CHAPTER 13

A Shared Language: Two Worlds Speaking to One Another through Making and Tinkering Activities

Amber Simpson, Jackie Barnes and Adam V. Maltese

Abstract

Making and tinkering is being viewed as an interdisciplinary approach to promote learning of knowledge, practices, and skills across science, technology, engineering, and mathematics (STEM) disciplines in informal (e.g., science and art museums) and formal (e.g., school-based makerspaces) contexts. In this chapter, we present two frameworks for mapping the overlap between making practices developed by Wardrip and Brahms (2015) and standards-based practices developed for PreKindergarten to Grade 12 education. We apply the two frameworks to a making task of one youth who constructed a car using LEGO and littleBits, electronic building blocks that snap together with magnets. Through the case of Bailey, we highlight how informal and formal learning environments speak to one another to promote STEM learning for students of all ages.

1 Introduction

Making encompasses a variety of activities including building, designing, adapting and/or repurposing objects and material into a physical or digital product of some sort. (Vossoughi & Bevan, 2014). A variety of tools and material can be leveraged including low-tech (e.g., conductive thread), high-tech (e.g., 3D printing), and no-tech (e.g., wood, plastic recyclables, cardboard) tools and material. Making happens in classrooms, basements, garages, museums, libraries, makerspaces, and art studios. As such, it “reaches across the divide between formal and informal learning, pushing us to think more expansively about where and how learning happens” (Halverson & Sheridan, 2014, p. 498). Peppler, Halverson, and Kafai (2017) agree that making provides opportunities for the historical divide between informal and formal learning environments to dissolve and inform one another. With the adoption of content and practice
standards across STEM subject areas in Pre-Kindergarten (PK)-12 school settings in the U.S., out-of-school learning sites such as museums, youth-based makerspaces, and afterschool programs have questioned their role in engaging youth as STEM professionals during making-related activities; bridging in-school and out-of-school learning contexts.

As such, making is being considered for its potential to promote learning across science, technology, engineering, and mathematics (STEM) disciplines (e.g., Simpson, Burris, & Maltese, 2017a; Bevan, 2017; Martin & Dixon, 2017; Quinn & Bell, 2013), as well as the arts (e.g., Clapp & Jimenez, 2016). In terms of learning, the focus is on the process of learning through making as opposed to the final artifact that is made (Gutwill, Hido, & Sindorf, 2015). In this chapter, we too consider learning to be an inherent process of design; and focus on learning practice skills common to STEM professionals (Lee, Quinn, & Valdés, 2013) as enactment of these skills provide youth with authentic opportunities to participate in STEM community (Lave & Wenger, 1991) and to become STEM-literate members of society (Zollman, 2012).

In this chapter, we present two frameworks for mapping the overlap between making practices and STEM practices. The first section describes how eight making practices map onto K-12 standards-based STEM practices (i.e., informal to formal), and the second describing how K-12 standards-based STEM practices map onto making practices (i.e., formal to informal); thus, highlighting how the two learning environments speak to one another to promote STEM learning for students of all ages. We further illustrate this notion by applying the two frameworks to a making task of one youth, Bailey, who decides to build a car. More specifically, youth were engaged in constructing something, anything, using LEGO and incorporating littleBits (2018) as part of an afterschool making program in an elementary school operated by facilitators from a local science museum.

In presenting the case of Bailey, three things should be considered while evaluating the practices and standards described below. First, our claim is not that specific actions of one child align perfectly or objectively with each standard listed. Our purpose is to show how this activity can potentially support practices valued within STEM standards. Additional standards to those listed might be relevant, but here we present a working example of one short making-interaction. Second, the interaction here is facilitated and scaffolded by facilitator(s); thus, the practices evident below should be considered in relation to the scaffolds present. Third, we consider the case of Bailey to not be representative of other youth his age. Youth provided with the same or similar task may or may not engage in the practices in the same manner as Bailey.
Mapping Making Practices to Formal Practice Standards

Makers use mathematical and scientific thinking as part of their craft. Further, it would be extremely difficult to argue that Makers aren’t designers. Makers solve unstructured problems with available materials, often using innovative methods. Research at the Children’s Museum of Pittsburgh resulted in a set of practices that are core to making as a result of multiple iterations in collaboration with museum Teaching Artists who facilitate the makeshop space. This framework (Wardrip & Brahms, 2015) illustrates one way that practices of making are conceptualized and articulated by practitioners. These were developed as emergent values and practices of Teaching Artists, and not driven by academic concerns or comparisons. Nevertheless, the practices have relevance to values and skills embodied within academic and STEM requirements focusing on engineering & design. In the following section, we align Pennsylvania [PA] Common Core academic standards most aligned to these eight making practices (see Appendix A). Clearly, the PA standards are only one example for alignment, but productively illustrate the potential for making practices to contribute to academic learning.

2.1 Learning Practices of Making

2.2.1 Inquire
Makers inquire through their openness and curious approach to the possibilities of the context through exploration and questioning of its material properties. The PA Science, Engineering & Technology standards list “Science as Inquiry” practices that stretch across content and grade levels. The core components of inquiry are reflected in the language of the standards. Students must identify answerable questions, evaluate reasonableness, decide whether and how to conduct an investigation, use inference, make predictions, use appropriate tools to gather data, develop descriptions, explanations, models, analyze alternative explanations and have legitimate skepticism, formulate and revise explanations where investigations may result in new ideas, procedures, or technologies.

2.2.2 Tinker
Learners’ show purposeful play, testing, risk taking, and evaluation of the properties of materials, tools, and processes during making activities. Tinkering also happens as part of both mathematical and science engagement, as a process similar to troubleshooting. The common core mathematics practices include a standard of students making sense of problems and persevering in solving them—tinkering actually supports persistence in this way. Further,
troubleshooting itself is a PA Science & Engineering standard (i.e. “Describe how troubleshooting as a problem-solving method may identify the cause of a malfunction in a technological system”).

2.2.3 Seek & Share Resources
Making often happens collaboratively. The process requires identification, pursuit/recruitment, and sharing of expertise with others as well as recognition of one’s own not-knowing and desire to learn. Common Core Mathematics Practices require the construction of viable arguments and understanding the reasoning of others, including the instructions a collaborator might share. Further, the PA Science & Engineering standards articulate the design process as a collaborative endeavor in which each person in the group presents his or her ideas in an open forum.

2.2.4 Hack & Repurpose
Makers often use obscure materials to create something new. They might harness and salvage materials, tools and processes to modify, enhance, or create a new product or process; including disassociating object property from familiar use. Similarly, Common Core Mathematics Practices support learners’ use of appropriate tools strategically, including in new or unexpected ways. The PA Science & Engineering standards also support repurposing, stating that learners compare how a product, system, or environment developed for one setting may be applied to another setting and to explain how modifying is used to transform ideas into practical solutions while testing and evaluating the solutions for a design problem. Hacking materials for a new purpose requires exactly these practices.

2.2.5 Express Intention
Through making, learners express their ideas and intentions. They do this through their discovery, evolution, and refinement of personal identity and interest areas through determination of short- and long-term goals; choice, negotiation, and pursuit of goals alone and with others. The PA Science & Engineering standards address intention both societally and through the process of design. Learners explore the design process as a collaborative endeavor in which each person in the group presents his or her ideas in an open forum and describe how the design of a message is influenced by such factors as the intended audience, medium, purpose, and nature of the message. They include the recognition that values and interests of individuals, businesses, industries, and societies, as well as cultural priorities and values, drive new technologies.
2.2.6 Develop Fluency
As learners make more and more diverse projects, they develop comfort and competence with diverse tools, materials, and processes while developing craft. Math, science, and engineering standards support the understanding and selection of appropriate tools for a variety of tasks. The Common Core Mathematics Practices include the use of appropriate tools strategically. The PA Science & Engineering skills require explaining how different technologies involve different sets of processes, and the selection and safe use of appropriate tools, products and systems for specific tasks.

2.2.7 Simplify to Complexify
Lastly, as learners engage in making practices, they might connect and combine component elements to make new meaning. Previous and additional practices can contribute to this understanding, as makers use scientific and technological skills of understanding how invention and innovation, as well as individual processes, lead to changes in society and the creation of new needs and wants within a larger system.

2.3 Case Study of Bailey Tinkering
The video of Bailey building a car (see Figure 13.1) shows mathematical thinking, but also strong connections to science, engineering, and design standard. For example, tinkering includes testing boundaries and affordances of materials, similar to the scientific process and inquiry through the investigation of properties, materials, and systematically testing hypotheses.

FIGURE 13.1 Image of Bailey’s construction of a car using LEGOs and littleBits
In part, Bailey’s talk reveals tinkering practices. In the first few seconds of the video, Bailey plays with and manipulates the littleBits, swinging a cord in circles after noticing its affordance of being swingable. In this way, he explores the affordances and constraints of each littleBit piece. Bailey’s early questions mirror this exploration of affordances, starting with “Can I ...” and “How do you use ...” or “How do these connect?” (Identify and collect information about everyday problems that can be solved by technology and generate ideas and requirements for solving a problem).

When something doesn’t fit or work as intended, Bailey changes the littleBits and Legos position to identify the cause of the malfunction by testing and evaluating his current method or strategy. In this way, he shows persistence in making sense of problems (Sense of problems and persevere in solving them) and purposeful play. A focused session of tinkering happens between approximately 2:00 and 5:00, beginning with Bailey wondering “How do they connect?” He manipulates the littleBits before saying “How do they go together?” The testing and manipulating of physical pieces show the testing and revision of tinkering practices to accomplish a goal (Describe how troubleshooting as a problem-solving method may identify the cause of a malfunction in a technological system). Another instance of Bailey finding a solution can be seen near 6:00. He exclaims “Ah. I’m going to make these so my tires don’t come off!” (He puts white covers over the motor bit or tire piece, in an attempt to keep them from sliding off the peg where they are placed.) At 6:45, he says “Oh, I found one way!” The scientific thinking reflected through tinkering is a systematic assessment of a problem and attempt, and revision, of potential solutions.

During the second ten minutes of the video, Bailey does a lot of aesthetic tinkering, but also struggles with dexterity and getting things to snap together. He clearly knows what he wants to make as he picks blocks from the bin, but the intended design doesn’t become clear until later. He’s showing intention by picking specific pieces from the bin, comparing them against his design, measuring them against each other, and continuing to go back to add to the design.

The third ten minutes depicts the placement of the battery onto the top of his car built during the previous 10 minutes. He troubleshoots how it might fit, and how it might stay secure in the Lego structure, sitting on top of his car. At 20:00, Bailey puts the battery pack in the back of the Lego structure and pushes the structure across the floor as a test. He turns the car on, before (23:00) again seeing if the battery fits in the Lego structure. It falls out. He continues building, and tries to fit it on top of the car (Test and evaluate the solutions for a design problem). Around 24:35 Bailey places the battery on top of the car, again, but asks “Where are the rubber bands? Can I use rubber bands?” finding a potential solution (Explain how modeling, testing, evaluating,
and modifying are used to transform ideas into practical solutions). At 25:25, he quickly places two bands around the top of the car to hold the Lego structure to the littleBit structure, and sticks the battery in back. Saying “Hmmm,” he then (25:45) places two Legos on either side of the battery to secure it in its slot. They won’t snap in, so he takes them off and turns the car on (Make sense of problems and persevere in solving them). Bailey continues to question affordances of the design, asking (at 29:00) “Can it ride upside down like that?” At 29:29, Bailey asks “Where’d those wheels go?” and crawls quickly to another mat, saying “I need this.” At 29:34, he says “I know what to do! ... Ah ha!” as he rubber bands the battery to its own wheel so that it can roll behind the car independently (Explain how many inventions and innovations have evolved by using deliberate and methodical processes of tests and refinements).

In the final (fourth) ten minutes, Bailey turns on the car. When it won’t move, he says “I know what to do! If it won’t move, then put it on the top!” He continues with “If we put it on the top! It’ll work if we put it on the top! ‘Cause if you put it with this, it won’t move” In this way, Bailey makes predictions about what might happen as he troubleshoots a design problem (Describe how troubleshooting as a problem-solving method may identify the cause of a malfunction in a technological system).

3 Mapping Formal Practice Standards to Making Look-Fors

We utilized PK-12 process skills within the U.S. as the foundation of the framework and what to “look-for” in terms of youth’s STEM learning in making and tinkering contexts. More specifically, we used the following standards: (1) Science and Engineering Practices in the Next Generation Science Standards ([NGSS], NGSS Lead States, 2013); (2) International Society for Technology in Education [ISTE] standards for students (ISTE, 2015); (3) Standards for Mathematical Practice in the Common Core State Standards (CCSS, 2017); and (4) Computer Science Framework (Association for Computing Machinery [ACM] et al., 2016). We previously utilized science and engineering practices to measure youths’ engagement (Simpson et al., 2017a), but found the NGSS Science and Engineering practices to be limited for evaluating informal settings. The framework discussed here is broader in scope and provides educators, evaluators, and/or researchers ways to observe indicators of youth learning through practices common to professionals across STEM fields (NRC, 2012).

Although these standards-based documents frame learning of these practices within a formal setting (e.g., school classroom), we have found evidence of youth enacting these practices within an informal STEM-related
making and tinkering setting (Simpson et al., 2017a). Our findings highlight how these practices “looked” different in an informal setting. We also found instances of engagement not explicitly stated within the parameters of these standards-based documents, such as reactions to failure. We built upon our understanding from this study to create an interdisciplinary framework of 11 STEM practices (see Appendix B). While this framework was created with middle grade students in mind (aged 10–14), we contend that these practices are also appropriate for students across grades K-12 (ages 5–18). In the following, we continue with the Case of Bailey from Day 1 to Day 2, highlighting the practice Analyzing and Interpreting Data and illustrating its commonality to the making practice Tinkering.

3.1 Case Study of Bailey Analyzing and Interpreting Data

On Day 2, Bailey continues re-assembling his car as one of the wheels was not attached to the mounting board, or the base of the car (see Figure 13.2). As Bailey tests his design at 3:50, it was turning in a circle as opposed to moving straight. Bailey’s expresses his dissatisfaction by picking up the car to make a change to his design. In making this change, the wheels continually fell off the base of the car. Yet, Bailey persists through his frustration for about 4 minutes before presumably making an informed decision at 8:04 to remove the hubs (or small plastic lids with a man-made central hole) from the motor bit as the hubs were hindering Bailey’s ability to attach the bits to the mounting board. Bailey’s persistence continues until 10:15 when he asks for help from a facilitator. In this case, we contend that asking for help does not indicate helplessness or defeat, but a practice common to STEM professionals as Bailey tried multiple times prior to seeking assistance (Simpson & Maltese, 2017b). Bailey again tests his design at 11:15. The car moves along a straight path until one of the hubs fall off. In which case, Bailey makes an informed decision to add white covers to keep the hubs from falling off; an informed decision that dates back to Day 1 (i.e., uses prior experience). At 12:15, Bailey again tests his design and notes “Mine’s leaving us. It’s escaping.” His perseverance led to success.

Around 13:48, Bailey decides to add a littleBit that lights up – “Where’s lights? I need a button” (Planning Statement) – as he searches for the needed littleBits
(Selecting Appropriate Tools). In adding these two bits, the car falls apart, yet again. Although Bailey continues expressing his frustrations (e.g., I don’t like this. It won’t stay together.”), he persists in re-assembling the car. Moving forward in this case to 26:38, Bailey moves to the middle of the gym floor. He again tests his design; yet, the car turns in a circle. As he examines his design, Bailey notices he forgot a vital piece of the car, a littleBit that connects the two pairs of wheels on either side of the car together. At 30:47, Bailey seems to experience success in testing the design as the car moves in a straight path and he states, “Finally, going!” As the car continues moving straight ahead, Bailey sets a challenge for the car to continue its path and “go to the black circle” located in the middle of the gym floor. As the car begins turning left, Bailey stops the car making an adjustment that leads to the car turning in a circle. Becoming more and more frustrated – “It won’t do what I want it to do.” – Bailey adjusts the white covers as suggested by a facilitator. As Bailey tests this design change at 34:37, the wheels are spinning, but the car is not moving. Considering his design from the previous day, Bailey makes an informed decision to place the battery on top of the car (uses prior experiences). The car now moves in a circle. At 36:02, he and a facilitator again test the design with no changes made to this previous test. Bailey turns the car over (i.e., examines car) and notes “This one [is] going right. This one left.” He provides an explanation that one of the wheels is turning in an opposite direction than the other three wheels. The video ends with Bailey making an informed design change, namely flipping the switch on the motor bit to turn in the same direction as the others.

4 Discussion

Here we investigate a case of engineering a car using littleBits and Legos. Through these two case studies we contend that we address the question posed by Peppler and colleagues (2017), “How do we maintain the emergent, messy, whimsical, engaging process of making while adhering to standards and shared practices?” (p. 6). In each case of Bailey, we essentially discuss the same practices and processes from two varying perspectives – one through the making practices and the other through state-mandated practice standards. Hence in many places, we are saying the same thing, but using different language or vocabulary. For example, within the Tinkering practice, we observed Bailey testing and evaluating the solutions for a design problem (3.4.8.D1), which is worded in the formal practice standards framework as Analyzing and Interpreting Data. Arguably, we are reaching across the divide between formal and informal environments as youth are learning to become members of the STEM community through engaging in making and tinkering activities (e.g., Lave &
Wenger, 1991). The two frameworks presented here are speaking to and with one another as opposed to contradicting one another. Therefore, is the above question by Peppler and colleagues the wrong question to ask? Based on our observations of Bailey, we ask, how can we better articulate the learning inherent in making practices in ways that are translatable to the language of academic knowledge, standards, and paradigms? Additionally, how can educators and policy makers articulate standards to better capture the authentic making practices that we truly care about?

We can also consider our work in terms of understanding how the learning process through the language used by educators, learners, and practitioners supports student learning through making and tinkering. Atman, Kilgore, and McKenna (2008) looked at the importance of language in engineering education to understand the thought and design process of novice engineering students. They found differences in how students responded to choices on a Likert-scale survey versus open response. They interpreted findings as showing the importance of understanding the internal speech that student designers develop through engineering education and working to access and support that language during the learning process. Further, they described students’ abilities to express their knowledge of engineering design using appropriate language as limited.

In addition, while the case discussed in this chapter highlights making for fun, the principles of figuring out whether the car is functional, how it works, and whether it adheres to the initial intended vision, compare to professional engineering practices. The project has a functional purpose and completion of the project requires understanding how and why the design works (or doesn’t work). Bailey applies scientific and mathematical practices to practical purposes of design. Both making and engineering require the intertwined goals of functionality and design. The two frameworks also align with principals of the engineering design process (e.g., Tayal, 2013); however, the practices in our framework are not framed as a cycle or decision-making process because we contend that engagement in the practices in making activities are “messy” and playful (Simpson et al., 2017a).

5 Conclusion & Implications

We encourage others in the formal and informal worlds of making and tinkering with youths to build upon these frameworks as a means to develop and refine a shared language for making practices that is also applicable to academic standards. Although, there are overlaps between the two frameworks, there are also examples where one framework can inform the other as a practice may not be included or apparent. For example, the formal practice
standards framework includes Communicate/Present Information to encourage youths to showcase and articulate their process and final object through the making experience. As another instance, the Making Practices framework includes Simplify to Complexify to highlight youths’ understanding of materials and processes by connecting and combining component elements to make new meaning. Additionally, future research should utilize these frameworks to examine how youths are engaged as STEM professionals and participating in the communities of practice in STEM areas (Lave & Wenger, 1991). Utilizing these as lenses across making contexts will help establish a research-base for highlighting areas of strength and areas of improvement in terms of youths’ learning of practice skills inherent in the design process. It will also aid in understanding how the two frameworks speak to one another, as well as areas where they can build upon one another. We further contend that these frameworks will be useful for establishing and maintaining learning communities and video-clubs (e.g., Sherin, 2007) around maker education; as well as other communities that span the informal-formal divide. We also hope that these will be useful to educators who seek to communicate the value of their making, art, and design practices in a STEM-focused academic context.

Notes

1 littleBits are electronic building blocks that snap together with magnets. Each building block has a unique feature (e.g., sound, light, motion, and dimmers).

2 If you would like access to the videos discussed in this chapter, email the first author at asimpson@binghamton.edu

References


**Appendix A: Pennsylvania Core and Academic STEM Standards Most Aligned to CMP Practices of Making**

**INQUIRE**

Learners' openness and curious approach to the possibilities of the context through exploration and questioning of its material properties

**CC Mathematics Practices**
- Make sense of problems and persevere in solving them

**Science as Inquiry Practices**
- Analyze alternative explanations and understanding that science advances through legitimate skepticism
- Understand that scientific investigations may result in new ideas for study, new methods, or procedures for an investigation or new technologies to improve data collection
- Identify questions and concepts that guide scientific investigations
- Formulate and revise explanations and models using logic and evidence

**Science, Technology and Engineering (3.4)**
- Explain how the type of structure determines the way the parts are put together
- Explain how technology is closely linked to creativity, which has resulted in innovation and invention
- Identify and collect information about everyday problems that can be solved by technology and generate ideas and requirements for solving a problem
- Explore the design process as a collaborative endeavor in which each person in the group presents his or her ideas in an open forum
- Test and evaluate the solutions for a design problem
TINKER
Learners’ purposeful play, testing, risk taking, and evaluation of the properties of materials, tools, and processes

CC Mathematics Practices
– Make sense of problems and persevere in solving them
CC Mathematics (2.1)
– Analyze proportional relationships and use them to model and solve real-world and mathematical problems
Science, Technology and Engineering (3.4)
– Explain why some technological problems are best solved through experimentation
– Show how models are used to communicate and test design ideas and processes
– Describe how troubleshooting as a problem-solving method may identify the cause of a malfunction in a technological system
– Explain how many inventions and innovations have evolved by using deliberate and methodical processes of tests and refinements
– Explain how modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions
– Identify and collect information about everyday problems that can be solved by technology and generate ideas and requirements for solving a problem
– Test and evaluate the solutions for a design problem

SEEK AND SHARE RESOURCES
Learners’ identification, pursuit/recruitment, and sharing of expertise with others; includes collaboration and recognition of one’s own not-knowing and desire to learn

CC Mathematics Practices
– Construct viable arguments and critique the reasoning of others
Science, Technology and Engineering (3.4)
– Identify and collect information about everyday problems that can be solved by technology and generate ideas and requirements for solving a problem
– Explore the design process as a collaborative endeavor in which each person in the group presents his or her ideas in an open forum
HACK & REPURPOSE

Learners harnessing and salvaging of materials, tools and processes to modify, enhance, or create a new product or process; includes disassociating object property from familiar use

CC Mathematics Practices
- Make sense of problems and persevere in solving them
- Use appropriate tools strategically

Science, Technology and Engineering (3.4)
- Apply a design process to solve problems beyond the laboratory classroom
- Identify and collect information about everyday problems that can be solved by technology and generate ideas and requirements for solving a problem
- Select and safely use appropriate tools, products and systems for specific tasks
- Test and evaluate the solutions for a design problem
- Compare how a product, system, or environment developed for one setting may be applied to another setting

EXPRESS INTENTION

Learners' discovery, evolution, and refinement of personal identity and interest areas through determination of short- and long-term goals; includes learners' responsive choice, negotiation, and pursuit of goals alone and with others

Science, Technology and Engineering (3.4)
- Interpret/explain how societal and cultural priorities and values are reflected in technological devices
- Demonstrate how new technologies are developed based on people's needs, wants, values, and/or interests
- Explain how throughout history, new technologies have resulted from the demands, values, and interests of individuals, businesses, industries, and societies
- Explore the design process as a collaborative endeavor in which each person in the group presents his or her ideas in an open forum
- Describe how design is influenced by such factors as the intended audience, medium, purpose, and nature of the message
DEVELOP FLUENCY
Learners’ development of comfort and competence with diverse tools, materials, and processes; developing craft

CC Mathematics Practices
- Make sense of problems and persevere in solving them
- Use appropriate tools strategically

Science, Technology and Engineering (3.4)
- Recognize that requirements for a design include such factors as the desired elements and features of a product or system or the limits that are placed on the design
- Explain how different technologies involve different sets of processes
- Select and safely use appropriate tools, products and systems for specific tasks
- Analyze the development of technology based on affordability or urgency
- Explain how societal and cultural priorities and values are reflected in technological devices
- Test and evaluate the solutions for a design problem

SIMPLIFY TO COMPLEXIFY
Learners’ demonstration of understanding of materials and processes by connecting and combining component elements to make new meaning

Science, Technology and Engineering (3.4)
- Describe how systems thinking involves considering how every part relates to others
- Explain how knowledge from other fields of study (STEM) integrate to create new technologies
- Describe how economic, political, and cultural issues are influenced by the development and use of technology
- Describe how invention and innovation lead to changes in society and the creation of new needs and wants
- Use data collected to analyze and interpret trends in order to identify the positive or negative effects of a technology
- Compare how a product, system, or environment developed for one setting may be applied to another setting
- Explain how throughout history, new technologies have resulted from the demands, values, and interests of individuals, businesses, industries, and societies
- Describe how the design of the message is influenced by such factors as the intended audience, medium, purpose, and nature of the message
### Appendix B: Mapping Formal Practice Standards to Making & Tinkering Look-Fors

<table>
<thead>
<tr>
<th>Practice</th>
<th>Making &amp; tinkering look-fors</th>
<th>Standards alignment</th>
</tr>
</thead>
</table>
| Make Sense of Activity | – Explain the meaning of the activity  
|                      | – Decompose the problem and/or investigation into manageable sub-problems  
|                      | – Analyze and explain constraints, given, unknowns, goals of the activity  
|                      | – Explain how different approaches (including those of peers) may be utilized in carrying out solutions to the activity | Mathematics Practice 1  
|                      | CS Practice 3 |
| Ask Questions Define Problems | – Pose questions that require further (or new) investigation or research (e.g., How can I make my own solar eclipse glasses?); considered questions of high-cognitive demand  
|                      | – Develop/define a design problem that can be solved through the development of an object, tool, process or system  
|                      | – Identify an interdisciplinary, real-world problem that can be solved computationally  
|                      | – Pose questions that seek clarification of a model/prototype, an engineering problem, an explanation, and/or an argument (e.g., What do you mean? How does adding this part help solve the problem?) | NGSS Practice 1  
|                      | CS Practice 3 |
| Develop, Use Models, and Select Appropriate Tools | – Sketch/draw a model  
|                      | – Build a model/prototype  
|                      | – Practice technique before final design  
|                      | (e.g., practice a pop-up cut on a scrap sheet of paper)  
|                      | – Select appropriate tools for design solution and/or investigation (e.g., hot glue or tape) | NGSS Practice 2  
<p>|                      | Mathematics Practice 5 |</p>
<table>
<thead>
<tr>
<th>Practice</th>
<th>Making &amp; tinkering look-fors</th>
<th>Standards alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan Investigation</td>
<td>– Write down or verbally articulate sequence of steps for an investigation or design process</td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Write down or verbally articulate needed material and tools to carry out an investigation or design</td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Brainstorm plans and ideas aloud with peer(s)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Select and use digital tools to plan and manage a design process that considers design constraints and calculated risks.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Articulate goals/expectations in relation to the activity</td>
<td>NGSS Practice 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mathematics Practice 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Technology Practice 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CS Practice 5</td>
</tr>
<tr>
<td>Attend to Precision</td>
<td>– Use appropriate vocabulary and definitions in oral and/or written communication</td>
<td>Mathematical Practice 6</td>
</tr>
<tr>
<td></td>
<td>– Measure (e.g., length, weight) with precision</td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Label accurately when measuring, graphing, etc.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Express numerical answers with a degree of precision (e.g., rounding error)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Calculations are accurate</td>
<td></td>
</tr>
<tr>
<td>Document and Explain Activity</td>
<td>– Synthesize observational notes into an oral and/or written explanation or visual representation.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Utilize prior experiences and/or prior knowledge to construct and/or support explanation (must be explicit)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Explain design solution, including constraints and criteria, and/or decisions made throughout the design or activity.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Document failures and explain how failures led to changes in activity or design</td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Document process through photographs and/or video files</td>
<td></td>
</tr>
<tr>
<td>Practice</td>
<td>Making &amp; tinkering look-fors</td>
<td>Standards alignment</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Analyze and Interpret Data</td>
<td>- Construct a hypothesis or conjecture based on observations (e.g., I think the wheel is the problem because it keeps turning right instead of staying straight.)</td>
<td>NGSS Practice 4</td>
</tr>
<tr>
<td></td>
<td>- Use digital tools to analyze data/information</td>
<td>CS Practice 6</td>
</tr>
<tr>
<td></td>
<td>- “Testing” model/object/design (i.e., trials) and make changes to design based on “tests” (and can defend this change – informed decision making as opposed to uninformed decision making)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- State and/or write “becauses” in relation to “tests” (e.g. This did not work because ...”)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Examine object or device (e.g., turning over in hand while “studying” object)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Persevere in solving problem</td>
<td></td>
</tr>
<tr>
<td>Use Mathematics and Computational Thinking</td>
<td>- Develop visual representation(s) of observations or investigations (e.g., frequency chart, bar graph) to identify patterns</td>
<td>NGSS Practice 5 Mathematical Practice 4 Technology Practice 5 CS Practice 4</td>
</tr>
<tr>
<td></td>
<td>- Apply mathematical concepts and/or processes (prior knowledge) to solve problems and/or investigations (e.g., indirect measurement, estimation, number sense, proportional reasoning, spatial reasoning)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Intuitive precision (e.g., “You’ve just built this tower with four toilet paper rolls and a flat piece of cardboard. Is the cardboard on the top flat? Why not?”; Are the four columns even?)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Create algorithms that a computer can execute</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Recognize patterns and/or repeated sequences in data or code within problem and/or investigation</td>
<td></td>
</tr>
<tr>
<td>Practice</td>
<td>Making &amp; tinkering look-fors</td>
<td>Standards alignment</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------</td>
</tr>
</tbody>
</table>
| Engage in Constructive Feedback and Argumentation from Evidence | – Compare and critique at least two designs and analyze whether they meet the demands of the activity  
– Provide suggestions to peer(s) in how to improve and/or change design and/or investigation using relevant evidence  
– Use definitions and appropriate vocabulary to construct arguments and respond to the argument of others  
– Make conjectures, suggestions and/or use counterexamples to support, improve, refute and/or critique the argument and ideas of others  
– Defend how the mathematical results is warranted to reach goal(s) of activity | NGSS Practice 7  
Mathematical Practice 3  
CS Practice 2 |
| Obtain and Evaluate, and Communicate Information in a Responsible Manner | – Engage in positive, safe, legal, and ethical behavior when using technology, including online social interactions  
– Conduct research (e.g., books, google) to inform design, investigation, interest, curiosities, etc.  
– Plan and employ effective research strategies to locate information and other resources for their intellectual or creative pursuits.  
– Evaluate the accuracy, perspective, credibility and relevance of information, media, data or other resources. | NGSS Practice 8  
Technology Practice 2  
Technology Practice 3 |
| Communicate/ Present Information              | – Communicate/showcase final product, design solution, and/or investigation clearly (i.e., appropriate manner that audience can understand)  
– Explain the mathematical results within the context of the activity  
– Use technology to demonstrate their learning in a variety of ways (e.g., documentation, social media, portfolio)  
– Cites the work of online resources (e.g., images)  
– Creates original digital works  
– Repurpose or remix digital resources into a new creation | NGSS Practice 8  
Mathematical Practice 4  
Technology Practice 1  
Technology Practice 6  
CS Practice 7 |

Note: NGSS refers to Next Generation Science and Engineering Standards. CS refers to Computer Science Framework.