Sentence-Starts for Claims During Different Stages of the Engineering Design Process

This document is intended to be used with STEM Teaching Tool #63, "How can teachers integrate argumentation from evidence into engineering design projects?." This tool describes the importance of student argumentation within engineering lessons. This document includes sentence starts and examples to support students in making arguments in engineering lessons.

The sophistication of claims and types of evidence available at each stage will increase in sophistication as students gain experience and progress through the grade bands. In addition, the types of claims you suggest to students and the evidence used will vary for each specific project. To learn more about how to get design projects started in your classroom visit STT #64.

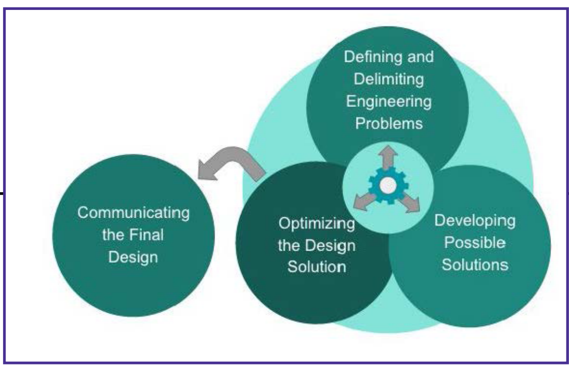
Many studies have shown that student talk is central to supporting deep sensemaking of students. One key to building more student-focused pedagogy is developing an authentic curiosity about student thinking. Studies have shown that students learn and respond in lively, scientific ways when asked open-ended questions, given agency over their learning, and use scientific criteria for knowledge claims.

Note: For the "Example" column, the problem context is a hat design challenge, in which students are tasked with designing a functional hat with the materials provided. To see an example design project using the same hat project as this chart, explore the engineering hats example.

Design Stage and Sentence Starters	Types of Evidence at This Stage	Examples (claim in bold, evidence/reasoning in italics)
	Defining the Problem	
1. This is a problem because... 2. One criterion for this project should be ______ because... 3. A solution to this problem must be able to/should do... 4. The ranking/relative importance of the criteria should be ______ because ______. 5. One constraint for this project is ______ because... 6. The testing conditions make sense/are appropriate because...	A. Problem context B. Science phenomena and explanations C. Cited science research D. Specific data measured or observed in a scientific context	• This is a problem because **once I went on vacation without a hat and I got a sunburn**. *A hat would have prevented this problem.* (1A) • This is a problem because in the video we watched we saw a lot of people with no hats waiting in the rain. *A hat would have prevented this problem.* (1A) • One criterion for this project should be **to put the hats on and off at least 10 times without damage** *because we are making hats for repeated use and we want them to last.* (2A) • A solution to this problem should **stay on in front of a fan on high** *because these hats will be worn outside and we want them to stay on in all weather conditions.* (3A) This testing condition is appropriate because **the fan on high feels about as strong as the wind in our town on a fall day.** (6D) • The most important criteria is **that the hat stay on your head while walking or shaking "yes" and "no"** because *every kind of hat needs to stay on the head or it can't solve any problems.* (4A) • One constraint for this problem is **the hat should weigh less than 200 grams** because *having something more than 200 grams on your head could hurt your neck over time.* (5A, B, or C)

Design Stage and Sentence Starters	Types of Evidence at This Stage	Examples (claim in bold, evidence/ reasoning in italics)
Developing Solutions		
1. This design will solve the problem because... 2. This design choice (material, construction, etc) is the best (or should be successful) because... 3. Our model will be at scale ______. We know this because ______. This is appropriate because ______. 4. This design idea should meet the criterion ______ because ______. 5. This design idea should be within the constraint ______ because ______.	A. Problem context B. Science phenomena and explanations C. Cited science research D. Specific data measured or observed in a scientific context E. Criteria and constraints F. Feedback and response to feedback G. Engineering documentation (sketches, test results, measurements, materials inventory, budget, photo-documentation, etc)	• Our hat design should meet the criteria “**warm” and “waterproof”** because *during our science tests, we found out that foil is waterproof and felt is the best insulator against cold.* (4D, E) • **The hat will stay on and not fall off in the wind** because *we will use this pipe cleaner shown here in the drawing.* (4E, G) • **Our hat design is under budget** because our *drawing and calculations show us using fewer materials than we are allowed.* (5E, G)
Optimizing the Design		
1. Our design meets/does not meet the criterion_____because_____ 2. Our design meets/does not meet the constraint ______ because_____ 3. Our design could be improved if we_______because______ 4. We are receiving and responding to feedback well because ______. 5. We chose not to implement (specific feedback) because ______.	A. Problem context B. Science phenomena and explanations C. Cited science research D. Specific data measured or observed in a scientific context E. Criteria and constraints F. Feedback and response to feedback G. Engineering documentation (sketches, test results, measurements, materials inventory, budget, photo-documentation, etc) H. Test results measured or observed • Compared to criteria/constraints • Compared to earlier iterations of the design • Compared to the other projects in the class • Opinion questions / surveys for subjective criteria	• Our design met the criteria of **staying on in the wind** because *when we stood 1 meter from the fan on the high setting, the hat stayed on.* (1D, E, H) • **Our design did not meet the durability criteria,** because *after we put it off and on 6 times, the chin strap broke and the criteria says it needs to go on and off 10 times without breaking.* (2D, E, H) • **We are taking a feedback idea to make the brim of the hat wider** because *we think it will make our hat solve an addition problem of sun in the eyes.* (4A, E) • **Our design will be improved by adding a layer of bubble wrap next to the person’s head** because *during testing, her hair kept getting stuck on the inside of the hat and it was uncomfortable.* (3D, F, H)

Design Stage and Sentence Starters	Types of Evidence at This Stage	Examples (claim in bold, evidence/ reasoning in italics)
Communicating the Final Design		
Note: The Framework defines the engineering design process with three phases (see figure below, left). We propose adding a final step of Communicating the Final Design— because the types of claims made during this step are distinct. Claims with evidence can be made in each step, but the type of claims and available evidence vary.		
1. Our design is good enough because ______ 2. Our design meets the minimum criteria because 3. Our design is the best because ______ 4. Our design could be made better if we ______ because ______. 5. Our final design was like our original design in these ways ______. We kept these things the same because ______. 6. Our final design was not like our original design in these ways ______. We changed these things because ______. 7. Our final design is LIKE the real object in these ways because ______. These similarities are important because ______. 8. Our final design is UNLIKE the real object in these ways because ______. These differences are important/not important because ______.	A. Problem context B. Science phenomena and explanations C. Cited science research D. Specific data measured or observed in a scientific context E. Criteria and constraints F. Feedback and response to feedback G. Engineering documentation (sketches, test results, measurements, materials inventory, budget, photo-documentation, etc) H. Test results measured or observed • Compared to criteria/constraints • Compared to earlier iterations of the design • Compared to the other projects in the class • Opinion questions / surveys for subjective criteria	• **Our design is good enough** because *our testing data shows that it meets all of the criteria and did not break any constraints.* (Specific claims can be made for how it meets each criteria and is within each constraint.) (1D, E, G, H) • **Our design is the best** because *it met all of the criteria and did not break any constraints, and it exceeded 3 of the criteria. No one else's project exceeded more than 2 criteria.* (Specific claims can be made for how it meets each criteria and is within each constraint, as well as how this compares to other projects.) (3D, E, G, H) • Our design could be made better if **we could do the testing with people who have many different shapes of head and types of hairstyles** because a *hat that is being sold should work well for many people.* (4A, E) • *When comparing our original design drawing to our final hat design*, **they are similar in shape**. (5G) • **Our design is unlike the real object** because we will have more expensive materials to work with. **This difference is important** because *it will make our hats cost more than if they were made of aluminum foil but also make them more durable.* (8E, G, H)



Clarification on Types of Evidence

A. **Problem context** is obtained from the reading, video, observations, personal experience, or students' prior knowledge of a situation that people want to change. This can be thought of as the who/what/why/where of the problem. Students can use the problem context as evidence to support claims about the appropriateness of solutions, desirability of solutions or features, and creation of criteria and constraints.

B. **Science phenomena and explanations** are often necessary to support claims about design features, material selection, and appropriateness of criteria and testing conditions. For example, students may have studied the impacts of extreme weather and use that understanding to set criteria for hurricane-proof houses. Scientific explanations may also be used as evidence to explain testing results or propose improvements.

C. **Cited science research** may be used as evidence by students, particularly older students, rather than requiring them to produce the scientific data themselves. This is also the case when it is not possible for students to conduct the scientific testing themselves, such as when designing a lander for Mars, which requires knowledge about the force of gravity and atmospheric conditions.

D. **Specific data measured or observed in a scientific context** can become the "prior knowledge" that students bring to an engineering design problem in classroom situations where scientific investigations happen prior to engineering design. For example, they may study various material properties in a science unit and then use their results as evidence to support material selection in later engineering contexts. In other cases, students may discover the need for a controlled experiments during the engineering design process and gather the necessary information at that time.

E. **Criteria and constraints** should be defined by the students in the first phase of the engineering design process (Defining and Delimiting Engineering Problems) based on the problem context and other factors . These criteria and constraints should include testing conditions that will be used to assess the competing design solutions. In the other phases of the process, criteria and constraints are some of the most important evidence that students can use to support claims. All testing results and design solutions can be compared to the criteria and constraints of the problem to determine if the solution solves the problem.

F. **Feedback and response to feedback** can be used as evidence for claims about design evolution, success with subjective criteria, and positive teamwork.

G. **Engineering documentation (sketches, measurements, materials inventory, budget, photo- or video-documentation, etc)** can be used as evidence for many types of claims, including claims about fidelity to the original design plan, evolution and improvement of the design over time, compliance with materials constraints or budget, adherence to the project timeline, and more. Specific types and amounts of documentation may be required as part of the initial criteria and constraints, strengthening opportunities for students to use documentation as evidence.

H. **Test results measured or observed** can be compared to to criteria/constraints, to earlier iterations of the design, or to the other projects in the class to support claims about design solutions. Testing methods defined earlier in the project are important in this comparison. In addition, students may also cite the results of opinion questions or surveys for subjective criteria such as "aesthetics." These results are the evidence students use to support claims about the success of their designs.