we interviewed them or researched how they live and the problems they have.		
	Know the Problem: We listed our constraints (limitations).		
	Know the Problem: We decided on our criteria (goals) and gave them a ranking.		
	Know the Options: We researched and thought about what had been tried before.		
	Know the Options: We brainstormed lots of ideas		
	Develop a Solution: We decided to make a prototype of a solution that fits the criteria and constraints.		
	Develop a Solution: Planning – we made an Initial Design Plan and decided what materials we would need.		
	Develop a Solution: Building – we followed our plan to build a prototype.		
	Develop a Solution: We tested our prototype to see if it would work and/or we got some feedback from others.		
	Develop a Solution: We modified or made plans to modify our prototype based on our testing or feedback. Our solution is the best it can be (optimized).		
	Develop a Solution: Communication -We presented, pitched, or explained our solution to others.		

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Name: ______________________________ Date: ______________

Group: ____

Peer Assessment Form

Write the names of your group members in the numbered boxes. For each criteria, rate yourself using the scale below. Then rate each of your group members. Record any additional comments on the back of the rubric.

4 = Always 3 = Often 2 = Sometimes 1 = Never

Criteria	Myself	1.	2.	3.	4.	5.
Participated in group discussions						
Helped keep the group focused and on task						
Contributed useful ideas						
Respectfully listened to others						
Took responsibility for a fair share of the work						

WEEKLY GROUP SELF-ASSESSMENT

HOW ARE WE DOING?

GROUP MEMBERS: ____

	Need to improve	Okay	Doing a great job!
Time management			
Equal effort by all			
Listening to everyone's ideas			
Best group effort of the week?			
The biggest issue we had was:			
Biggest challenge ahead (next week or through completion of the project):			

ASSESSMENT RESOURCES

Project-based learning

PBL Works https://my.pblworks.org/resources?f%5B0%5D=type%3A27

http://www.edutopia.org/10-assessment-tips-for-class

Group Work

Eberly Center
https://www.cmu.edu/teaching/designteach/teach/instructionalstrategies/groupprojects/assess.html

Assessing Small Groups
https://canvas.stanford.edu/courses/73326/files/2177347/download?verifier=MsvUGEn6AIXABrcUHQG9CKVy0wgm4SnjVqgxTh1T&wrap=1

21st Century Skills

PBL Works https://my.pblworks.org/resources?f%5B0%5D=type%3A27

DoDEA (Dept of Defense Education Activity) rubrics
https://content.dodea.edu/teach_learn/professional_development/21/docs/21st_century_skills_rubrics/reflection_evaluation_rubrics.pdf

Partnership for 21st Century Learning

http://www.p21.org/our-work/resources/for-educators

Asia Society https://asiasociety.org/files/gcen-measuring21cskills.pdf

Rubrics

http://www.schrockguide.net/assessment-and-rubrics.html