# Making Deeper Learners:
## A Tinkering Learning Dimensions Framework v 2.0

## Background

It's not hard to see that when kids are engaged in creative Making activities, they're enthusiastic, focused, and sometimes extraordinarily inventive. In STEM-rich Making, we see them actively grappling with the phenomena, concepts, and tools of science to design, build, and get their constructions working. This kind of active and self-directed learning is a powerful model for what we want to see young people doing in school; it represents what some people describe as "deeper learning" where ideas and concepts are learned in meaningful and applied contexts, and learning becomes both more resilient and transferable.[1]

But time is the big commodity in school. How does time spent on Making activities connect with and advance learning goals that schools and teachers have for students across the curriculum? What kinds of dispositions and capacities do students develop that can be applied in new contexts and even subject matter areas? If Making represents a form of "deeper learning" does Making also help young people become "deeper learners," and what does this mean in the classroom?

In 2015, educators from the Exploratorium Tinkering Studio and the Lighthouse Community Charter School in Oakland—both of which had been actively designing and studying Making and Tinkering programs in afterschool settings—decided to collaboratively explore how out-of-school time Maker programs could support learning that flowed into, and was valued by, the school day. We were interested in documenting the conceptual, dispositional, and social-emotional learning that teachers felt made students stronger.

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# A Research-Practice Partnership

To answer this question we formed a research-practice partnership (RPP) to design and study an afterschool tinkering program at the school. In RPPs, educators and researchers are equally involved in identifying the research question, making meaning of the data, and building capacity for ongoing improvement.[2] Over three semesters (2016-2017), we implemented and documented the afterschool Tinkering program, including tracing the learning trajectories of a number of participating middle school students, and later interviewing their classroom teachers.

Our mutual interest in how learning from Tinkering in afterschool time could flow into the school day, was undergirded by respective capacity-building goals for our staffs. Lighthouse sought to create a professional learning community for its afterschool program educators, whose work schedules conflicted with the school's professional development activities for classroom teachers. The Tinkering Studio sought the opportunity for its museum educators, who typically work with one-time drop-in visitors, to develop extended relationships with young people, and to design and support semester-long Tinkering units that could be adapted by others for use in their classroom or afterschool settings.

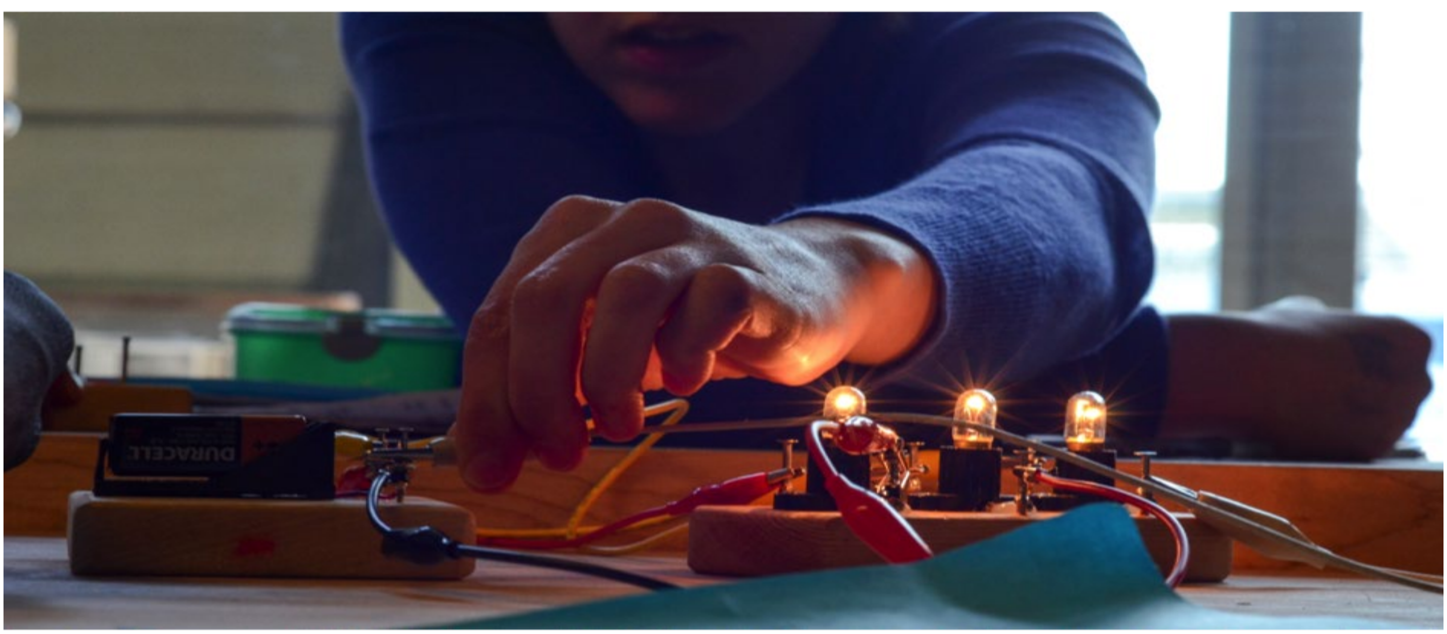
# Theory

Our study was underpinned by two related sociocultural theories of learning: cultural-historical and critical pedagogy.[3] This meant that we paid attention in particular to how young people were supported, by each other and by adults, to draw on their own experiences, ideas, and cultural resources to participate in and contribute to the Maker program community. In the process, we noted how they exercised and developed their agency—their ability to take action and to own their own learning—including their ability to learn from as well as teach one another.

# Data Collection

Tinkering Studio and Lighthouse staff co-designed three sequential semester-long Tinkering units: Circuits & Electricity, Motion & Mechanisms, and Light & Shadow. The program met weekly, typically for two hours each session.

Using participant observation methods, researchers documented the Lighthouse-Exploratorium Tinkering



afterschool program through observation field notes, videos, photos, audio recordings, student surveys, student journal entries, and interviews of students and adults. Additionally, when requested, researchers assisted four other Lighthouse educators in documenting their afterschool programs that similarly supported student creativity and agency but in subject areas such as robotics, music, and cooking.

Each month, following a model developed at Lighthouse for classroom teachers, we held (and documented) a 90-minute "inquiry group" meeting involving afterschool educators, program directors, and researchers from Lighthouse and the Tinkering Studio to:

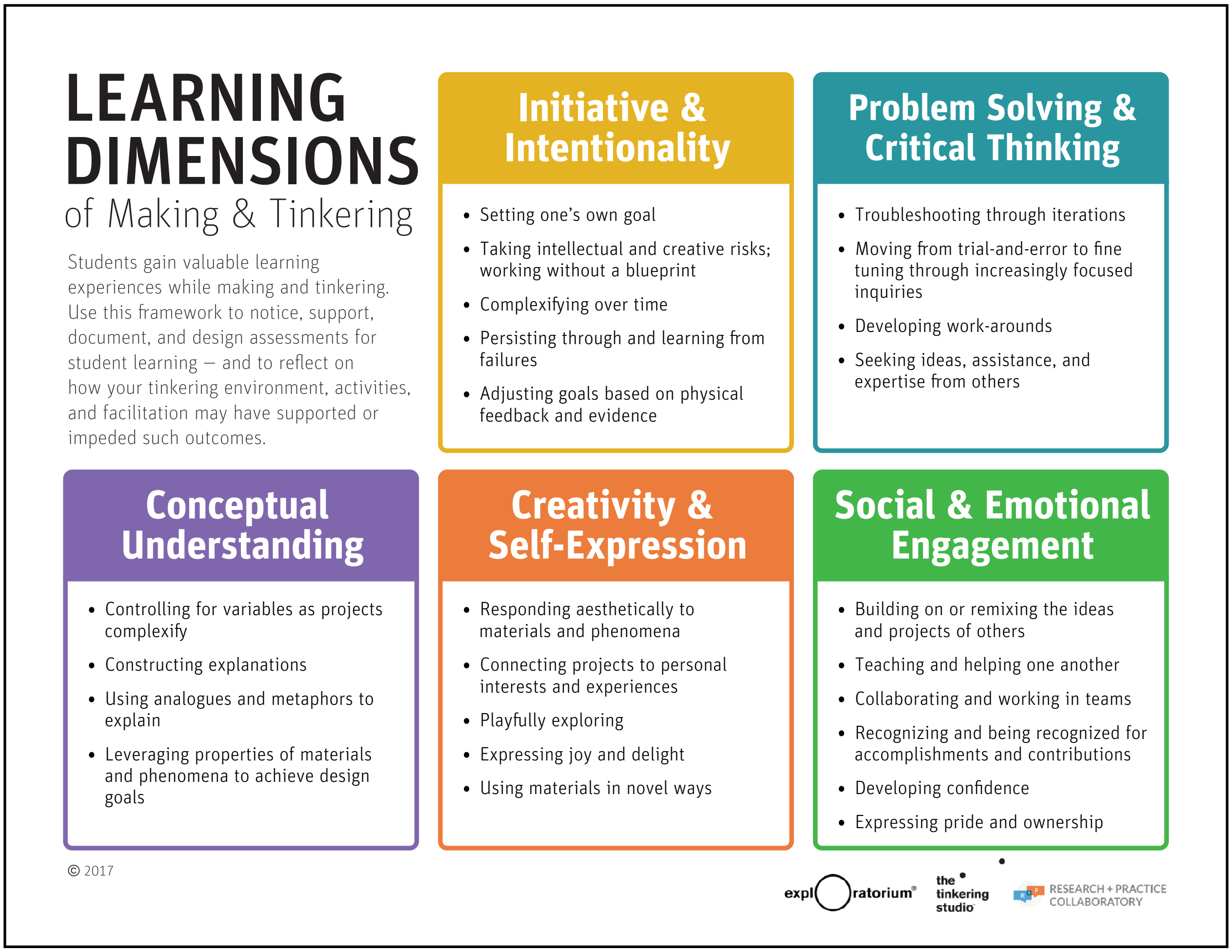
> *1. Review and discuss the emerging research data documenting young people's afterschool Maker work and learning trajectories.*
>
> *2. Reflect on the relationship between the afterschool educators' learning goals, their program design strategies, and the evidence they saw or were collecting of student learning outcomes.*

For this project, each semester, afterschool educators created poster presentations describing their program goals and learning outcomes, supporting their claims with different forms of evidence including student work, student journal entries, interviews, and observations of student activities. These posters were publicly displayed, and viewed by school leaders and staff as well as by educators from other Bay Area schools. Over time, our analysis found that evidence cited in the posters became both more robust—namely, that there was more of it—and more detailed. These reflective discussions and public presentations, along with interviews of students, classroom teachers, and the Tinkering Studio leaders informed the focus and development of the Tinkering Learning Dimensions Framework.

## Developing the Tinkering Learning Dimensions Framework 2.0

The Framework went through multiple iterations. An earlier published version was based on video data collected at the Exploratorium Tinkering Studio with one-time visitors.[4] It had highlighted four dimensions: Engagement, Initiative & Intentionality, Conceptual Understanding, and Social Scaffolding. The Framework version 1.0 was useful for recognizing (and supporting) what active and creative learning looked like during Tinkering—i.e., in the moment—but it was less useful for informing us about longer-term outcomes learners were developing through Tinkering; and especially what kinds of Tinkering learning outcomes and dispositions might be flowing into the school day. The data that informed the four dimensions in version 1.0 had some limitations, including that we did not know how the Tinkering experiences fit within the visitors' overarching learning trajectories—we couldn't see change or growth over time, or know what knowledge or resources learners brought with them to the experience we were documenting. Without prior (or continuing) knowledge about the learners, the team was hesitant to make claims about whether they saw evidence of developing creativity, understanding, or identity.

Through collaborative analysis of the data collected in the Lighthouse-Exploratorium RPP, over the three semesters, we developed several different versions of a new Framework. We debated issues such as whether persistence was an indicator of intentionality or social and emotional engagement (and we agreed that probably it is both—or that you rarely have one without the other; but we decided to focus the dimension of social and emotional engagement on issues related to belonging, and the dimension of initiative and intentionality on issues related to developing and pursuing an idea with purpose).




Ultimately we integrated the Lighthouse-Exploratorium Framework with the version 1.0 Tinkering Studio Framework (partly to avoid confusion among educators already using version 1.0). We elaborated existing and added new constructs and indicators that had emerged from our longitudinal data. Our more extended involvement with the participating young people had allowed us to document key dimensions such as their deepening understanding of and dexterity with scientific phenomena, the ways they drew on their existing interests and experiences to develop their project goals, and their development of confidence and ownership over their own learning, and how these developments were noticed and leveraged during the school day. These learning outcomes may have been fostered by the museum Tinkering experiences as well, but we had lacked the longitudinal data to make that claim.

## Learning Dimensions Framework Constructs

There are a couple of important caveats to keep in mind about the Learning Dimensions Framework. First, as the vignettes included in the Appendix to this document show, the dimensions do not develop linearly or hierarchically. Frequently multiple dimensions become intertwined during the process of tinkering; and this complexity is part of what makes Tinkering a rich learning experience. For example, as one develops an idea and intention, one becomes socio-emotionally invested in it, and will persist in problem-solving to realize one's goal. At the same time, in the course of trouble-shooting, ideas can shift, understanding can deepen, a sense of ownership and pride can increase. Second, many of the learning dimensions only became evident over time, through triangulation of the videos of students' tinkering, excerpts from student science journals, and interviews with students and/or their teachers. Third, and foundational to this work, is our finding that the dimensions do not "just happen" without careful attention paid to the nature of the Tinkering activities, environment, and pedagogy.

The purpose of the Framework is ultimately to guide the design and facilitation of Tinkering activities and environments that can produce these learning outcomes. For example: *Is this activity designed in ways that allow for "ongoing complexification," to allow for a variety of student ideas and intentions? Or is there really only one direction or end point possible?*

The Framework can also be used as a reflective tool to formatively assess student learning. For example: *Is there evidence that students are "refining and focusing their inquiries over time"?* Such evidence would indicate that students have a deepening conceptual grasp of the activity's key variables and the behaviors of the relevant phenomena.

In the next section we provide brief summaries of each of the dimensions.

## DIMENSION 1: Initiative & Intentionality

This dimension refers to the ways in which Tinkerers engage with the activity, develop their own ideas or goals, and pursue them. As such, Tinkerers demonstrate self-directed learning, purpose, and persistence.

> *Their [shark] models were unbelievable. … You know, Suyen was looking at a model but trying, retrying, balling up the clay again, redoing the fin. … And then the painting, you know, getting the right color paint, do the counter shading, 'So how am I going to represent the gills?' So anyhow, her shark is amazing, her seven-gill shark. It blew me away. And so I couldn't help but make the connection that Katrina and Suyen are both in this afterschool program class where they're learning about failure leads to success and trying something. And so I can't help but think like the reason their models were so amazing is because they were willing to take risks and then try it again. … The fact that she didn't give up and she kept persisting is very different about what I know about her from the past, having taught her last year. When things would get hard she'd give up. So I'm wondering how that's having an effect on her just persistence.*
> *— Middle School Math/Science Teacher A*

We have documented a number of indicators for the ways Tinkerers demonstrate initiative and intentionality:

- **Setting one's own goal**
- **Taking intellectual and creative risks by working without a blueprint**
- **Complexifying one's project over time**
- **Persisting through and learning from failures**
- **Adjusting and redirecting ideas/goals, based on physical feedback and evidence**

## DIMENSION 2: Problem Solving & Critical Thinking

When tinkering, a number of rich challenges and problems arise that force tinkerers to engage their critical thinking and problem-solving skills. Indeed, tinkering is defined in the research literature—and distinguished from more recipe-like making activities—as "playful and improvisational problem-solving."[5] But as critical thinking is developed, students' inquires become more focused and intentional, and less a matter of trial-and-error (which can be a good place to start, in the "playful" stages of the inquiry).

> *I can see the kids who are coming up from [Local] Elementary, which has a very rich making culture, are much more, not only skilled, but they're also much more willing to problem-solve. And they're ready to go.*
> *— Middle School Librarian*

Classroom teachers also noted that the ability to be a creative problem-solver and critical thinker are characteristics and skills highly desired in non-educational contexts where people live and work on a daily basis.

> *They're building skills that will help them academically in the future. And they'll just be successful in any school context. But actually, I guess even more importantly, those skills are important because they're important in life….specifically the persistence aspect of 'If I'm stuck, I try another way.' I feel like some of my students have built that, and some have totally not, and I just think with like the more complex problems that are given in common core context, that's really important. And that's like more relevant to life, because the problems you solve in life are never going to be like as cut and dry as the problems you usually see on math word problems.*
> *— Middle School Math/Science Teacher B*

Indicators of this learning dimension include:

- **Troubleshooting through iterations**
- **Moving from trial-and-error to fine tuning, through increasingly focused inquiries**
- **Developing work-arounds**
- **Seeking ideas, assistance, and expertise from others**

## DIMENSION 3: Conceptual Understanding

Tinkerers develop conceptual understanding by working with phenomena, concepts, and tools to achieve their ideas and goals. Learning STEM is the means to their creative ends. Through iterative design and redesign they can refine as well as make visible how they understand phenomena such as the relationships between symmetry and balance or slope and velocity. The applied, creative, and self-directed nature of their work supports deeper understanding.

> *Writing is hard for them. A lot of them are English learners. But after we did the Making projects, I feel like their focus paragraphs, where they had to write about it, was a lot clearer than other times they've written about something we just read about or talked about or watched a video about. … They were able to explain it more eloquently. That was really interesting. And I think it comes with understanding it better, and having to use that language. Because as you're making, you're constantly asking them to use the vocab and use the language and explain to their partners why they want to add this attachment, or take off this part.*
> *— Middle School Science Teacher A*

We have documented a number of indicators for the ways Tinkerers demonstrate their development of conceptual understanding, including:

- **Controlling for variables as projects complexify**
- **Constructing explanations**
- **Using analogues and metaphors to explain**
- **Leveraging physical properties of materials and phenomena to achieve design goals (STEM as a means, not an ends)**

## DIMENSION 4: Creativity & Self-Expression

Creativity sits at the heart of Tinkering. Developing an idea, one's own idea, and creatively working with materials and phenomena to realize it makes the experience deeply satisfying and personal. Unlike more recipe-like Making activities, Tinkering activities that don't come with blueprints tend to encourage and amplify students' creative ambitions that in turn create unintended constraints that can complicate and drive ongoing complexification and care in their work—requiring careful measurements, balancing, positioning, or finishing touches—which can lead to richer learning activities that can deepen understanding over time.

> *I think their individual nature of them having their own vision for their project – creates a certain amount of investment that pushes them to keep going, even when they're stuck. Versus if they're stuck on like a math worksheet, they're just automatically not as invested as like a project that they're really trying to execute in a specific way to achieve their own specific vision. So I think that creative aspect supports persistence in kind of a unique way. Whereas persistence in a traditional classroom: I feel like is harder to build in kids.*
> *— Middle School Math/Science Teacher B*

Tinkering also frequently involves "audiences" for the work—fellow Makers, the broader school community, or parents or friends for whom the objects are presented as gifts. This dimension of activity leads to great focus on craftsmanship, entailing mastery of materials, tools, and phenomena.

> *[In our book making project] we talked about how to make your illustrations more accurate. For example, one girl had her sharks walking. And so they were walking on their fins. And so during the feedback session we talked about how, well, sharks really don't walk on their fins, but how could you revise this to [make it] more scientifically accurate: That they're swimming to school, they're not walking to school.*
> *— Middle School Math/Science Teacher A*

Indicators that tinkerers are exercising and developing their creativity include:

- **Responding aesthetically to materials and phenomena**
- **Connecting projects to personal interests and experiences**
- **Playfully exploring**
- **Expressing joy and delight**
- **Using materials in novel ways**

## DIMENSION 5: Social & Emotional Engagement

A key dimension of learning in Tinkering involves recognizing, and being recognized for, one's accomplishments and contributions (ideas, skills, collaboration). Through their active participation in and leadership within a Tinkering community, students develop a sense of belonging, and build their identities as creative thinkers.

> *So I see, over the semester, they come with some trepidation about whether they can do these things and they'll just give it up if they can't do it. But then they see that it's fun and they want to keep going. And finally – I think they built some level of, "I can do," ... They all have their different stuff they bring and some*

*have more confidence than others. But generally I see it grow all around, to know they can do something if they stick with it. That's pretty important just for school in general.*
*— Middle School Engineering Teacher*

*There are so many chances for kids to become experts in something. And then somebody else needs to do it. So there's a super authentic: 'Hey, I can teach you this.' That's really built confidence. And I know Katrina a little bit. And she can be pretty quiet in class. So it's cool to see her step out of her shell a little bit … I've seen that progression in a lot of students through making.*
*— Middle School Math Teacher A*

We have documented a number of indicators for the ways Tinkerers demonstrate their social and emotional engagement within Tinkering communities, including:

- **Building on or re-mixing the ideas and projects of others**
- **Teaching one another and providing assistance**
- **Collaborating and working in teams**
- **Recognizing and being recognized for accomplishments and contributions**
- **Developing confidence**
- **Expressing pride and a sense of ownership**

## Conclusion

Making provides a context for students to develop, apply, and make visible their thinking and understanding. When Tinkering projects are designed to support students' pursuit of **their own ideas**, students become more committed to persisting to understand and realize their idea.

When activities are **designed with multiple entry-points and pathways**, and room for complexification, students are more likely to develop **an idea that they care about**.

When STEM phenomena and concepts are the "tools and materials" that students work with to realize their ideas, students **take up STEM with purpose and commitment**. This leads to deeper understanding.

The interplay between creative vision and STEM understanding is what has driven the enterprise of science and engineering as cultural practices. Tinkering can bring joy to this process, as students develop understanding, dispositions, and social skills that can support and deepen their sense of belonging and their capacities as learners.

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