EXPERIMENTING, EXPERIENCING, REFLECTING: COLLECTIVE CREATIVITY IN THE LIBRARY

Submitted in partial fulfilment for the degree of

PhD in Arts

Aarhus University

Aarhus, Denmark

by

Amos Blanton, MA EdS

supervisor

Dr. Andreas Roepstorff

co-supervisor

Dr. Peter Dalsgaard

2023 Rev. 1.01 15 August - Revised article ”Experiments towards a Pedagogy of Creativity and Learning in the Library”

Published by Aarhus University at Open Books
Date of publication: April 17 2026
Date of PhD defense: October 3 2023

ISBN: 978-87-7507-592-8
DOI: https://doi.org/10.7146/au.625

Citation for published version (APA):
Blanton, A. (2026). *Experimenting, Experiencing, Reflecting: Collective Creativity in the Library*. Aarhus University. https://doi.org/10.7146/au.625

Experimenting, Experiencing, Reflecting: Collective Creativity in the Library

This practice-based dissertation examines collective creativity from the perspective of a non-formal educator doing design-based research in the library. Building on theoretical foundations in Constructionism and Tinkering, the Reggio Emilia Approach, and Stuart Kauffman's theory of the adjacent possible, it describes new methods for creating conditions for the study of collective creativity in short-term, playful, open-ended, non-formal learning environments. Out of this process (and in collaboration with others) emerged *Playing with the Sun*, an open-ended construction kit and collection of tinkering activities designed to enable learners to build an intuitive sense of how different forms of sustainable energy work.

Eksperimentere, opleve, reflektere: Kollektiv kreativitet I biblioteket

Denne praksisbaserede afhandling undersøger kollektiv kreativitet set fra perspektivet af en uformel underviser, der laver designbaseretforskning på et bibliotek. Med udgangspunkt i et teoretiske grundlag inden for konstruktionisme og tinkering, Reggio Emilia pædagogikken og Stuart Kauffmans teori om det tilstødende mulige, beskriver afhandlingen nye metoder til at skabe betingelser for studiet af kollektiv kreativitet på kort sigt i legende, åbne, uformelle læringsmiljøer. Ud af denne proces (og i samarbejde med andre) opstod Playing with the Sun, et åbent byggesæt og en samling af tinkeringaktiviteter designet til at give eleverne mulighed for at opbygge en intuitiv fornemmelse af, hvordan forskellige former for bæredygtig energi fungerer.

Acknowledgements

People

Thanks to Ben Mardell for his enthusiasm, energy, and thoughtfulness and to Mark Moore for his creativity, brilliance, and generosity. I have been incredibly lucky to have such great thinking partners on this journey.

Thanks to my advisors: Andreas Roepstorff for patience, coaching, and for giving me the freedom to set my own constraints. Peter Dalsgaard for extensive feedback, coaching, and interesting and exciting discussions. Sidsel Bech-Petersen for thoughtful co-design, encouragement, and support.

And thanks to my collaborators in Aarhus Bibliotekerne: Jane Kunze for all the work she's done to make this work possible, and for her honesty and ability to be direct. Henrik Viking Hansen, Mathias Kær Helge, Matilda Kristina Ejgreen Tjellden and Sara Petrat-Melin for the creativity, energy, and patience they brought to our work together on Playing with the Sun. And thanks to Lisbeth Mærkedahl, Marie Pasgaard Ravn, Rasmus Ott, and Sofie Gad of the original Creative Learning Research Group for their thoughtful discussions and playful experimentation.

Thanks to the Carlsberg Foundation for their support through the Experimenting, Experiencing, Reflecting project. And thanks to Aarhus Public Libraries for supporting this research in many different ways. It is an honor to be even a small part of such a wonderful project to reinvent libraries.

Thanks to Ryan Jenkins of Wonderful Idea Co. and Sebastian Martin of the Tinkering Studio at the Exploratorium for doing residencies at Dokk1, and for being the inspiring and generous master tinkerers they are. Thanks to Ricarose Roque for advice, feedback, and hosting me for a wonderful residency in Boulder. Thanks to Liam Nilsen for his thoughtful design feedback and always brilliant facilitation. And thanks to Mike Petrich for his advice and feedback about Tinkering and reflection.

And thanks to those who contributed in many different ways: Andrew Sliwinski, Sarah Trahan, Joe Dumit, Lennart Björneborn, Klaus Thestrup, Karsten Olsen, Sophie Erlund, Maria Xanthoudaki, Robert Jensen, Joan Hart, and especially my wife Kara Lochridge.

And finally, thanks especially to my friends and collaborators from the community of constructionist practitioner researchers for letting me be a little part of their “Scenius”: Mitchel Resnick, Natalie Rusk, Jay Silver, Eric Rosenbaum, Sayamindu Dasgupta, Tiffany Tseng, Karen Brennan, Andrés Monroy-Hernández, Amon Millner, Celeste Moreno, Ronni Hayden, Karen Wilkinson, and Luigi Anzivino.

Projects (and their associated Scenius) to Thank

The solarengine elements in the Playing with the Sun construction kit, as well as the core design philosophy, was inspired by the open-source “Scenius” of the BEAM robotics community.

The Playing with the Sun website was adapted from an HTML template by HTML5Up. The resources site is made with MkDocs and hosted by Gitlab, as is the rest of the source code for the project. The circuit boards were made wtih KiCad. The articles and thesis were drafted in Markdown, and rendered with Pandoc. I used a Pleroma microblogging server running on a raspberry Pi computer with Yunohost as its operating system as a public design notebook for recording my design and research process, which was rendered into a static website with the help of Mastodon Archive.

Table of Contents

Experimenting, Experiencing, Reflecting: Collective Creativity in the Library **2**

Acknowledgements **3**

1 Introduction **10**

2 Practitioner Journey **17**
- 2.1 Teaching and Advising Unschoolers 17
- 2.2 Counseling and Family Therapy 18
- 2.3 Joining the Scratch Team at MIT 19
- 2.4 LEGO Foundation 23

3 Literature Review on Collective Creativity **26**
- 3.1 Research on Collective Creativity 26
  - 3.1.1 Quantitative Inquiries into Collective Creativity 27
  - 3.1.2 Collective Creativity in Business and Management 32
  - 3.1.3 Innovation Communities 35
  - 3.1.4 The Collective Creativity of Creative Improvisation 37
- 3.2 Discussion 43
  - 3.2.1 The Limitations of Current Research 43
  - 3.2.2 Applying the Adjacent Possible to an example from Von Hippel's Research 45

4 Theoretical Background and Methods **51**
- 4.1 Theoretical Foundations 56
  - 4.1.1 Constructionism and Tinkering 56
  - 4.1.2 The Reggio Emilia Approach and Reflective Documentation . 67
  - 4.1.3 The Adjacent Possible and the mapping of collective creativity 69
- 4.2 Theory in Practice: Design Based Research to Develop Contexts to support Collective Creativity 74
  - 4.2.1 Design Evolution at the Scale of the Project as a Whole . . . 77
  - 4.2.2 Methodology for the design of workshops and data collection . 78

5 Outcomes and Implications **81**

5.1 Track one: Practice-Based Research into Collective Creativity in the Library . . . 85

5.1.1 Challenges . . . 85

5.1.2 The Fundamental importance of Iteration . . . 91

5.1.3 Ways Forward . . . 91

5.2 Track Two: Methods, data, and theoretical contributions for the Study of Collective Creativity . . . 93

5.2.1 A New Method for Creating the Conditions for and Studying Collective Creativity . . . 93

5.2.2 Data gathered about collective creativity and implications . . . 95

5.2.3 Theoretical Contributions . . . 97

6 Conclusion **100**

7 References **103**

8 Article: Experiments towards a Pedagogy of Creativity and Learning in the Library **110**

8.1 Abstract . . . 110

8.2 Introduction . . . 110

8.2.1 Background . . . 114

8.3 Methodology . . . 114

8.4 Findings . . . 117

8.4.1 Case Study #1: Creative Confidence or "Handlemod" in Creative Activities . . . 118

8.4.2 Case Study #2: Learning from the Facilitation Strategies of Parents and Grandparents . . . 120

8.5 Analysis . . . 123

8.5.1 Reflecting on Documentation of learning experiences leads to new questions and new ideas. . . . 123

8.5.2 The Librarian educators observed already used a patchwork of ideas from various learning theories, but they rarely had space and time to reflect on them. . . . 124

8.5.3 Proposing theory in the form of explanations of Documentation requires a firm epistemic stance. 126
8.5.4 In the absence of a shared definition of quality in learning experiences, it's difficult to know where to begin. 128
8.6 Discussion 129
8.7 Conclusion 131
8.8 Acknowledgements 132
8.9 References 133

9 Article: A Short-term Ecology for the Having of Wonderful Ideas: Collective Creativity and Cross-Pollination 137
9.1 Design 139
9.2 Run 141
9.2.1 Cross-Rejection of Ideas 143
9.2.2 Theory for Creating a Short-Term Ecology of Wonderful Ideas 144
9.3 Learn 148
9.3.1 Mapping Collective Creativity 149
9.3.2 From Who-dunnit to Who-all dunnit 151
9.3.3 The Tralfamadorian Sex Hypothesis of Collective Creativity . 154
9.4 References 156

10 Article: Recursive Prompting: A Method for Collectively Exploring a Design Space 159
10.1 Abstract 159
10.2 Introduction 159
10.3 Background 160
10.3.1 Constructionism and Tinkering 160
10.3.2 The adjacent possible 161
10.3.3 Recursive Prompting as a Strong Concept 163
10.4 Methodology 164
10.5 Method of Recursive Prompting 164
10.5.1 Participant Experience Flow in Recursive Prompting Activities 165
10.6 Case Study: Recursive Prompting at the CES Conference 167
10.6.1 Findings from the case 169
10.7 Discussion 174

10.8 Conclusion and future work . . . 175
10.9 References . . . 176

11 Project: Playing with the Sun 179
11.1 Areas of Focus for Playing with the Sun . . . 183
11.1.1 Activity Design . . . 183
11.1.2 Construction Kit Design . . . 184
11.1.3 Pedagogy . . . 187
11.2 Published Elements of Playing with the Sun . . . 188
11.2.1 The Playing with the Sun Website . . . 189
11.2.2 The Playing with the Sun Resources Website . . . 189
11.2.3 Publicly Shared Source Code . . . 190
11.3 The Process of Designing the Construction Kit and Activities . . . 191
11.3.1 Early Drawing Machines Activities . . . 194
11.3.2 Human Power as an Alternative to Solar Energy . . . 200
11.3.3 A Construction Kit with the Potential to Support Different Activities . . . 202
11.3.4 A key pedagogical distinction: Goal vs. Prompt driven Learning activities . . . 206
11.3.5 Formulating the Activities and Maker Faire . . . 208
11.3.6 Residency on Documentation and NEXT Library 2023 . . . 210
11.3.7 Conclusion and Ways Forward . . . 211

12 Appendix 1: Berlin Playing with the Sun EER Workshop 213
12.1 Playing with the Sun, EER.info website . . . 213
12.1.1 Design . . . 214
12.1.2 Run . . . 216
12.1.3 Learn . . . 221
12.1.4 Acknowledgements . . . 224
12.1.5 References . . . 227

13 Appendix 2: Copenhagen Drawing with the Sun EER Workshop 228
13.1 Drawing with the Sun, EER.info website . . . 228
13.1.1 Design . . . 228
13.1.2 Run . . . 230

13.1.3 Learn 234

14 Appendix 3: Learning about Facilitating Creativity from Parents and Grandmothers 236

14.1 Learning about Facilitating Creativity…, Aarhus Bibliotekerne Website 238

1 Introduction

Collective Creativity has been studied in many different academic disciplines, from business and management (Catmull 2008; Parjanen 2012) to education (Tang et. al 2020; Vygotsky 1990), to literature and the sciences (Fischer & Vassen 2011; Monechi et. al. 2019), to psychology (Sawyer & DeZutter 2009). While definitions vary somewhat by discipline, there is general agreement that collective creativity refers to the emergence of innovative ideas from a group of individuals working together with a shared purpose. The most poetic definition comes from the musician Brian Eno (Frere-Jones 2014), who refers to it as "Scenius," the collective form of genius that emerges from a "scene" of creative people who share some interest (such as an art scene or music scene).

The existing research suggests that collective creativity is something that is important but difficult to design for. Ethnographic studies describe intrinsically motivated, skilled people who are essentially playing with ideas together. Out of these improvisational explorations emerge new ways of thinking that show demonstrable and often surprising value. But thus far, most attempts at creating brief experiments that elicit collective creativity do not preserve this intrinsic motivation to a large degree. It can be difficult to see the correspondence between laboratory experiments and the phenomena of collective creativity in the wild.

To my knowledge, collective creativity has never been studied through practice-based research in non-formal learning environments. There are advantages to be explored if we can learn how to engage non-formal educators in libraries and science museums as both researchers and practitioners. They have access to a steady stream of people to observe and experiment with. They can invite them to participate in collectively creative activities without resorting to extrinsic motivation, as long as the activities are genuinely engaging. This makes non-formal learning environments excellent contexts for experimenting with and iterating on different approaches to designing for collective creativity. If we can create activities that offer pedagogical value to the learner and elicit collective creativity, then we will have also created excellent circumstances for semi-naturalistic observation and research.

This PhD research aims to develop our understanding of collective creativity through the design, documentation, and analysis of hands-on tinkering workshops in non-formal learning environments like libraries. These kinds of learning environments have some characteristics that make them different from schools. Citizens come to them voluntarily, without coercion, for brief periods of time. Adults and children often visit together as a family. Non-formal learning institutions can offer drop-in activities, in which the learner can preview what's happening and join for as long as they wish to. Today, many libraries are interested in exploring new means of supporting social creativity and hands-on learning for citizens (Jochumsen et al., 2010). Dokk1 library in Aarhus, the primary location for much of this research as well as a co-sponsor, is one example.

Tinkering is an approach to playfully engaging with and learning about various phenomena through iterative, improvisational, and exploratory hands-on creative design (Bevan et. al. 2015). It is a further articulation of a learning theory first developed by Seymour Papert called constructionism (Papert 1982). The pedagogy of Tinkering was developed for non-formal learning environments like science centers, makerspaces, and libraries by the Tinkering Studio at the Exploratorium (Vossoughi & Bevan, 2014), which is itself a science center. The tinkering activities they have developed and shared emerged out of an iterative process of proposing, testing, and re-proposing activity designs based on observations of thousands of people interacting with them on the museum floor.

As a means of situating this research, I worked with library educators to reinterpret Tinkering in their local context as a means of laying a foundation for developing a pedagogy of creativity and learning native to the library. This collaboration was important for a variety of reasons. For one, my colleagues have cultural knowledge and sensitivity about Denmark and their local community that I do not. In my view, this is vital to the success of design based research on learning experiences because this kind of work is invariably subtle, challenging, and complex. For another, I have a sense that people creating the conditions for the study of collective creativity should "eat their own dog food" (Danish: "prøve på egen krop," which translates literally to "try it on your own body"). When possible, the process of designing for and researching collective creativity should employ collective creativity too.

The theory and methods applied here are borrowed from both constructionism and the Reggio Emilia approach, a pedagogy of early childhood creativity and learning developed by the children and teachers of Reggio Emilia, Italy (Giudici et al., 2008).

In this tradition, the educator is understood to be a practitioner-researcher. Their research has to do with understanding children's creativity and intelligence, and how to support their growth and development. The data of that research consists of Documentation, which Krechevsky et. al. (2013) defined as "The practice of observing, recording, interpreting and sharing through a variety of media the processes and products of learning in order to deepen and extend learning." Through collective reflection on Documentation of children's explorations, Reggio educators develop theory to explain their observations and guide their interventions. Their approach seemed to me to be the best answer to what Seymour Papert described as a need for "a methodology that will allow us to stay close to concrete situations." (Papert, 1993)

The first article of this PhD is about reinterpreting the Reggio Emilia approach to Documentation in the context of the library. The research question is: *How can we create the conditions for a dialog between theory and practice that can enable library educators to develop a pedagogy of creativity and learning for the library*? The article is titled *Experiments towards a Pedagogy of Creativity and Learning in the Library.*

In preparation for deeper inquiry into collective creativity in the library, I began by experimenting with methods for documenting and mapping the movement of ideas through groups of people engaging in collectively creative processes. This research was done as part of the the Experimenting, Experiencing, Reflecting research project (EER)[1], a collaboration between the Interacting Minds Centre at Aarhus University and Studio Olafur Eliasson supported by the Carlsberg Foundation. EER invites the public to participate in experiments designed to create new knowledge about perception, decision-making, action, notions of togetherness, collaboration, and the transmission of knowledge. Along with Aarhus Public Libraries, the EER project is a co-sponsor of this PhD research. The primary area of synthesis is in building our understanding of collaboration and transmission of knowledge in the context of collectively creative activities.

Throughout the project EER has remained true to its name. It values iterative encounters with phenomena that inspire reflection, which subsequently influences how the next experience is perceived. In this it is well aligned with the core argument for the pedagogical value of tinkering and playful, inquiry based learning. These kind

[1]See: https://eer.info

of reflective loops are present at all levels of the work, from the design-based research methods used to develop activities with library educators, to the experience of a child exploring what they can do with a solar panel and a motor. The use of documentation is intended to make these processes visible and amenable to study.

The second article, titled *A Short-term Ecology for the Having of Wonderful Ideas: Collective Creativity and Cross-Pollination*, explores the question of how to capture and describe the movement of ideas through collectively creative activities. It describes a tinkering workshop in which a third of the participants were assigned the role of "catalysts," documenters charged with enabling the cross-pollination of emergent ideas throughout the group as a whole. The research question is: *How can we catalyze the cross-pollination of ideas through group reflection in a tinkering activity, and is there evidence that this leads to the emergence of new ideas through collective creativity?* This led to a new method for documenting, analyzing, and mapping the movement of ideas through a group engaged in a tinkering activity.

The third and final article is titled *Recursive Prompting: A method for Collectively Exploring a Design Space*. It describes a work-in-progress method for the design and documentation of drop-in tinkering activities in non-formal learning environments. Recursive prompting is a means of scaffolding a design process such that new participants are encouraged to build on the insights and ideas of previous ones. The research question is: *Can the method of recursive prompting enable unspecified participants to contribute to an open-ended exploration of a design space that results in progressive growth in complexity, clustering around the emergence of valuable ideas, and novel applications?* The short answer is: *not yet.* But I argue that the concept holds promise for future exploration and development by practitioner researchers.

Seymour Papert once said "You can't think about thinking without thinking about thinking about something" (Papert, 2005). Collective creativity also needs a 'something,' in the form of a topic or subject area, in which the collective can be invited to be creative. In this research, that something is called *Playing with the Sun,* a project founded by myself and Ben Mardell of Harvard Project Zero.

Playing with the Sun seeks to create the conditions for children to develop an intuitive sense of how sustainable sources of energy work through playful tinkering. In this the initial phase of the project we offer early thoughts about pedagogy (written with

Ben Mardell), a small set of tinkering activities, and an open-source construction kit[2] designed to support learning through play in non-formal learning environments. The construction kit and activities were developed in collaboration with Mark Moore and the teknologiforståelse (technological literacy) team in Aarhus Public libraries.

The goal of *Playing with the Sun* is to develop a foundation for general, basic literacy about sustainable energy, not to produce the next generation of engineers. A second but equally important goal is to experiment with the design of learning experiences that support shared, collective inquiry and collective creativity. At time of writing, many people are content to wait while experts in universities and corporations try to solve the technical and design elements of the ongoing climate emergency. But to transform the way we live here and now, there is a need for more methods to invite local citizens to engage with the problem directly, perhaps along the lines of Eric Von Hippel's research into distributed and free innovation (Hippel, 2005).

The products of Playing with the Sun are described in the section of the same name, and offered as a *project* for consideration as part of this PhD dissertation (in addition to the three articles). The section includes links to the Playing with the Sun website, the resources website that contains information about the construction kit and activities, and the public source code repository. The project is published in this way in accordance with best practices used to share similar open-source constructionist educational initiatives. The section concludes with a description of the process used to develop the activities and construction kit so that other librarian educators can understand and potentially emulate it. Two appendices that contain documentation of Playing with the Sun workshops, one of which includes a link to a brief (7 minute) video, are included to aid review of the project, but appear seperately at the end of this document.

The chapters of the kappe or thesis introduction describe the core theoretical ideas and methods that inform and shape this research. It begins with a description of my journey as a practitioner in the fields of counseling psychology and education over the past two decades, and how different experiences informed and shaped my thinking about play, creativity, and collective creativity. It should clarify the subjective biases

[2]A construction kit in this context refers to a collection of materials designed to enable learning through open-ended, interest-driven creative projects. Pico Crickets, Little Bits, and LEGO Technic are all examples of highly developed and refined construction kits.

that shape the design and analysis used in this work. But it is also a means of making space for the experiences of a practitioner within a written, academic conversation, a domain in which practitioners do not always have a voice.

A literature review containing a summary of research on collective creativity selected on the basis of its potential to inform practice follows. It includes a discussion section in which I experiment with applying Kauffman's theory of the adjacent possible (Kauffman et al., 2018) to an example of collective creativity described in von Hippel's research on innovation communities (Hippel, 2005). The literature review is intended to serve as a starting point for framing the methods, applicable theory, and the research questions.

In the process of creating the literature review I noted a lack of suitable methods for creating the conditions for intrinsically motivated collective creativity that could be studied on a brief timescale. While the transactional analysis used by Sawyer and DeZutter is one means of capturing the interplay between participants that underpins the emergence of collective creativity (Sawyer & DeZutter, 2009), I could find no method of gathering evidence of the communication between different subgroups of a larger whole. These are areas where this research makes methodological contributions to the existing literature.

The chapter on Backgrounds and Methods describes the learning theories that shape the activities designed to invite collective creativity as part of this research, as well as the methods used for study and analysis. Constructionism, as articulated in the science-museum based Tinkering tradition, figures prominently, as does the Reggio Emilia approach to Documentation. Both of these have been developed by and for research practitioners, and Tinkering has been put in practice in non-formal learning environments like museums, libraries, and makerspaces around the world. Kauffman's adjacent possible is introduced and positioned as a means of framing the exploratory processes of tinkering in design.

The Outcomes and Implications chapter describes two different tracks that ran concurrently through the research process. The first track was the effort to establish foundational conditions for doing practice-based research into collective creativity in the library. The second involved experiments and research into collective creativity done as part of the Experimenting, Experiencing, Reflecting project. Out of this second track emerged new methods and new means of analyzing and rendering empirical data. Out of the first track we get a clearer understanding of the potential for this kind of design based research as well as challenges that must be overcome in order to do it better.

Why is collective creativity important today? I am old enough to remember when "21st century skills" meant programming computers and navigating layers of abstraction. Today, many of us are worried that 21st century skills might turn out to mean the ability to weld spikes to the front of your car, or negotiate with local warlords for the safety of your family. Whatever our uncertain future holds, collective creativity within localized groups of people has always been one of humanity's strongest plays. Perhaps shared, collectively creative design processes, built around libraries and based in local communities, could be a strong foundation for doing more of it.

2 Practitioner Journey

Abstract

This chapter summarizes the author's journey over the past 20 years working as a practitioner, and how these experiences inform this research. It begins by describing impressions about the relationship between agency and learning gained from working with unschooled teenagers. It goes on to describe the author's training and work as a family therapist, and how ideas from complexity science, cybernetics, and systems theory informed his practice. At the end it describes work designing and maintaining environments to support collective creativity in the Scratch Online community, and subsequent work designing open-ended playful learning experiences for LEGO.

2.1 Teaching and Advising Unschoolers

In the summer of 2002 at the age of 27 I worked as an advisor at Not Back to School Camp, a sleep-away camp for home schooled and unschooled teenagers led by Grace Llewellyn, author of the *Teenage Liberation Handbook*. The structure of Not Back to School Camp is simple: Each day a selection of campers and staff are scheduled to give hour long workshops on any topic that interests them. Workshop topics range from medieval history, a game of tag, to how to bake cookies. Those not giving workshops are free to attend whichever workshop sounds the most interesting to them.

As I was walking down to lunch after giving a workshop on converting Diesel engines to use vegetable oil as fuel, a teenager I'd met a few days earlier asked me to show him how to make oxygen with hydrogen peroxide and a potato. I had mentioned running this experiment as a science teacher in school, and every time he saw me afterwards his excitement and enthusiasm would flare up again. So I spent my lunch break searching for a potato and some hydrogen peroxide, and showing him the experiment. From his wide eyes and rapt attention, I could see he found the appearance of the oxygen and its effect on the candle flame fascinating, even thrilling. For him, it inspired a raft of new questions about chemistry. For me, the experience raised a host of new questions about pedagogy.

It struck me how different his and the other unschooled teenager's attitudes towards learning were when compared to the students I had been teaching science to the year before. Like most teenagers I encountered in schools, my students were, with a few exceptions, surly and uninterested in what I was teaching. There were times that I could succeed in penetrating their cultivated disinterest, often with hands-on experiments. But even when I managed to sneak some meaningful learning past their defenses, it was clear that we were still playing on different teams. I came to recognize that in school my role as a teacher was to try to make them excited about something which they had no interest in, to be a kind of "hype-man" for Science. "We Make Learning Fun!" proclaimed the banner in the Wal-Mart back-to-school section, the implication being that without some sort of sugar-coating, learning is fundamentally boring and unpleasant.

But at Not Back to School camp, teenagers were constantly inviting me to explore and play with ideas and to share what knowledge I had. Afterwards I began reading John Holt and other authors from the radical education movements of the 1960s and 1970s to try to understand why and how this dramatic difference came about. I came away with the impression that the student's agency, or the lack of it, mattered tremendously when it came to their engagement. Teenagers who would never stand for learning being pushed onto them could, given the right circumstances, happily pull their own learning process along by themselves. But the "cart" of their learning needed to be placed behind, and not before, the horse of their curiosity.

2.2 Counseling and Family Therapy

Several years later I completed a three year graduate program in counseling psychology. During my studies the ideas I found most inspiring and of most practical use as a counselor came from the existential and humanistic traditions. Both of these theories argued that the drive to self-actualization and personal growth are inherent within human beings (Rogers, 1995, and Yalom, 1980). The role of the psychotherapist is to create a relationship that facilitates that process of growth and healing in the client, often by addressing barriers to it. This matched very closely with what I had observed as an advisor and facilitator of learning experiences for self-directed learners: Their innate curiosity drove them to discover new knowledge. My role was to facilitate that process.

During the subsequent two years I spent as a family therapist working with disadvantaged families at risk of having children removed from parental custody, I noted how important the child's context - shaped in large part by the relationships between family members - was to their well being. It became clear that family dynamics could cause individual family members to manifest all sorts of symptoms and pathology, causing them to become what family therapists call the "identified patient" (Minuchin, 1974). The symptoms of the identified patient reflect the sickness within the family dynamic, which could be treated to address those symptoms. Treating the identified patient can help only inasmuch as it helps him or her to better manage the stress caused by the dysfunctional patterns in the family.

The systemic nature of so much of mental illness was never more apparent than when I brought young clients to consult with our resident play therapist. Given a sandbox, a few toys, and an open-ended prompt, the child would map out the destructive dynamics in the family and how their symptoms were a response to them. This seemed obvious to me and my colleagues. But the medical and legal systems arrayed around my clients were all geared towards seeing pathology as a property of the individual, a framing that often led to harmful and destructive interventions on their part.

After modest success with a few client families, I noted that group dynamics could manifest wellness in individuals as well as pathology. In fact, there seemed to be a collective drive towards health in families, similar to the drive towards wholeness I saw in my practice as an individual psychotherapist. My role was to try and address barriers to health, usually founded in past trauma, so that the family could establish a new and healthier dynamic that no longer needed to manifest an identified patient.

2.3 Joining the Scratch Team at MIT

In 2008 I moved from Virginia to the Boston area. After a random life-changing encounter with Jay Silver, then a graduate student in the Lifelong Kindergarten group at MIT Media Lab, I joined the Scratch Team as online community coordinator. From the outside, this looks like a surprising change in field. But it was made easier by the recognition of the alignment between the theoretical model I used as a family therapist and educator and the theory of learning behind the project. According to Constructionism, the drive to learn comes from the learner, just as humanistic and existential psychologists see the drive to wholeness and healing as coming from the client (Rogers 1995). Both are expressions of what Maturana & Varela (1980) called "autopoesis," the tendency of living organisms to both chemically and cognitively self-organize.

This recognition of a foundational similarity across disciplines is no coincidence: Seymour Papert's constructionism was often concerned with how to make powerful ideas from cybernetics and systems theory explorable by children (Martin, 1988). A quick look into his intellectual ancestry leads to Gregory Bateson. Bateson was one of the founders of cybernetics, which he defined as "a branch of mathematics dealing with problems of control, recursiveness, and information, [which] focuses on forms and the patterns that connect" ('Cybernetics', 2023). He's also acknowledged as one of the founders of family therapy. In many ways, family therapy is the application of cybernetics and "the patterns that connect" to the work of addressing pathology in family systems.

Part of what I had to offer that proved valuable as a member of the Scratch Team was an understanding of how group dynamics could shape interactions, even in text-mediated communications. Having had a few years of professional experience with programming and computer hardware after college, and many more as a tinkerer with open-source software, I could also speak the language of technology and software development. As the Scratch project grew I took responsibility for setting policy and managing both the team of moderators and the team of programmers developing the website for the 150,000 actively contributing users per month and the over 10 million projects uploaded. At the time, the Scratch website was the largest online programming community for children in the world (and I am told it still is).

When I first encountered Scratch in its early days, I noted how the members of the Scratch Team - then just a few graduate students and two staff members - played an active role in the online community by making and sharing projects and commenting constructively on other contributor's projects. This was an attempt to seed the new online community with similar values and practices as those already well established in the culture within the Lifelong Kindergarten group. Comments made by Scratch Team members were mostly positive, and when critical were always constructive.

As is still the case with all Scratch projects uploaded to the website, the source code is made available so that anyone can read, add to, or remix a Scratch project in order to add their own ideas. But soon the volume of new projects was such that the Scratch Team's contributions were dwarfed by the firehose of new content generated by children. They made new games, animations, stories, and simulations of all kinds that those of us on the Scratch Team never could have imagined. One sub-community repurposed the Scratch website gallery pages as spaces for complex and ever-evolving role-playing games that operated through the commenting system, complete with projects containing detailed images and descriptions of each new character. We were constantly surprised by the ways that children would adapt Scratch and the website to their own creative purposes.

The Scratch Team understood early on that the success of the Scratch community depended on maintaining a friendly and collegial environment to support the sharing, remixing, and evolution of Scratch projects. Uploading one's first effort at programming to a public website is emotionally risky, especially because the internet is not always kind to new creators. We invested a great deal of energy to ensure that the environment remained (mostly) collegial and respectful. One such intervention involved inviting active community members who exemplified the values we wished to see more of to take on special roles as representatives of the community (Roque et al., 2013). Others involved sharing projects to help younger community members learn to take community-wide ghost stories - which sometimes led to a kind of mass online hysteria - with a grain of salt.

As the Scratch community grew and matured, it became clear that most of the engagement and learning we witnessed was driven by smaller communities of interest that formed within the larger community. Each of these many sub-communities - from the "Platform Gamers" to the "Warrior Cat RPG players" - were continually exploring and innovating within their own sub-genre of Scratch projects. Some valued the complexity of code in a project, while others felt the aesthetics of the included images and animations were most important. Each sub-community functioned like a small evolutionary niche in the vast ocean of the Scratch website. A well-loved project within a niche raised the collective bar for its community members with new ideas, aesthetics, and programming techniques. And because all of the elements of the project were visible and available for remixing, it soon became a source of new, timely, and highly relevant knowledge for all members of the community to subsequently build on. One could witness their reflective conversations about their evolving definitions of quality just by reading the comments.

Around this time, my friends Jay Silver and Eric Rosenbaum, both graduate students in the Lifelong Kindergarten group, were in the process of developing a new constructionist learning tool called "MaKey MaKey." MaKey MaKey is a small device that makes it easy to turn almost anything - from a banana, to your friend's hand - into the equivalent of a key on your computer keyboard. When you touch something connected to MaKey MaKey, the computer sees it as a key press event and does whatever it would do if you pressed the same key on the keyboard. This makes it possible to play a synthesizer with keys made out of bananas, or play a video game using a play-doh based game controller. MaKey MaKey was launched on Kickstarter and quickly became the highest-backed ed-tech product in Kickstarter's history.

Jay and Eric were clearly the drivers of this project. But as I look back on the process of its creation, I notice how fundamentally similar it was to what I was seeing every day within healthy sub-communities on Scratch. A group of enthusiasts - in this case constructionist educators in the Lifelong Kindergarten Group - participate in an ongoing process of reflective conversation and iterative prototyping. Now and then new projects and prototypes would emerge and become part of the conversation, in turn catalyzing further reflection and learnings. Jay and Eric are both brilliant individuals, each in their own way. But they aren't as brilliant as the team of graduate students that surrounded and included them. The effect is much greater when one adds Mitch Resnick, Grace Llewellyn, Seymour Papert, John Holt, Edith Ackerman, John Dewey and the many other thinkers who inspired them into the mix. Jay and Eric made MaKey MaKey happen, but so did the community or "Scenius" that surrounded them.

In retrospect I can identify a few factors that seem necessary (but not necessarily sufficient) for these kinds of ongoing reflective conversations to result in innovations like Scratch and MaKey MaKey. The first was the collegial, thoughtful, and reflective tone set by Mitchel Resnick, Natalie Rusk, and the other members and staff of the Lifelong Kindergarten group. The second was the passion and interest in the topic shared by the entire team. The third was the abundance of materials and tools (including, crucially, open-source software) and the ability to use them for quick, dirty, and highly iterative prototyping. As in most research groups, there were plenty of high level abstract conversations to be had. But unlike most academic environments I've encountered before or since, what was valued most wasn't only the quality of your intellectual argument, but rather what you learned when you tried putting your ideas out into the world [3]. When designing constructionist toolkits like Scratch and MaKey MaKey, the evidence that counted most was what creative learners made with the tools, and how that reflected movement and growth in their understanding.

2.4 LEGO Foundation

In 2015 my family and I moved to Denmark so I could take a job in LEGO Foundation, where I began working on the design of learning through play activities in LEGO House. Over the course of a year our design team developed seven hands-on learning through play activities that formed the core of the visitor experience. Together with my colleague Tina Holm-Sørensen and integrating work from Bo Stjerne Thomsen, I co-authored Learning through Play in the LEGO House, a small handbook summarizing the main design principles and processes we utilized while designing the open-ended learning through play activities that remain at the core of the LEGO House experience.

Soon after LEGO House opened I founded the LEGO Idea Studio, a small design studio in the home of the original founder of LEGO that functioned as an exhibition for new technologies in play and learning as well as a space to develop and run new hands-on learning through play workshops with technology. During this time I co-led a research project on technology and play with former colleagues at the Lifelong Kindergarten Group and new colleagues from the Tinkering Studio at the Exploratorium science museum in San Francisco and the Reggio Children Foundation, in Reggio Emilia, Italy. I become the primary liaison to the Reggio Children Foundation, collaborating with them on the design of Scintillae, an Atelier devoted to exploring the intersections of play and technology as seen through the lens of the Reggio Emilia approach.

I became interested in the idea of reflective documentation, a core practice in the Reggio Emilia tradition. Documentation involves the curation of images, video, quotes,

[3] During the time I worked in the Media Lab, the unofficial slogan for success changed from "Demo or die" to "Deploy or die," reflecting a shift in emphasis from an already practical orientation to one that engaged even more directly with the world in all its complexity.

and other evidence gathered while working with children, the goal of which is to make children's learning visible. Reflection with other educators on Documentation of children's research is at the core of the Reggio approach. It is the evidence that teachers interpret together to improve and develop their practice, as well as their primary means of sharing their work with the rest of the world. It is also a means of advocating for the rights of children as independent thinkers, capable of guiding their own learning processes, when given the right support.

As a practitioner, Documentation seems like a strategy with the potential to change how people view learning for the better. As Kohn (Appleman & Thompson, 2002) and many others have argued, the strategies used for evaluation have a profound effect on teaching styles and on how we think about learning. Over the past several decades, the rise of standardized testing has helped shift the popular understanding of education towards what Sir Ken Robinson described as a "manufacturing" model (Robinson & Aronica, 2015). This "one size-fits-all" approach holds that children are more or less the same, so it follows that they can be taught or processed in the same ways. By demonstrating the rich and idiosyncratic nature of children's self-directed learning processes, Reggio's approach to Documentation contradicts the manufacturing model with concrete evidence of children's creativity and intelligence. I believe, as many others do, that Documentation has the potential to be a fulcrum with which to change how the world thinks about learning and education.

But as many former graduate students and employees of the Lifelong Kindergarten Group have experienced after leaving, I missed the shared purpose and community orientation of the LLK culture, and the encouragement and support for trying new things. While many of my colleagues at LEGO Foundation shared my passion for learning through play, I found it difficult to work with executive leadership that had no practical experience in education or play. I was unable to articulate my vision for developing collective creativity as a means for achieving our shared goal of reinventing learning in a way that the leadership at that time could understand.

Therafter I embarked on the research for this PhD, and my role changed from practitioner to practitioner-researcher. In the background section I will describe the various methodological choices I've made and the reasons behind them. Some are theoretical, some are based on my experience as a practitioner, and some are based in on ideas that emerged out of the conversation between the two. But first it is necessary to look at the literature on the subject of collective creativity and to examine critically some of the different methods that have been used to create new knowledge about it.

3 Literature Review on Collective Creativity

Abstract

This chapter contains a review of research on collective creativity viewed by the author as having the potential to be relevant and useful for practitioner researchers. It includes brief summaries of relevant quantitative research, as well as ethnographic research from the realms of business, music and drama improvisation, and innovation communities. The Discussion section applies Kauffman's concept of the adjacent possible to a documented example of collective creativity from Von Hippel's research into innovation communities.

3.1 Research on Collective Creativity

Bateson & Martin define creativity as "generating novel actions or ideas, particularly by recombining existing actions, ideas or thoughts in new ways or applying them in new situations" (2013). Collective creativity is defined in different ways depending on discipline and context, but for this research we will define it as the emergence of innovative ideas from a group of individuals working and communicating together towards a shared purpose. Utility, sometimes suggested as a necessary ingredient for work to be considered creative in creativity research, is viewed as a nice-to-have but not a requirement. Aesthetic creativity is on equal footing with practical innovation.

As a practitioner and designer of creative learning experiences, I evaluate research mainly on the basis of two factors. The first is the accuracy of fit to my experience of the phenomena under study. Do the words and concepts used in the research correspond in a meaningful way to what I have observed as a practitioner? The second is its applicability to real world practice - in this case, to designing or facilitating for collective creativity. Can I use these ideas in the design of collectively creative workshops to test their utility in the real world?

The research on collective creativity is not what one could characterize as extensive. This may reflect the challenges of generating useful knowledge about what is universally acknowledged as a highly complex phenomena. Even in individuals, creativity is difficult to measure with any rigor. When conceptualized as a product of collective effort, it becomes even more challenging to model and characterize. Each discipline makes its own compromises in attempting to create new knowledge about collective creativity.

My method was to search for relevant books and articles using the keywords “collective creativity” and “cooperative creativity” in the Royal Danish library and on the web. I selected results that appeared to have the most potential to be useful for practitioners interested in developing activities, communities, or environments that invite or cultivate collective creativity. While reading these articles and books I would follow up on references that also appeared to have potential utility for practitioners. Because no single discipline can convincingly claim to have definitive knowledge about the topic, and because of my preference for scholarship that could inform practice, I chose a broad selection of work from different disciplines.

3.1.1 Quantitative Inquiries into Collective Creativity

In *Efficient Team Structures in an Open-Ended Cooperative Creativity Experiment*, Monechi et al. (2019) designed an experiment that invited visitors to a public space to contribute to collective creations made out of LEGO bricks. They monitored the position of participants using RFID sensors placed around the base of the build area so that they could collect data on who was building where and next to whom.

The research makes several conclusions, notably: “faster growth of the artworks is more likely to occur when the working teams have specific topological features, namely an optimal balance between weak and strong ties in a preferably large group” (Monechi et al. 2019). Weak ties were said to be between people who spent a comparatively smaller length of time working at the same build station, while those who spent a larger proportion of their total build time were said to have strong ties. A large group simply indicates that a larger than average number of people were actively building at the station at the same time, which contributes to faster growth. Monechi et al. also conclude that “Finally, a high level of commitment, i.e., focusing on only one artwork, improves building efficiency” (2019). This means that the data showed an increase in the rate of growth of the constructions when participants spent their time working on only one building project rather than moving between them.

Cooperative creativity in this research refers to people working side by side on an open-ended LEGO build. There may or may not be communication or shared conceptualization happening between them, but this is not part of the data collected. In this area, this research differs from much of the qualitative research from other disciplines, which takes as given that for people to be creative together, some form of communication and sharing of information is fundamental to the process. If neither are present or monitored in the study conditions, it becomes challenging to say with certainty that they are analyzing the same phenomena, even if all parties use (mostly) the same words to describe it.

Another notable methodological concern is that "creativity" in this study is quantified by measuring the height of a LEGO build, with faster rates of growth described as indicating greater creativity than slower rates of growth. One could as well make the claim that one kind of fertilizer is more creative than another because it makes corn grow tall faster. It's difficult to see how the height of a Lego build could be used as a valid proxy for something as complex as creativity.

Rosenberg et. al.'s *Social Interaction Dynamics Modulates Collective Creativity* (2022) is a recent cognitive science paper that explores, quantitatively, how group dynamics affect dyads engaged in a creative task. The study invited participants to create low-resolution pixelated designs with a touchscreen interface, technically an open-ended task because the number of different possible configurations is approximately 36 thousand. [4] The prompt given to participants was to make shapes that are "interesting and beautiful." The authors then analyzed participant's interaction patterns and looked for correlations with participant's fluency (defined as the number of distinct saved designs) and originality (defined as designs that differ significantly from one another.)

Rosenberg et. al. utilize an experimental protocol from cognitive science called creative foraging (Hart et al., 2017), which the authors state "opens the way for automated high-resolution study of creative exploration." The protocol identifies two distinct modes of creative search. Exploration involves making shapes that are significantly different from one another. Exploitation happens when the subject comes upon what might be described as a 'genre' of shape - for instance, shapes that look

[4] This is not small, but neither is it particularly large compared to many other open-ended possibility spaces. For scale, we can compare it to the number of possible configurations of six 2x4 Lego bricks, which is 915,103,765 (*How Many Combinations Are Possible Using 6 LEGO Bricks?*, 2017).

vaguely like letters - and then creates a range of different possibilities within that genre (i.e. many letter-like shapes.)

This concept of exploration / exploitation is recognizable from my experience as an educator and practitioner designing open-ended creative activities. Tinkerers tend to begin by exploring different possibilities in what could be described as exploration. Once they settle on an idea (which often emerges from the early process of trying different things and seeing what sort of feedback the materials give them), they tend to shift towards the goal of developing that idea - which could be described as exploitation, or perhaps fine scale tinkering within a single theme or area of focus. If they hit an insurmountable roadblock, get bored, or get inspired by someone else's project, they may shift back into exploration mode to see what other self-imposed constraints might be interesting to work within.

The materials and structure of the activity offer varying levels of constraint that incentivize different levels of exploration or exploitation - a factor which does not seem to be considered in the above mentioned research. For example, an activity involving building marble runs offers more opportunities for exploration of different ramp designs as the marble makes its way down the run. In essence, the serialization of the movement of the marble down different sections of ramp enables widely divergent ramp designs for each leg of its journey. Thus the nature of the activity and the materials used make it easy to operate in what Hart et. al would likely characterize as "exploration."

But an activity that asks the participant to build drawing machines (or any other discrete object) forces the user to iterate and build from whatever state their drawing machine project is currently in. Exploitation of the current idea is thereby at least a little incentivized, because the costs of taking their build apart and starting over in a radically different exploration phase are significant. Of course, explorations of new project themes that result in fundamental transformations are still possible without requiring a full tear-down and rebuild. One can be building a caterpillar and suddenly realize that it might make a better spaceship. That jump could be characterized as a shift from exploitation to exploration that then quickly moves into a new area of exploitation.

Rosenberg et. al. conclude that social dynamics may have an effect on the ratio of exploration and exploitation (or scavenging, as they refer to it) in what they define as collectively creative activities. Dyads that take turns manipulating the screen and creating new designs seem to be more exploratory and have a wider variety of designs. While those which they define as "dominance" relationships, where one person operates the screen, seem to "scavenge" or "exploit" more within fewer categories or genres of designs. (The authors candidly admit that this pattern of one person inputting most designs may not be due to "dominance" of one member over another, and instead might simply be because it's more convenient to have one person operate the interface.)

Overall the authors of both quantitative studies, and indeed much of the work on collective creativity I have encountered in cognitive science and experimental psychology, seem to be engaged in a search for fundamental principles that can then be operationalized in mathematically predictable ways - an aspiration that is consistent with the values of their disciplines. They appear to operate on the belief that there are a few significant variables that, once identified and modeled using the correct mathematical formula, will enable both a deeper understanding of collective creativity and perhaps even the ability to influence or control it in rigorously quantifiable ways. Towards the end of finding and modeling these significant variables, methodologically this approach seems willing to simplify things with two assumptions. The first is that many of the potential variables excluded are essentially noise or otherwise irrelevant to the outcome. The second is that if there are multiple variables involved, that isolating and analyzing one or two will yield understanding that has utility and explanatory power in understanding the phenomena. Through the rigorous application of quantitative methods like these, they appear to believe that a model that mathematically proves its ability to predict outcomes in advance will emerge.

But there is no clear evidence that these assumptions are applicable to the realm of human psychology and learning. In *the Children's Machine*, Seymour Papert framed the argument against what he called Scientism this way (1993). Newton's laws of motion are an example of the utility and elegance of the quantitative approach in physics. They describe a small set of significant variables and a means of using them to quickly calculate future outcomes. Papert points out that there are no theories in the realm of psychology with comparable utility and predictive power.

"Although it has been the dream of many psychologists to possess a

> similar science of learning, so far nothing of the sort has been produced. I believe that this is because the idea of a"science" in this sense simply does not apply here, but even if I am wrong, while we are waiting for the Newton of education to be born, different modes of understanding are needed." (Papert, 1993)

Were Papert alive today, he might point out that this approach continues to absorb immense resources in spite of an ongoing crisis in the field which has shown that less than half of major studies in experimental psychology are replicable (OPEN SCIENCE COLLABORATION, 2015). Some argue that very little has changed in the 10 years since this replication crisis was first acknowledged (Ritchie, 2022).

It is possible that a formula that can successfully model collective creativity might someday be created. But there is a risk that it might be just as complex as the entire phenomena it attempts to model. According to Kauffman, only some algorithms in the theory of computation can be described as "compressible," which means that a shorter algorithm or set of formulae could predict the state of a system at any given point in time with a relatively simple calculation, as Newton's Laws of motion can (1995).

> The theory of computation is replete with deep theorems. Among the most beautiful are those showing that, in most cases by far, there exists no shorter means of predicting what an algorithm will do than to simply execute it, observing the succession of actions and states as they unfold. The algorithm itself is its own shortest description. It is, in the jargon of the field, incompressible (Kauffman 1995, p.22).

It is likely that any algorithm of sufficient complexity such that it could be used to model collective creativity would also be incompressible. If this framing of the problem is applicable to the study of highly complex interactions like collective creativity, it suggests that approaches seeking to reduce it down to a few significant variables that are mathematically predictable, replicable, and potentially additive may never result in a conceptualization that practitioners would be likely to describe as useful.

The methodologies used by Monechi et al. (2019) and Rosenberg et. al. (2022) prioritize reliability (achieving consistent, repeatable results) at the expense of concept validity (confidence that the experiment accurately reflects the phenomena under study). If the quality of sensitive dependence on initial conditions applies to collective creativity, as Sawyer (2012) argues it does. Then even when starting from a near-perfect measurement of the system's state at time 0, the only way to find out what it will do in the future is to wait and see how it develops. The reason is that even the smallest purturbations or measurement errors in complex processes like these are recursive, so as a result they build up over time and destroy the ability to make reliable predictions. This suggests that even under the best imaginable experimental circumstances, reliable predictability, at least in a strict sense, may be difficult and perhaps impossible to achieve.

3.1.2 Collective Creativity in Business and Management

Literature on collective creativity in the business world tends to look at how the conditions for collective creativity can be cultivated or designed for through various management practices, and to describe the benefits this can bring to organizations developing products that require creativity. Sometimes this begins with calling into question elements of prevailing views about creativity.

Catmull, one of the founders of the movie studio Pixar, points out that many film studio executives have a "misguided view of creativity that exaggerates the importance of the initial idea" (2008, p. 65), arguing that it is more productive to focus on designing communities and processes that support the development of creativity over time. Emphasis is placed on constructing "an environment that nurtures trusting and respectful relationships and unleashes everyone's creativity" (2008, p. 66) and a peer culture where "Everyone is fully invested in helping everyone else turn out the best work. They really do feel that it's all for one and one for all." (2008. p. 69) Notably absent is the idea of a linear curriculum or set of steps for developing collective creativity. Catmull's work instead favors designing an informal environment that supports communal interaction, even going so far as to suggest office layouts that increase the likelihood of serendipitous encounters. "Most buildings are designed for some functional purpose, but ours is structured to maximize inadvertent encounters.... It's hard to describe just how valuable the resulting chance encounters are." (2008)

Towards the goal of supporting an "all for one and one for all" culture, Catmull outlines the design of organizational and meeting structures used in Pixar. In daily review sessions colleagues give and get feedback on one another's work. He notes that "[O]nce people get over the embarrassment of showing work still in progress, they become more creative." Postmortems are held on the completion of all projects, successful or otherwise, in order to understand what contributed to success and what could be improved. Safety - in the sense of ensuring that colleagues feel it is safe to share ideas even if they are 'half-baked', or likely to fail or be discarded - is prioritized in group social interactions, and is one of 3 operating principles Catmull describes as key to the company's success.

Throughout Catmull's writing about Pixar, there is a strong emphasis on evaluating processes and social dynamics of teams. Standard management practices might turn to external evaluations in order to make decisions about whether to invest further in a project. Catmull offers this instead:

> "The development department's goal is to find individuals who will work effectively together. During this incubation stage, you can't judge teams by the material they're producing because it's so rough – there are many problems and open questions. But you can assess whether the teams' social dynamics are healthy and whether the teams are solving problems and making progress." (2008)

This emphasis on evaluating process and relationships over products, especially during the ideation stage, is a theme present throughout much of the descriptive literature on collective creativity. If there is a goose that lays the golden egg of collective creativity, it may be made out of the relationships between collaborators and the quality of their communication.

Many of the structures and interventions Catmull describes as key to Pixar's success are designed to support group reflection. Such an approach is positioned as the most effective means of working with the complex problem of creating a successful film that is meaningful, relevant, and entertaining.

Catmull's descriptions of Pixar's process are reminiscent of Donald Schön's characterization of why the complex processes of reflective practice described in his work are necessary even in an age that places so much value on a technical problem solving approach, which he calls technical rationality.

> "Technical Rationality depends on agreement about ends. When ends

> are fixed and clear, then the decision to act can present itself as an instrumental problem. But when ends are confused and conflicting, there is as yet no"problem" to solve. The approach of reflective practice is contrasted from that, and justified, by the complex and context rich nature of the work. Therefore a problem *needs to be posed before it can be solved*. This need is what differentiates the role of "technician" from reflective practitioner, as it is born from the inability to simply match abstractions to local manifestations - which simply doesn't work or leads to disaster." (Schön, 1983, emphasis mine)

The work of a Pixar development team is to figure out what problem or set of problems to pose that can then be solved through the iterative problem solving processes of producing the film. In this view, the posing of the right problem(s) is as or more important than merely problem solving. According to Catmull, the social dynamics of the team are the best indicator of the potential for future success as they iterate through the various extant problems and invent new ones to solve in the process.

In a review of literature on collective creativity from the business world, Parjanen (2012) points out that collective creativity tends to be undervalued in business organizations, in spite of the fact that most businesses require the creativity and expertise of many employees in order to be successful. Diversity in the composition of teams tends to increase the likelihood that they will be innovative (Johansson, 2004; Paulus, 2000 in Parjanen 2012). Citing the work of Hargadon & Beckhy (2006, in Parjanen 2012), Parjanen states :

> The locus of creativity in the interaction moves to the collective level when each individual's contributions not only give shape to the subsequent contributions of others but, just as importantly, give new meaning to others' past contributions." In other words, creative contributions do not consist only of new ideas or directions to explore that build on the work of others, but also of reinterpretations of existing knowledge which subsequently change the frame within which the work is happening.

It follows naturally that diversity and interdisciplinarity in teams are considered to be important pre-requisites for collective creativity. Creative reinterpretations of existing ideas are less likely when the group consists of people with identical backgrounds and viewpoints. Another way of describing reinterpretations of the sort Parjanen describes in the business world (at least at a broad scale) is the verb “pivot.” A pivot is when a business chooses to change the purpose of its product and refocus on a different goal / relationship to the market – a reinterpretation of goals and means writ large.

3.1.3 Innovation Communities

In Democratizing Innovation (2005), Eric von Hippel describes communities of practice whose collective experimentation has shaped the design of many objects and systems in our world. He provides numerous examples of innovations that have emerged from such groups, which he calls “innovation communities.”

> “I define “innovation communities” as meaning nodes consisting of individuals or firms interconnected by information transfer links which may involve face-to-face, electronic, or other communication. These can, but need not, exist within the boundaries of a membership group. They often do, but need not, incorporate the qualities of communities for participants, where “communities” is defined as meaning“networks of interpersonal ties that provide sociability, support, information, a sense of belonging, and social identity” (Wellman et al. 2002, p. 4)” (Hippel, 2005)

Participants in innovation communities tend to behave in a collaborative manner by assisting one another in developing, applying, evaluating, and distributing innovations (Hippel, 2005, p. 105). Von Hippel points out that a significant body of empirical evidence supports the idea that this kind of user innovation drives the development of many, if not most, industrial and consumer products (Hippel, 2005). This he attributes to the valuable contextual information that only end-users, at the last mile of the long process of product design, have access to. Being end-users, they can immediately perceive the short-comings or limitations of a product because they live in the ideal test environment for the product under development: the real world.

Yochai Benkler, a scholar known for his work on peer production in open-source software communities, summarizes von Hippel’s work this way.

> Over decades, von Hippel and others have shown that the diversity of challenges and requirements presented to users in the real world are too diverse to justify firms investing in solutions. As a result, users solve problems and innovate, and only after a class of uses and solutions is defined do firms enter to "productize" the solution, once its characteristics are reasonably well-defined. (Benkler, 2017)

This immersion in context sets innovation communities apart from design teams or think tanks whose work is not automatically situated in the same way. Rubrics like IDEO's Design Thinking (2015) emphasize the need to devote energy to gathering relevant context by seeking user feedback. In innovation communities, the gathering of user feedback happens effortlessly, because the designer and the end-user are in fact the same person, who is also part of a surrounding community of enthusiastic designer / end-user amalgams.

End-users in a design role have access to the rich context in all its messy glory, but may not always have the tools and skills to innovate. As technologies that enable rapid prototyping like 3D printing and laser cutting become cheaper and available to more and more people, the opportunity costs of innovation go down. This makes it much easier for end-users to make changes that may result in innovation (Hippel, 2005). While *Democratizing Innovation* does not mention libraries or library makerspaces specifically, these days one would be hard pressed to find a public space where citizens are more likely to encounter the resources and practices of rapid prototyping.

Von Hippel's work here has little to say about the pedagogical and environmental challenges of supporting user innovation. This is where educators in the Maker movement and libraries can make a contribution. As most librarians with 3D printers will tell you, it's not enough to place rapid prototyping technologies in the public spaces of libraries. Without pedagogical interventions and support to help people understand *how to use them, when to use them, and why to use them*, a 3D printer in a library will often sit unused, gathering dust.

In addition to tools that decrease the opportunity costs for rapid prototyping, von Hippel points out that free access to relevant information is important for innovation communities. Open source software, software for which the source code is made publicly available to anyone who wishes to see it, is an example of a category of tremendously successful products that are often built by and for user innovation communities. According to Github's Octoverse Study, 90% of companies use open source software, which also makes up the foundation for most of the web (*Octoverse 2022*). While some open source software projects are funded by companies with a vested interest in developing certain features, many projects are still driven entirely by users.

> "Open source software projects are object lessons that teach us that users can create, produce, diffuse, provide user field support for, update, and use complex products by and for themselves in the context of user innovation communities." (Hippel, 2005)

There are numerous benefits to the open-source approach to software development (Benkler, 2017). Not only does making the source code available to anyone who is interested remove barriers to entry for potential contributors, it also allows technically skilled users to identify potential causes of bugs or security problems as well as aspects of code that could use improvements. Public issue tracking attached to open-source software repositories makes it possible to synthesize relevant information from different users, and provide software developers with the necessary context to make better and quicker fixes and features.

3.1.4 The Collective Creativity of Creative Improvisation

In the discipline of psychology, Keith Sawyer and associates have done extensive work on collective creativity, sometimes under the name of "distributed creativity" (Sawyer & DeZutter, 2009) which is for our purposes close enough. Sawyer's work builds on the work of his mentor Mihaly Csikszentmihalyi, who suggested that creativity emerges from a system which includes both the individual and the disciplinary domain in which they are embedded, such as the body of knowledge built from prior work (Csikszentmihalyi, 1988, 1990; in Sawyer & DeZutter, 2009). Sawyer's work explores how creative output emerges from collective processes, focusing especially on improvisational theater and music where outcomes are unspecified at the start of the interaction.

In his book *Group Genius: The Creative Power of Collaboration* (2007), Sawyer describes numerous examples of creative ideas emerging from collective interactions across history. He argues that the work of "geniuses" the likes of Sigmund Freud, Auguste Renoir, and Albert Einstein are all manifestations of collective inquiry which then subsequently gets attributed (falsely or at least inaccurately) to said genius. He also cites numerous examples of technologies - the mountain bike being one example - that emerged not from the minds of individuals, but from groups pursuing shared interests over years. These interest groups form what could be described as an evolutionary environment that breeds innovation (speciation?) of new technologies. The proto-mountain biking enthusiasts created an evolutionary niche, and over years the bicycle evolved better brakes, stronger frames, and fatter tires in order to successfully inhabit that niche.

In their article *Distributed creativity: How collective creations emerge from collaboration*, Sawyer & DeZutter (2009) were particularly interested in what they call "Collaborative emergence" - a form of distributed creativity they describe as occurring in collaborative groups that are unscripted and relatively unconstrained, and from which unexpected creativity can result. Using video tape to document the performances of improvisational theater groups, they analyzed the interactions of participants to understand how new creative narratives emerged. They found that this kind of creative emergence was most likely in groups with the following four characteristics:

> • The activity has an unpredictable outcome, rather than a scripted, known endpoint; • There is moment-to-moment contingency: each person's action depends on the one just before; • The interactional effect of any given action can be changed by the subsequent actions of other participants; and • The process is collaborative, with each participant contributing equally. (Sawyer & DeZutter, 2009)

It is worth noting here that collective tinkering activities, such as those that are the focus of the better part of the research described in this PhD, also tend to share these qualities, at least at the scale of two tinkerers working together. Building a drawing machine using an iterative, tinkering approach is also improvisational in that the final outcome is not predetermined, but instead emerges from a playful, improvisational, design process. When tinkering happens in collaboration with other tinkerers, a similar type of contingency as that which is described by Sawyer and

DeZutter is likely to occur, provided that the environment supports collaborative social interaction and the participants are willing to communicate and share creative control.

In *Extending Sociocultural Theory to Group Creativity*, Sawyer suggests that collective creativity in improvisational groups can best be understood when situated in the paradigm of complexity theory.

> "A performing group is a complex dynamical system (Johnson, 2001; Kauffman, 1995), with many properties typically associated with such systems: sensitivity to initial conditions, rapidly expanding combinatorics as time progresses, and global behavior of the system that cannot be predicted even if the analyst has unlimited advance knowledge about the individual components." (2012)

This statement has important methodological repercussions. Sensitivity to initial conditions refers to what is more commonly known as the butterfly effect: the idea that even very small changes in a complex system, such as the flapping of a butterfly's wings, can have profound effects in the future, like a hurricane developing halfway across the world. The idea was created by the meteorologist Edward Lorenz (1963), who was working with computer algorithms that attempt to predict weather through recursive calculations. He noticed that even an infinitesimal change of the initial values in his simulation soon resulted in wildly different outcomes as the simulation developed over time. This is why weather is still so difficult to predict and model accurately beyond a limited time horizon, even to this day: it is non-linearly contingent upon a huge number of variables like pressure, moisture levels, and insolation, to name only a few.

Ward (2001) described the problem posed for prediction in complex systems by sensitive dependence.

> …any model that attempted to show what could happen would have to take in an impossible amount of detail. It would have to include large movements of air such as the jet stream, the trade winds, the Sirocco and Mistral, as well as the exhalations of everything that breathes, the draughts caused by slamming a door and eddies caused by butterflies flapping their wings (p. 73).

If we apply the idea of sensitive dependence to collectively creative group interactions, we can easily imagine at least as many factors as might effect the weather. Participants bring their own collections of knowledge, experience, interests, and personality traits into the room with them. Some may be hungry, some satisfied, others pre-occupied, bored, curious, etc. In short, any collectively creative interaction with a random group of people has the potential to be influenced by and contingent upon the entirety of human experience available to each participant.

This high level of contingency suggests that it may be difficult or impossible to create laboratory conditions for the study of collective creativity that would consistently yield the same *specific* or exact outcomes, even given mostly the same inputs. Because if a slight difference at the 10th decimal place in any one of the qualities involved can quickly lead to dramatic differences as time passes, there is no way to isolate a few causal factors from the noise. It is possible that sensitive dependence on initial conditions is the reason why so many experimental studies in psychology fail to replicate, leading to the ongoing replication crisis.

This argues against trying to run a strictly controlled laboratory experiment using an open-ended construction kit, because there is no way to get precisely the same creative output twice. The same would apply to any open-ended construction kit, such as a collection of Lego bricks. If, as Sawyer argues, collectively creative interactions do indeed have the quality of sensitive dependence on initial conditions, then we cannot expect precisely the same results twice under any circumstances, regardless of how accurately we select and evaluate study participants or control the environment beforehand. How then is it possible to study this phenomena if it cannot be strictly controlled? What meaning can we make from results that are not strictly repeatable, and could never be used to validate a hypothesis in the natural sciences?

Sawyer and his collaborator's strategy is to use methods like interaction analysis of video documentation to examine the unfolding of collectively creative processes at a fine timescale.

> "Group phenomena are unpredictable before they occur, and they can only be explained by analyzing the temporal unfolding processes of emergence, using methodologies designed to analyze communicative interaction." (Sawyer, 2012)

Emergence is another concept from the realm of complexity theory. It refers to the creation of something new or “greater than the sum of its parts” that is unpredictable, even given complete knowledge of the world prior to its existence (Sawyer, 2012). New narratives or themes in improvisational music or comedy are emergent phenomena, in that they are not planned or predictable in advance of the circumstances that lead to their emergence. And yet the emergence of a theme may shape and influence subsequent interaction. In this way the emergent phenomena is both an *effect* of the group interaction and a *cause* of what happens in subsequent moments. In other words, it is recursive. Whatever emerges through the group begins to shape and influence what the constituent individuals do next. According to Sawyer, emergent themes must influence what is happening next if the improvisational group is to be successful.

This only increases the already daunting methodological challenges of studying collective creativity, because now each actor is in dialog not only with one another but also with (and through) the emergent theme. Therefore the researcher must employ a methodology that attempts to understand what is happening at both the level of the individual and the level of the group, since each are sensitive to and influence the other. Sawyer’s suggestion about how to handle this is as follows:

> “first, by analyzing the individual mental processes that lead to each participant’s creative contributions; second, by analyzing the interactional dynamics of how these successive contributions result in the emergence, over time, of a collaboratively created outcome; third, how individual actions and emergent group creations interact over time.” (Sawyer, 2012)

Since each is contingent upon the other, this makes for a highly complex analysis.

Sawyer believes that innovation and creativity emerge from iterative group processes over time. In the popular model of the individual genius, any communication or reflection key to the process of innovation happens inside the head of the genius, and communication is therefore unnecessary (except to announce conclusions). Mitch Resnick points out that for many people, Rodin’s *The Thinker* exemplifies this idea.

> Throughout history, thinking and learning have too often been framed as activities done by individuals, on their own. When people think about thinking, they often think of Rodin’s famous sculpture The Thinker,

> which shows a lone individual, sitting by himself, in deep contemplation. Of course, some thinking happens that way, but most doesn't. Most of the time, thinking is integrated with doing: We think in the context of interacting with things, playing with things, creating things. And most thinking is done in connection with other people: We share ideas, get reactions from other people, build upon one another's ideas. (Resnick, 2017)

According to both Sawyer and Resnick, genius is often the product of more than one mind. This introduces the necessity of understanding communication that happens between minds. Thus Sawyer's seven key characteristics of effective creative teams include: "Successful Collaborative Teams Practice Deep Listening," and "Team members Build on Their Collaborator's Ideas." (Sawyer, 2007). His research suggests that not only is communication crucial to collectively creative processes, but that the quality and intensity of that communication is also important. In order to be successful, improvisational actors need to listen carefully to one another while simultaneously developing their own ideas, which they must be willing to discard if they no longer complement the emerging group theme.

Sawyer also notes that the design of activities and contexts that invite improvisation requires the finding of what we might call "sweet spots" on the spectrum between structure and freedom.

> "The key to improvised innovation is managing a paradox: establishing a goal that provides a focus for the team – just enough of one so that team members can tell when they move closer to a solution – but that's also open-ended enough for problem-finding creativity to emerge." (Sawyer, 2007)

(Note that the idea of 'problem-finding creativity' bears a strong resemblance to what Schön describes as 'problem posing' in the previous quote from *The Reflective Practitioner*.)

Later on in *Group Genius*, Sawyer touches upon the issue again. "The key question facing groups that have to innovate is finding just the right amount of structure to support improvisation, but not so much structure that it smothers creativity" (2007). He cites research suggesting that constraints play an important role in supporting creativity. While most people might assume that the removal of constraints opens up more possibilities, he points to evidence that the opposite is true. Effectively Sawyer believes that freedom and constraint must be in balance in activities that support collective creativity. Too much constraint or structure stifles, while too little fails to maintain the collective focus that supports the emergence of new ideas.

This is a dynamic I have written about in my own work as a designer of open-ended improvisational tinkering activities (Blanton, 2019). Unless a participant has an unusually high degree of creative confidence (as some artists tend to), offering them an unconstrained blank canvas on which to be creative is not a good idea. Most people will feel nervous and intimidated, and unsure of how or where to begin. In working with educators interested in learning about creative learning activities, I often describe this as a state of being "under-constrained." On the opposite end of the spectrum, giving a participant a step-by-step set of instructions to follow in which there is little to no opportunity for following their own interests is unlikely to be engaging or memorable as a learning experience. I would describe this as being "over-constrained," which often happens when a rigid agenda is set by an external authority or curriculum. A core aspect of the design of tinkering activities is finding the right level and means of offering constraints so that the learner feels supported and knows how to begin, even if we intend for all of us, including the educators involved, to be surprised at where they end up.

3.2 Discussion

3.2.1 The Limitations of Current Research

Both Von Hippel and Sawyer's research attempts to grapple with the complexity of collective creativity by employing qualitative methodologies that engage with the phenomena in all its multivariate richness. Their work tends to focus on description rather than prediction, and thus reliability is difficult to measure or quantify. As such they can be accused of making statements about collective creativity that are difficult to falsify, experimentally or otherwise. The usual imprecisions and potential for misinterpretation that come with operating primarily in written language (as opposed to mathematics) also apply here. Where quantitative methods of describing collective creativity prioritize reliability over concept validity, here the tradeoff appears to be the opposite.

But the prioritization of reliability in quantitative experimental methods seems to carry a risk that the experiments become so far removed from documented real-world examples of collective creativity that they become unrecognizable by practitioners. In other words, they have questionable concept validity.

In addition to the epistemic challenges highlighted by ideas from complexity science discussed earlier, there is also a risk that quantitative work in the field draws conclusions that, even if correct, seem trivial, something which Dumit (2014) pointed out about research in neuroscience. He quotes the famous cognitive scientist Allan Newell describing the limitations of reductionist epistemologies:

> Every time we find a new phenomenon…we produce a flurry of experiments to investigate it…and the combinational variations flow from our experimental laboratories. Yet by only varying issues and binaries, matters simply become muddier and muddier as we go down through time. Thus, far from providing the rungs of a ladder by which psychology gradually climbs to clarity, this form of conceptual structure leads rather to an ever increasing pile of issues, which we weary of or become diverted from, but never really settle. (Newell, 1973, in Dumit 2014).

The limitations of the literature suggest that we are still in the early stages of developing our understanding of collective creativity. What is needed are methods for gathering data that have clear concept validity first, and some sense of reliability at the level of observable patterns (at least in the aggregate, over many iterations). Establishing new methods for doing practitioner research on collective creativity is one way to address this need. Ideally, such a method would have a relatively low cost, low complexity design that could be used in many different settings with many different people. It should allow for frequent, ongoing observations of diverse groups of intrinsically motivated people being creative together. This would make it possible to form a picture of the general character of the internal processes of collective creativity.

3.2.2 Applying the Adjacent Possible to an example from Von Hippel's Research

"The adjacent possible consists of all those things (depending on the context, these could be ideas, molecules, genomes, technological products, etc.) that are one step away from what actually exists, and hence can arise from incremental modifications and recombinations of existing material." (Tria et al., 2015)

The adjacent possible is a theory for understanding the exploration of a space of possibilities which the biologist Stuart Kauffman first proposed as an explanation for speciation in the fossil record (2014). Simply put, the adjacent possible is what's next door to whatever state something is in right now. Before the Post-It note existed, it was an adjacent possible of the plain paper note taped to a wall. Once invented, the Post-It note became an "actual" from which new adjacent possibles could emerge in various realms, everything from making fish scales in craft activities to a tool for organizing and reorganizing collections of thoughts in design meetings.

Each time an adjacent possible transitions into an "actual," it changes the space of possibilities not only for itself, but also for the entire system of which it is a part. As a result, each movement into an adjacent possible is not only a potential optimization within the current context, but also has the potential to define a new evolutionary niche from which new adjacent possibles can emerge. Kauffman (2014) provides an example from the fossil record that describes the evolution of the swim bladder, which allows fish to maintain neutral buoyancy at different heights within the water column. Thought to have evolved from the primitive lungs of a lungfish, the evolution of the swim bladder made possible a new ecological niche in the oceans which thousands of species soon evolved to fit into.

The theory of the adjacent possible provides a useful lens with which to view existing research on collective creativity. For example, in Democratizing Innovation (2005), Von Hippel quotes Shah's interview with Larry Stanley about the development of high performance wind surfing boards.

> In 1978 Jürgen Honscheid came over from West Germany for the first Hawaiian World Cup and discovered jumping, which was new to him, although Mike Horgan and I were jumping in 1974 and 1975. There was a new enthusiasm for jumping and we were all trying to outdo each other

> by jumping higher and higher. The problem was that . . . the riders flew off in mid-air because there was no way to keep the board with you—and as a result you hurt your feet, your legs, and the board.
>
> Then I remembered the "Chip," a small experimental board we had built with footstraps, and thought "it's dumb not to use this for jumping." That's when I first started jumping with footstraps and discovering controlled flight. I could go so much faster than I ever thought and when you hit a wave it was like a motorcycle rider hitting a ramp; you just flew into the air. All of a sudden not only could you fly into the air, but you could land the thing, and not only that, but you could change direction in the air!
>
> The whole sport of high-performance windsurfing really started from that. As soon as I did it, there were about ten of us who sailed all the time together and within one or two days there were various boards out there that had footstraps of various kinds on them, and we were all going fast and jumping waves and stuff. It just kind of snowballed from there. (Shah 2000, in Hippel, 2005)

This story illustrates Eno's concept of "Scenius" (Frere-Jones, 2014) in that it describes how a technological innovation grew out of a collective exploration of new possibilities in the nascent wind surfing "scene" or community of practice. In light of ideas related to the study of collective creativity touched upon earlier, including the idea of the adjacent possible, we can interpret the story as follows.

1. A visiting member of the same community of practice discovers a local activity that's new to them and becomes enthusiastic about it. Their enthusiasm reinfects the group from which the idea originally came.

It's noteworthy here that the visitor's enthusiasm plays a vital role in this story even though it has no direct bearing on the physical design changes that later emerge. Apparently all Jürgen Honscheid does is get excited about jumping. But that excitement is contagious within the community of practice, and therefore vital to the process that follows.

2. Excitement about / engagement with the new practice foregrounds a problem.

We can infer that the problem, jumping tends to result in falling off the board, was present for years before the visitor came. But no one was engaging with that problem until the renewed enthusiasm for jumping within the community highlights it and brings it into people's conscious awareness. This initiates a search of adjacent possibles in the relevant design space.

3. There is an adjacent possible with low opportunity cost that might solve the problem.

Stanley, the narrator, who evidently had been tinkering with new board designs for some time, has a leftover board from a previous design experiment lying around that turns out to be relevant and easily testable. As is often the case with tinkerers, the presence of old prototypes and spare materials with low opportunity costs allows them to quickly bricolage an "adjacent possible" to try to solve newly-posed problems. [5] In this case, the board with straps he has on hand quickly proves the utility of straps for jumping.

4. The newly actualized adjacent possible that proves useful is quickly abstracted and shared throughout the community of practice, which enables the development of an entirely new niche.

Kauffman's idea of the adjacent possible describes the emergence of solutions that lead to greater fitness for individual species. It also stipulates that the exploration of the adjacent possible can, at least in some cases, end up redefining the entire ecosystem such that entirely new niches are created. New (and therefore mostly empty) ecological niches will often lead to what is referred to in evolutionary biology as adaptive radiation - the emergence of many new species in a relatively brief period of time that quickly evolve to fill the new niche ('Adaptive Radiation', 2022, and Kauffman 2014.)

In this case, "The whole sport of high-performance windsurfing really started from that." (Shah 2000, in Hippel, 2005). The category of Windsurfing is now expanded to contain a new niche into which many new board designs with straps quickly emerge. We can trace the origin of this niche and the breakthrough that made it possible

[5] For many tinkerers and artists, the presence of a collection of seemingly disorganized but readily accessible things lying around in their workshop function as a collection of "objects to think with," a kind of auxilliary brain one can use to quickly prototype solutions to newly emergent problems.

to the exploration of the adjacent possible by individuals in a collectively creative community of practice - a windsurfing “Scenius.”

This story also illustrates the importance of the presence of what Seymour Papert (1980) described as “objects to think with” in the context of innovation communities. Stanley has a board nearby that already has straps on it. This implies access to a workshop and tools used to affix those straps, as well as sufficient storage space with which to keep old prototypes like “The Chip” around, even when they may not have a clear purpose in the moment. As Resnick points out, “Most of the time, thinking is integrated with doing: We think in the context of interacting with things, playing with things, creating things.” (2017). The presence of “The Chip” becomes a part of Stanley’s thinking, so much so that he says “it’s dumb not to use this for jumping.” It would unacceptably stupid - *a kind of cognitive failure* - not to explore this particular adjacent possible when the opportunity costs are so low.

Had “the Chip” not been easily available, it’s possible that Stanley would have had the idea of adding straps. He’d need a board he could experiment with (and possibly cause expensive damage to), some sort of strap material, and probably a drill and screwdriver or some strong adhesive. But that’s not the same as having something so near to hand that it’s dumb not to try it. He might just as easily have had the idea for straps but no straps handy to try it with. He might also have lacked the confidence with tools and materials to make such a modification easily, and have had to ask someone else to help him realize his idea. This would further increase the opportunity costs for converting an adjacent possible into an actual in order to see how it works.

Even if he had the necessary tools, materials, and confidence, without the recent enthusiasm for jumping in his community, it’s quite possible that he would have thought “That’s a good idea - I should try it,” but then become distracted by the next new trend in the community and never followed up. Would high performance wind-surfing exist today? Would someone else have eventually added straps for jumping? Or would some new enthusiasm besides jumping have gripped the wind-surfing community’s attention, possibly leading to some other as yet undiscovered niche? That’s not a question we can answer, but neither is it a possibility we can rule out. As Kauffman argues, the introduction of new niches through the exploration of adjacent possibles renders algorithms we might use to predict the future "un-prestateable"(Kauffman 2014). Prediction beyond a very limited timescale is therefore impossible.

This is just one anecdotal story, but von Hippel and Sawyer's work describe many more, and I have witnessed a few that fit this general pattern as a participant in innovation communities. In terms of research and knowledge creation, it argues for an ecological view of innovation and collective creativity. But what is perhaps more important to the practitioner (especially Maker educators) is that these stories argue for concrete actions that can readily be put into practice. Innovation communities need access to tools and materials for prototyping that decrease opportunity costs for exploring adjacent possibles. [6]Prototyping is essentially the exploration of an adjacent possible, rendering it a new "Actual" from which to see what new adjacent possibles emerge.

The lower the opportunity costs, the more adjacent possibles can be explored under a given circumstance, and the more likely new and useful ideas can be discovered. These factors are already well known to most Maker educators, and in fact form a large part of the value proposition that the Maker Movement offers. But framing their work as supporting the collective exploration of adjacent possibles may prove valuable in that it provides a theory that explains, in relatively concrete terms, *why* it is so important to provide easy access to tools and materials. What else could Maker educators try in order to improve the conditions for the exploration of adjacent possibles in their spaces?

The social factors of collective creativity, and how to go about fostering them, are much less well understood. How do we import a foreign fellow enthusiast to our space, and make it possible for their enthusiasm to spread? How do we foster a collegial environment that supports the sharing, rather than hoarding, of new ideas? What if Stanley decided his idea was too important to share without profiting from it, and so patented it and charged a $300 licensing fee to anyone who put straps on their board for the next 10 years? Both public perception and intellectual property law (which tends towards a highly individualistic interpretation of the products of creativity) must also have an effect on conditions for collective creativity.

[6]This has important implications for anyone living a disadvantaged life under capitalism. People living in precarious situations without a baseline collection of objects-to-think with are at a tremendous disadvantage when it comes to their ability to innovate, solve problems, and respond creatively to challenging situations.

I have attempted to describe a few factors I can recognize and argue as significant in this story - but there are undoubtedly many more. As we try to understand these many variables involved in collective creativity, it begins to look like other so-called “Goldilocks” phenomena. The formation of life on earth required our planet to be “Just right,” as in not too close but not too far from a sun that’s not too big and not too small. The rocks that formed it must have had the right mix of constituent elements, the right amount of volcanic activity, a comet shielding asteroid belt, etc. etc. It appears as though a dizzying number of factors had to be “just right” in the Goldilocks zone for the whole experiment of life on earth to begin and mature to its current state. Is it the same for collective creativity? It might be. We can identify some factors that are important, but the state of the art with regards to creating the conditions for collective creativity is still in its infancy. Like mankind’s understanding of medicine and physiology in the middle ages, we can recognize some of the processes that when missing or interrupted will reliably result in the death of collective creativity. But that’s a long way from creating it, or even reliably maintaining it.

If Kauffman(2014) and Bateson (2002) are correct in their assertion that innovation is fundamentally analagous to speciation, only operating at different scales of time, then Stanley and his surfboard is as much an exploration of the adjacent possible as the Cambrian explosion of species. Viewed in this light, the practitioner attempting to design for collective creativity is doing the same thing that someone attempting to restore a damaged ecology might: Try to get as many factors into the Goldilocks “just right” zone as they can, using both awareness and instinct. Then observing how things go and adjusting as needed. The complexity of such a task may be why Keven Kelly points out that most attempts at creating Scenius have failed, and asserts that the best that can be done when one encounters Scenius is to “NOT KILL IT” (Kelly, 2008).

---

4 Theoretical Background and Methods

Abstract

This chapter describes the theory and methods that shape this research. The literature of collective creativity shows a lack of methods that are short-term, low-cost, population agnostic, ecologically valid and that engage the intrinsic motivation of participants. Such a method or methods can be used to gather new forms of empirical data on collective creativity. Constructionist learning theory and associated progressive pedagogies provide a foundation for creating the conditions for creativity and what Eleanor Duckworth called "the having of wonderful ideas." Kauffman's theory of the adjacent possible provides a model for systematically mapping and describing creative processes that span multiple participants across time. Even with these theoretical and practical foundations, designing methods that could be used to create the conditions for collective creativity requires an extensive, iterative, and collectively creative design process that takes time. This can be done through design based research.

From my perspective as an educator and research practitioner interested in designing for collective creativity, the most useful literature that is currently available on the topic is ethnographic in nature. It tends to describe a variety of rich contexts where collective creativity has demonstrably occurred. Sawyer's work (2014) observing and analyzing improv groups describes important psychological and social dynamics, such as communication styles and common practices. Von Hippel's work (2005) on user innovation communities contains retrospective interviews and descriptions of how important and influential ideas emerged "in the wild." All of this research tends to describe instances of collective creativity that occurred in relatively long time scales, from days to years.

While demonstrably valuable, the ethnographic study of collective creativity among these populations requires that the researcher make a very large commitment of time and resources. From a small and specialized population, interlocutors must be identified, negotiated with, and studied, sometimes at length. In contrast, the experimental quantitative methods brought to bear on the study of collective creativity operate on much shorter time scales. One designs and then deploys controlled conditions in a laboratory and then finds volunteers from the general population to participate in the experiment. Data collection for each participant usually lasts somewhere between a few minutes to an hour or so.

As argued in the literature review, many quantitative experimental methods used to study collective creativity thus far have questionable concept validity. Thus there is a need for short term “experiments” in collective creativity that engage with it in all its complexity and nuance. The goal is to create the conditions for semi-naturalistic and brief case studies of collective creativity. The design should attempt to preserve the rich contextual qualities that are documented in the longer time-scale ethnographic research whenever possible.

Most of the interlocutors in Von Hippel and Sawyer’s research on collective creativity engage with the process because it’s fun and meaningful to them in some way. The same can be said about participants in amateur music and theater improv groups. My own experience as a researcher in the collectively creative environment of MIT Media Lab’s Lifelong Kindergarten Group, during which innovative products like MaKey MaKey and Scratch 2.0 emerged, suggests that curiosity and deep interest are vital to collective creativity. But generally speaking, experimental subjects in lab environments do not have much intrinsic motivation driving their participation. This is one reason why they are frequently offered some form of payment or extrinsic compensation for their time. As Kohn (1999) argues, this can have strong psychological effects, including the crowding out of the space that intrinsic motivation might otherwise fill.

There are advantages to being able to run relatively low cost, short-term experiments in the form of activities designed to invite collective creativity, especially if they don’t require highly specialized or skilled participants. For one thing, short-term experiments allow for a much larger and diverse sample of participants from which to gather data. Rather than observing how a small group of skilled improv enthusiasts behave creatively together, we can draw from broader categories of people that don’t already possess particular specialized traits or skills - academics, artists, children, and perhaps even a category as general as ‘people in the library.’ If participation and data collection can take as little as 20 minutes and no longer than a few hours, it should be possible to observe many participants in the course of a single day. Once such a method is successfully designed and proven, it might even be possible to enroll practitioner researchers working in many different locations into doing the research. That would allow us to observe how the activities play out in different contexts, over many iterations, potentially leading to new insights and knowledge about collective creativity.

No extrinsic compensation need be offered if the experience of participation is entirely voluntary, enjoyable, and can make a reasonable claim to offer value as a learning experience. Thus the quality of intrinsic motivation present in the ethnographic research on collective creativity can be preserved, at least to some extent. The passion felt by someone playing with a creative "tinkering" activity over the course of an hour may not be comparable in magnitude to that of a dedicated surfer tinkering with his surfboard over the course of months or years (to cite one example from Von Hippel's research (2005) on user innovation). But the experience of playing with or "riffing on" design ideas in community may be comparable in emotional quality and character at both time scales, at least when compared to a task assigned to a subject in a lab experiment.

This chapter describes the theoretical foundations for a method for creating the conditions for collective creativity such that empirical ethnographic data can be collected on short timescales with a general population. Both the practical and theoretical aspects of the experiments are built on constructionist learning theory (Papert 1980), as developed and taught to me by research practitioners at MIT Media Lab's Lifelong Kindergarten Group (Resnick 2017), and the Tinkering Studio at the Exploratorium (Bevan et. al. 2015). My goal was to extend the design of tinkering activities and associated Reggio Emilia inspired documentation strategies (Guidici et. al. 2010) towards a method for researching collective creativity. These methods have the potential to make it possible for research practitioners in non-formal learning environments to create the conditions for collective creativity, to document it as it happens, and to share and reflect on that documentation in such a way that generates new knowledge.

The development of this method is part of a design based research process which attempts to break the problem down into smaller pieces. To create the conditions for collective creativity that spans both time and participants, it will be necessary to capture and document insights from one participant and feed them forward as the inspiration or prompt for another. This is the core of the idea described in the article titled *Recursive Prompting: A Method for Collectively Exploring a Design Space*. The research question was "Can we design a systematic method for unspecified participants to contribute to an open-ended exploration of a design space that results in progressive growth in complexity, clustering around the emergence of valuable ideas, and novel applications?"

The original aspiration of this PhD research was to develop this method through design based research with a small team of research practitioners in a Danish library by first giving them a foundation in Tinkering pedagogy and the practice of reflective documentation as developed by the children and teachers of the city of Reggio Emilia. Like most librarian educators, my collaborators have a deep knowledge of local culture and a variety of other skills and contextual knowledge that I, as someone relatively new to working in libraries and to Denmark, do not possess. Since this research aims to be inclusive rather than exclusive of all potentially relevant local context, this knowledge is important. But getting to a place where we could do many iterative design based research experiments on collective creativity takes time and the right conditions, and we came up against limitations in both.

The article titled *Experiments towards a Pedagogy of Creativity and in the Library* describes the early period of laying that foundation for Library educators in Aarhus Public libraries. The research question was "How can we create the conditions for a dialog between theory and practice that can enable library educators to develop a pedagogy of creativity and learning in the library?" Unfortunately, the Covid 19 pandemic made it difficult for that work to proceed as originally planned. Learning how to become a tinkering educator happens mostly through a process that is best described as an oral tradition. It is an iterative, cyclical process involving reading, group reflection, and running and observing many tinkering workshops. My thinking was to onboard my collaborators in tinkering, and then engage them as co-practitioner-researchers running collectively creative tinkering activities in the library.

Soon after the work described in that paper, the *Playing with the Sun* (PwtS) project emerged as the subject area for this research. Activities with and around the PwtS construction kit and sustainable energy became the topic area around which we invited people to be collectively creative. A new team of library educators was formed around the project, and so a new process of constructionist onboarding began. Since most of this phase happened after the Covid 19 pandemic restrictions were relaxed, it included residencies with tinkering experts from Wonderful Idea Co. and the Tinkering Studio at the Exploratorium, during which we ran workshops for librarian educators from all across Denmark. In addition to readings we were able to run activities, begin practicing documentation, and have reflective discussions on the evidence collected. The PwtS design team consisted of 5 librarian educators who met and worked together for most of every Tuesday for almost a year and a half.

Throughout the work in the library I was also part of the Experiencing, Experimenting, Reflecting project (EER), a collaboration between the Interacting Minds Centre and Studio Olafur Eliasson. EER is a Science and Art research collaboration that seeks to explore collaboration, transmission of knowledge, togetherness, decision making, perception, and shared action. It consists of a group of researchers affiliated with the Interacting Minds Centre (of which I am one) working with members of Studio Olafur Eliasson. Together we investigated these areas through the lenses of art and science.

My own work in EER is focused on the area of “transmission of knowledge” and “togetherness” (albeit interpreted on a very short time scale). An early *Playing with the Sun* experiment in designing for collective creativity is described in the article titled *A short-term ecology for the having of wonderful ideas: Catalyzing collective creativity through cross-pollination.* The research question was: How can we catalyze the cross-pollination of ideas through group reflection in a tinkering activity, and is there evidence that this leads to the emergence of new ideas through collective creativity? This early experiment gave intriguing results that led to a method of creating “maps” of distributed creativity as a means of making the empirical data collected understandable and explorable.

The process of developing experiments that support collective creativity depends on the established practice and theory of constructionism, the relevant aspects of which will be described in greater detail below. But in order to develop a method for collecting and analyzing empirical data of collectively creative experiences, two additional theoretical ideas from different traditions were required.

The Reggio Emilia approach to early childhood education has developed a methodology generally referred to as "Documentation" (which I often refer to as "Reflective Documentation" in order to differentiate it from ordinary tedious paperwork, it's most common meaning in English.) Reflective Documentation is a means of capturing qualitative data from children's learning experiences. This data is then reflected on together by the educators working with the children, and used to both formulate subsequent interventions as well as develop new theory about children's learning and creativity. Reflective documentation is at the core of the Reggio Emilia approach, and provided the inspiration for the documentation strategies used in this research.

The second theoretical idea is Stuart Kauffman's adjacent possible. The adjacent possible suggests that innovation and creativity in both evolution and design happen as a series of discrete steps from what is (an "actual") to possibilities that are just next door (the "adjacent" possible.) As a theory this has proven explanatory utility in biology, design, and the study of creativity. But it has methodological implications for the study of collective creativity that this research explores.

Using design based research with these theoretical foundations, and the help and patience of colleagues in Aarhus Libraries and the Interacting Minds Centre, I was able to develop a method for creating the conditions for collective creativity and systematically mapping the emergence of ideas. It is not without limitations, and in need of many more iterations before it can make any serious claims to rigor. This describes how far I got in three years minus one pandemic.

4.1 Theoretical Foundations

4.1.1 Constructionism and Tinkering

"The role of the teacher is to create the conditions for invention rather than provide ready-made knowledge." -Seymour Papert

Constructionism is a learning theory rooted in constructivism, which itself grew out of the work of the psychologist Jean Piaget. Constructivism holds that learning happens through an active process in which the learner exercises agency and initiative.

> What unifies constructivists across the board, is the notion that children are active builders of their own cognitive tools, as well as of their external realities. In other words, knowledge and the world are both construed

> and interpreted through action, and mediated through tool- and symbol use. Each gains existence and form through the construction of the other. (Ackermann, 2010)

Generally speaking, constructivist educators are skeptical of efforts to bring about learning by simply transferring information into the learner's mind. Like many other progressive educators, they tend to prioritize experience-based learning which engages the child as an active builder of knowledge, rather than an empty vessel to be filled. Onto this foundation in constructivism, Papert added his own twist.

> Constructionism–the N word as opposed to the V word–shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe. (Papert & Harel, 1991)

The conceptual conceit of constructionism is that it is possible to design activities, play materials, and construction kits that function as what Papert referred to as "Microworlds" (Papert, 1982). A microworld engages a learner in the process of building their own artifact in a constrained but still open-ended environment. Lego bricks are one example of a microworld, the Logo programming language is another, and Scratch (both the programming language and the online community) is yet another. Each of these provide a limited palette of tools or primitives with which the learner can construct a functionally infinite range of different projects inspired by their own curiosity and interest. Where constructivism holds that people learn through actions based on the knowledge they have, constructionism holds that it is possible to facilitate this learning process through the careful design of microworlds.

Much of the success and popularity of constructionism today can be traced to the success of software based microworlds like Logo and Scratch. At time of writing, the Scratch Online community statistics page reports 128 million projects shared by 107 million registered users (*Scratch - Imagine, Program, Share*, 2023). These numbers don't reflect quite as much participation as they might seem to, due to common usage patterns in online communities. But there is still a lot of engagement and creativity happening in these microworlds. (Note: I worked on the Scratch project for six years, from Scratch 1.3 through the release of Scratch 2.0.)

In addition to well known initiatives like Scratch, constructionism has informed the development of hardware based construction kits like MaKey MaKey, programming and craft initiatives like TurtleStitch, and the thinking behind the popular publication Make Magazine. In their book *Invent to Learn*, Martinez and Stager argue that constructionism is the primary learning theory behind the Maker movement, even though it is not always generally acknowledged as such (2019).

Mitchel Resnick, a former student of Seymour Papert's and the director of the Lifelong Kindergarten group at MIT Media Lab, published an updated take on constructionism in his book *Lifelong Kindergarten* in 2017. His further articulation of constructionist thought is known as *Creative Learning*. Designed for a general audience, creative learning emphasizes the importance of what Resnick calls the 4 "P's": *Projects, Peers, Passion, and Play*. Resnick makes the case that children need more opportunities to playfully create projects they are passionate about in a community of peers. He argues that allowing more open-ended play, attuned to the interests of the learners, will result in more meaningful learning experiences.

In a project initiated by his long time collaborator Natalie Rusk, Resnick also co-founded a constructionist learning initiative called the Computer Clubhouse (Resnick & Rusk, 1996). With over 100 clubhouses spanning 29 countries since 1993 (*Computer Clubhouse History*, 2023), the computer clubhouse project creates small, volunteer driven spaces where youth have access to computers and other technologies with which to build projects of all kinds – from creating games to graphic design to anything else they can imagine. The computer clubhouse is a non-formal learning environment where the agenda for what will be created with the computers is set by its own members, and assisted by adult volunteer facilitators who bring expertise in various relevant technical fields.

Capital "T" Tinkering here refers to constructionist pedagogy designed to support learning experiences in non-formal learning institutions like science centers, museums, makerspaces, and libraries. This articulation of constructionism was initially developed through the efforts of Karen Wilkinson and Mike Petrich at the Tinkering Studio at the Exploratorium Science Museum in San Francisco (Bevan et al., 2015). Mike and Karen studied at the Harvard Graduate School of education with Eleanor

Duckworth among others, and worked at the Science Museum of Minnesota with Natalie Rusk before founding the Tinkering Studio. Today the pedagogy of Tinkering can be found in science museums and makerspaces around the world.

But the word tinkering (lower-case "t") is also used to describe the exploratory, playful and creative process of tinkering itself. In this the more common usage, it describes an approach to learning about how things work and constructing something new. Resnick and Rosenbaum (2013) use it to describe the actions of learners regardless of whether they are in formal or informal learning contexts.

> Sometimes, tinkerers start without a goal. Instead of the top-down approach of traditional planning, tinkerers use a bottom-up approach. They begin by messing around with materials (e.g., snapping LEGO bricks together in different patterns), and a goal emerges from their playful explorations (e.g., deciding to build a fantasy castle). Other times, tinkerers have a general goal, but they are not quite sure how to get there. They might start with a tentative plan, but they continually adapt and renegotiate their plans based on their interactions with the materials and people they are working with. (Resnick & Rosenbaum, 2013)

In essence, the pedagogical value offered by capital "T" Tinkering is to immerse the learner in the best possible situation for them to experience and practice lower-case "t" tinkering. Constructionists like Resnick and Rosenbaum argue that learning to tinker with technology, develop one's own projects, and debug issues that arise in the process is valuable in its own right. As with all forms of project based learning, as the learner becomes better at the *process* of creating projects, they are also exposed to a great deal of information or *content* pertinent to the technologies with which they are working. This forms another basis for arguing that Tinkering is a valuable pedagogical approach for teaching STEM literacy.

In science museums and other non-formal settings where Tinkering is practiced, learners are invited to drop in and play with engaging activities like marble runs or scribbling machines for as long as they wish to. Social aspects of the interaction are designed to encourage contagious inspiration, group reflection, and the sharing of ideas (Vossoughi & Bevan, 2014). However, as a theory of learning, Tinkering is still mostly oriented towards creating the conditions for individuals to have their own meaningful learning experience.

All of these manifestations of constructionism have as a central goal the creation of conditions for what Eleanor Duckworth called “the having of wonderful ideas” (Duckworth, 1972). The role of the educator is to create the best possible conditions for learner driven exploration of meaningful ideas. In other words, the emphasis is less on “teaching” in the literal sense of conveying information into the learner’s mind, and much more on creating the best possible conditions for the learner to engage in their own learning process.

Towards that end, various design principles that inform efforts to build constructionist construction kits and activities have emerged. Papert described the need for a *low-floor* - meaning that it should be easy for learners to get started with whatever tools or materials are offered - as well as a *high ceiling* - meaning that it should be possible to make relatively complex, detailed projects with those materials (Resnick & Rosenbaum, 2013). To this Resnick added *wide walls*, meaning that it should be possible to explore a wide variety of different ideas depending on the interests of the learner (2017).

In the past decade, both the Tinkering Studio at the Exploratorium and the Lifelong Kindergarten group have spent a great deal of effort running in-person and online workshops designed to give educators a hands-on experience of constructionist learning activities. Resnick and colleagues in the Lifelong Kindergarten Group have spent enormous amounts of time and resources developing and maintaining the community of educators around the Learning Creative Learning (LCL) project. Part online learning course and part online community, LCL is a space for educators interested in learning about and practicing creative learning (Gabaree et al., 2020). Similarly, the Tinkering Studio devoted a great deal of effort creating massive online courses (MOOCS) about Tinkering on the Coursera platform, which educators from around the world can participate in for free. This is in addition to maintaining an active presence in conferences for science museums in Europe and the US.

True to their constructivist roots, both the Tinkering Studio and the Lifelong Kindergarten Group maintain that the skills of a constructionist designer and facilitator cannot be shared exclusively through writing. They must be learned through iterative experience and reflection with other educators. In this sense, constructionist learning has many of the qualities of an oral tradition. Groups of peers do workshops together, reflect on the significance of what they observe, make changes to their design or approach, repeat, etc. etc. Quality in every relevant domain, from facilitation skills to design skills, is understood to depend greatly on iteration.

This explains why so much of my own efforts in this research were invested in establishing a context for peer reflection and collective design with librarian educators in Aarhus. I could not have just "done it myself," even if that would have saved a lot of time spent creating contexts for colleagues in the library to encounter, question, and make sense of the core ideas of constructionism and the process of tinkering design and facilitation. Even if I wanted to be a "lone genius" of constructionism, that would be a contradiction in terms (and especially ironic given the topic of this PhD). Quality work in the design of constructionist toolkits, activities, and microworlds is *always* a collective effort emerging out of a community of dedicated research practitioners working iteratively and reflectively in context with learners. In my view, there is no alternative.

4.1.1.1 Tinkering Environments and Activities While all versions of constructionism described thus far create useful knowledge about creating the conditions for innovation and creativity, Tinkering is most closely aligned with the time scale and informal context required for this research. Tinkering activities were born on the Exploratorium "floor," where wandering museum-goers were invited to tinker with marble runs or scribbling machines that caught their eye. Perhaps as a result of the niche they evolved to fill, they are likely to capture the attention and spark the curiosity of passersby. In the design language of constructionism they have a very "low-floor," meaning that their general principles are easily understood such that it makes it easy for people without any experience or aptitude to get started building. Tinkering activities are the least technically intimidating of all constructionist activities, and the most accessible. These qualities make tinkering the best constructionist foundation for research designed to create the conditions for short-term collective creativity, especially in the context of a library.

In addition to offering free online courses on Tinkering through Coursera, the Tinkering Studio has participated in a variety of research projects that resulted in publications that describe the basic principles of tinkering design and facilitation. The learning dimensions framework and associated descriptions of "facilitation moves" (Bevan et al., 2018) emerged out of research that used video recordings to capture and analyze the process of tinkering (Gutwill et al., 2015). The "Learning Dimensions of Making and Tinkering" describe 5 areas of cognitive and socio-emotional development that tinkering educators design and facilitate towards. Each dimension contains bullet-points that describe indicators of learning that can be used as shared reference points when observing and reflecting on tinkering experiences.

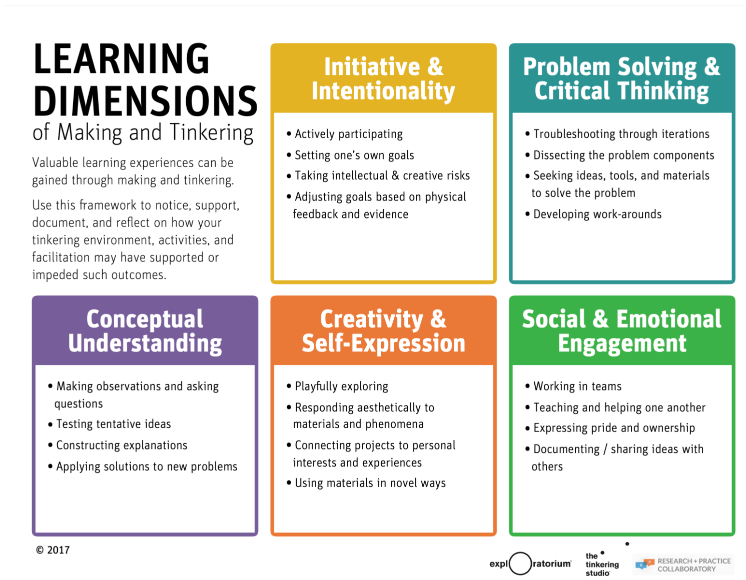


Figure 1: The Learning Dimensions of Making and Tinkering: A Professional Development Tool for Educators | Exploratorium

While the development of any and all of these qualities can be argued to be pedagogically and intellectually valuable, it is understood that different activities invite them to varying degrees. Nonetheless they describe a general definition of what would qualify as a tinkering activity, and a rough criteria for qualitatively evaluating their design.

Key design elements of Tinkering Activities The literature on the design of Tinkering activities and associated pedagogy is far from comprehensive. A great deal of Tinkering design must be learned through iterative practice and reflection, in close relationship with local learners and immersed within their surrounding context. Still, a few words on the topic will help to highlight areas that are particularly relevant to the goals of this research.

Tinkering activities can be run as “drop-in” events, which allow passersby to join and participate at will depending on the availability of workspaces and materials. This creates an ongoing flow of overlapping participants dropping in and out of the activity that has some advantages. For one thing, new participants can quickly learn how to engage with the activity simply by watching what others are doing. Projects being worked on by a range of participants demonstrate what can be done by learners starting from different skill levels with varying lengths of build times. These often serve as excellent “sample projects” which, in the aggregate, define a broad range of possibilities for participation. If the passerby sees someone getting started building something that looks easy, someone else making something complex and interesting, and another making something completely different, then they have been given an excellent introduction to the activity’s low floor, high ceiling, and wide walls. That should make it easier for them to imagine a way to get started.

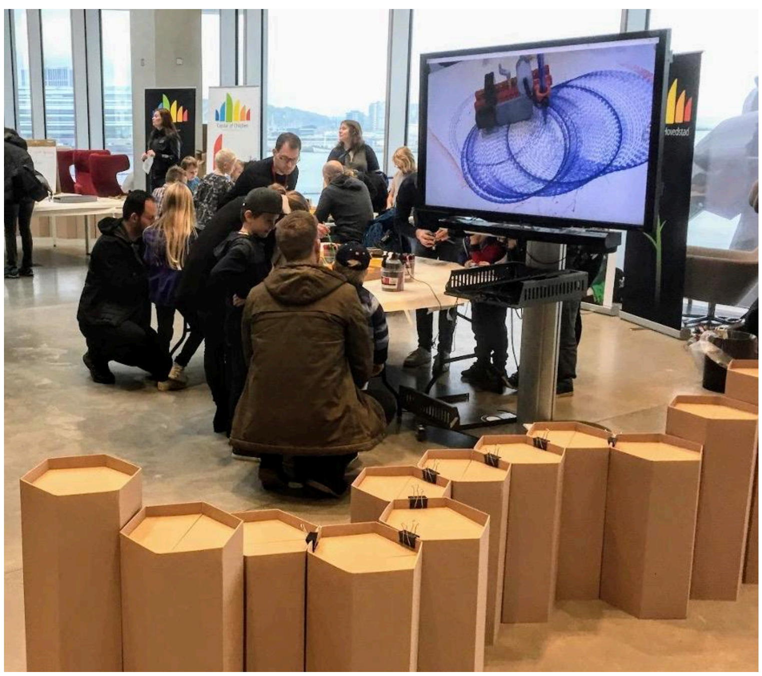


Figure 2: A “drop-in” activity in Dokk1 Library called LEGO Art Machines, developed in a collaboration between the Tinkering Studio at the Exploratorium and the author in 2016.

Tinkering activities can also be run as more formal “workshops” in which all participants begin and end at roughly the same time. This requires slightly different activity design and facilitation strategies. The facilitators will want to have several sample projects already made and on display in order to give the participants a sense of the different entry points possible and the variety of directions to explore within the activity's constraints. They may also wish to spend more time demonstrating how the different elements of the construction kit or activity work. When all the participants start at the same time, they won't get to look over the shoulders of people with more experience and time spent engaging with the activity.

Prompt

An open-ended activity designed to elicit creativity needs a prompt. As Sebastian Martin of the Tinkering Studio explained during his residency with the Playing with the Sun team at Dokk1 in 2022, a learning prompt is distinct from a learning goal. A learning goal implies that all the learners reach the same knowledge or conclusion described by the goal. A learning prompt serves as a starting point for learner-driven exploration that may lead to as many different outcomes as there are participants. Even though they begin from the same prompt, learners won't necessarily learn the same things. Instead, each learner's projects will reflect their interests, knowledge, skills and choices. This partly accounts for the ability of tinkering activities to engage diverse learners across a range of ages that's much larger than most educational activities. Each learner can use the open-ended nature of the activity to locate their own particular zone of proximal development (Vygotsky, in Ackermann, 2010) and start working from there.

A prompt that leads to the same outcome for a diverse group of learners is too constrained. One that leads to no outcome, or the anxiety of "white piece of paper syndrome" may not be constrained enough. A good prompt sits in the Goldilocks zone of "constrained, but not too constrained." The art of open-ended activity design depends on finding the right level of constraint. A great deal of the work of designing open-ended tinkering activities involves iteratively erring on the side of being too open-ended, and then too constrained, back and forth until the "Goldilocks" sweet-spot suited to the population one is working with is found.

Facilitation

In Tinkering pedagogy, the role of the educator is often described as "Facilitator" instead of "Teacher." The distinction serves to clarify whose ideas are being explored. The facilitator's role is to assist the learner's self-driven practical and intellectual exploration. Karen Wilkinson of the Tinkering Studio at the Exploratorium put it very succinctly when she said "The big idea is their idea." When facilitators intervene, it should be in service of the learner's interests or nascent goals. This requires them to quickly get an understanding of what those interests are by observation. They can then intervene in a variety of ways: helping the learner get un-stuck, providing logistical support such as finding more glue sticks when they run out, helping with technical troubleshooting, connecting to big ideas, etc.

The "Spark Sustain Deepen" (Gutwill et al., 2015) framework was developed to describe common strategies for the facilitation of tinkering activities. At the beginning of the experience, the facilitator's goal is to "Spark" initial interest of the learner, and help them find an entry-point to their participation. "Sustain" has the facilitator supporting the learner through the unavoidable challenges of the creative process. And "Deepen" has them helping the learner make connections with other relevant ideas and reflect on the work.

This focus on the learner's ideas takes on an additional dimension of importance when applied to the goals of this research. The objective here is to create the conditions for collective creativity. This requires that the ideas that emerge out of the process are novel and reflect the insights and ideas of the participants. Classical goal-oriented teaching strategies would be unsuitable for this research because they are often designed to get the learner to a state of knowledge that is already known, rather than inspired them to generate new and creative ideas. To put it another way, the goal of these experiments is not to design contexts where people come up with "the" correct answer. It is instead to design contexts for people to come up with many answers to a problem space that they themselves have had a hand in inventing.

Environment Design

The environments where tinkering activities are run tend to be designed to make tinkerers feel as comfortable and casual as possible. When I asked Mike Petrich to explain the principles behind the interior design of the Tinkering Studio, he explained that they found a great deal of their inspiration in kitchens. The kitchen is a casual, creative space that exists in almost every home. It contains the tools necessary for culinary creativity, and tends to define a kind of DIY aesthetic. Tinkering can feel emotionally risky for people without much experience being creative. A casual, kitchen-like environment is one way to help put them at ease.

Tinkering spaces are often designed to support contagious creativity. For example, worktables tend to be shared and "communal," so that it's easy to see what others are building and take inspiration from it. Materials and tools should be easy to access so that when someone has an idea, it doesn't take them long to find what they need to try it out. The best tinkering environment minimizes the opportunity costs of having an idea and making it into a reality (regardless of whether the opportunity costs are practical or emotional in nature.) For this reason, competition is almost never used by the designers of Tinkering activities. While it may excite some learners it is likely to intimidate others, and has the potential to work against the friendly, collegial, collaborative environment that best supports tinkering.

Opportunities for Reflection built-in to Activity Design

Activities in which pairs of learners work together have an advantage over those in which learners work alone, in that the need to articulate and execute a project together necessitates communication and group reflection. This makes each participant's thoughts and motivations tangible, and potentially documentable, by the researcher. Even simple communication creates an opportunity for reflection.

The normal tinkering activity structure starts with a brief introduction and prompt, followed by a (minimum 30 minutes) building session, followed by a "show and tell" in which each participant shows what they made to the group and answers brief questions form the facilitator about some aspect of their process. These provide more opportunities to gather observations, stimulate reflections, and collect relevant data about the evolution of collectively creative ideas.

In recent years both the Tinkering Studio at the Exploratorium and the Lifelong Kindergarten Group at MIT Media Lab have engaged in shared research projects with the Reggio Children Foundation, including one which I co-led while employed by the LEGO Foundation. These constructionists share similar core values and intellectual ancestors with the educators of Reggio Emilia. They are also interested in the Reggio approach to reflective documentation as a methodology for practice based research.

The pedagogy of tinkering forms the foundation for my efforts at creating the conditions for collective creativity. But the Reggio Emilia approach to documentation has inspired the means of collecting data, as well as creating the conditions for collective research.

4.1.2 The Reggio Emilia Approach and Reflective Documentation

Developed over the course of the past 60 years in the Northern Italian city of Reggio Emilia, the Reggio Emilia approach seeks to engage children as protagonists of their own creative learning process (Vechi 2010, Krechevsky et al., 2013). As a body of theory developed by and for practitioners, it has inspired teachers in thousands of kindergartens, early childhood centers, and schools around the world. Each year, hundreds of educators visit the city of Reggio Emilia to study. Many more purchase books about the method published by the Reggio Children company and made available in over a dozen languages.

Central to the Reggio approach is the method that its practitioners refer to as "Documentation." Documentation is described in detail in a book that emerged out of collaboration with Harvard Project Zero titled *Making Learning Visible* (Giudici et al., 2008). Krechevsky et. al. define it as "The practice of observing, recording, interpreting and sharing through a variety of media the processes and products of learning in order to deepen and extend learning" (2013). Images or video of a child engaging with an activity or idea are documentation, as are notes describing what they did and said. The child's artistic creations are often presented and analyzed, especially in that they can inform the educator's understanding of the thought processes behind them.

Reflective documentation serves many roles. First, it is a means for doing research on a topic relevant to the pedagogical goals of the educators. In the blog post on the website of the Scintillae Atelier titled *Triplo Viso Strano* ('Triplo Viso Strano', 2020), the educators describe an activity or "proposal" that invited children to explore digital and analog tools together as a means of creative self-expression. As children explored the activity, the educators were careful to document what they said and what they made in photographs and recorded quotes. The blog post publishes this documentation as well as the educator's analysis and interpretation of its meaning. Done in this way, documentation and associated reflective practices function as a method for doing practitioner research. Educators use it to ask research questions, formulate answers based on the data, and generate new questions.

Documentation is also a means for educators to reflect on their own ongoing practice, and to refine and develop their skills. If the educator collects documentation in the process of running an activity that supports children's creative self-expression with digital technology, then at the end of the week they will have something to reflect on with other educators. They might present it to colleagues and ask for ideas on how their proposal could be improved, or even if it is aligned with the values they believe in as educators. Documentation becomes the shared evidence that a community of educators can use to ground their theory making. It serves to ground what might otherwise become an abstract, overly academic discussion.

After being analyzed and reflected on with peers, a small portion of collected documentation is edited and finalized for publication. This can take the form of books, small run print-outs that resemble "zines", blog posts, formal presentations, and many other forms. Often Reggio schools will have large documentation boards with documentation of children's play mounted on the walls. Published documentation becomes a means of communication with parents, educators, politicians and other stakeholders about the work being done in the schools. By making the children and the teacher's research accessible and understandable to a wider audience, it invites them into a conversation about the creativity and intelligence of children.

In terms of the Reggio practitioner researcher's ability to generate theory to explain observations, documentation serves a central role. From speaking with many Reggio inspired teachers, my impression is that they do not aspire to create objective knowledge about children's learning. Due to strong influences coming from the work of Gregory Bateson and others, they would tend to view notions of "objectivity" independent of cultural context as misguided and potentially dangerous. Instead, rigor in the Reggio tradition emerges out of subjective consensus. A theory or explanatory idea that has value is one that has its basis in documentation, and resonates with the experience and observation of other practitioners over time. Reflective documentation is the evidence that must be shared with such a theory. Like all evidence, it may or may not validate the theory, but it should reliably make it potentially disprovable, or at the very least subject to alternative interpretations. Thus documentation and the associated reflective processes constitute rigor in this particular methodological approach to knowledge creation.

In the corpus of published Reggio Emilia documentation of children's learning, there are examples of documenting the collective creativity of children. For example, the book Theater Curtain (Vecchi & Reggio Children Srl, 2002) consists of documentation and interpretation of children's collaborative work to design a curtain for a theater - an important cultural landmark - in the city of Reggio Emilia. This can be described as kind of medium-term ethnographic design research, in that it describes the interactions within a small culture - in this case, a kindergarten class - that develop into a completed product. There are moments when individual contributions are described, along with their influence on the project as a whole.

However, the timescale that this work operates on is still longer than the targeted timescale of this research. There remains a need for a different means of understanding and representing the data of collective creativity at the scale of minutes, instead of days. There is also a need to more closely identify and capture individual contributions to see their relevance to the whole at this time scale. In order to find a systematic means of doing so, I turn to an idea from Biology that has already crossed over to the world of Design.

4.1.3 The Adjacent Possible and the mapping of collective creativity

"The adjacent possible consists of all those things (depending on the context, these could be ideas, molecules, genomes, technological products, etc.) that are one step away from what actually exists, and hence can arise from incremental modifications and recombinations of existing material." (Tria et al., 2015)

Conceived of by the biologist Stuart Kauffman (2014), the adjacent possible is a useful concept for understanding the exploration of a space of possibilities. Simply put, the adjacent possible is what's next door to whatever state something is in right now. Before the Post-It note existed, it was an adjacent possible of the plain paper note taped to a wall. Once invented, it became an "actual" from which new adjacent possibles could emerge in various realms, from using them to make fish scales in kindergarten craft activities to a tool for organizing collections of thoughts in design meetings.

Each time an adjacent possible transitions into an "actual," it changes the space of possibilities not only for itself but also for the entire system of which it is a part. As a result, each movement into an adjacent possible is not only a potential optimization within the current context, but also has the potential to introduce a new evolutionary niche which radically changes the entire system. Kauffman provides an example from the evolution of the swim bladder, an organ which allows fish to maintain neutral buoyancy. Thought to have evolved from the lungs of a lungfish, the swim bladder enabled the fish that had it to control their position in the water column, conferring huge advantages. This small step from primitive lung to swim-bladder opened up a world of possibilities which thousands of species thereafter evolved to fill, which then radically changed the oceanic ecosystem itself.

Within the realm of technology, one could describe the adjacent possible with the story of the development of the mouse-driven graphical user interface (GUI), or windowed computing, at Xerox Parc. Prior to the existence of the GUI, human computer interaction was mostly limited to typing text commands into a terminal. The GUI began as an adjacent possible to the terminal, but once it existed it made possible a new form of interactivity on which the subsequent history of computation has been dependent. So the discovery of an adjacent possible like this is not simply the story of a discrete and immediate evolutionary advancement. In some cases, as with the swim bladder and the GUI, it results in the creation of a new emergent ecology that enables a near infinity of subsequent adjacent possibles. In the case of the GUI, we are still building on this insight 50 years later. In the case of the swim bladder, fish are at approximately 400 million years and counting.

Kauffman points out that this quality of the adjacent possible opening up new domains of possibility has profound implications because it renders our world "unprestateable" - meaning that evolution of domains like genetics, economics, culture, and technology will never be algorithmically predictable (Kauffman 2014). This has profound implications for positivistic branches of science that attempt to deal with these types of complex phenomena, and for this research on creativity. If Kauffman is correct, it will never be possible to algorithmically predict specific outcomes in creativity research, at least not within ecologically valid experimental circumstances. The reason is that each new movement into the adjacent possible has the potential to change the entire system that surrounds it. Whenever this happens, all bets are off.

Creative design processes can also be described as stepwise movements through adjacent possibles, whether at the scale of a creative workshop, or of the evolution of life on earth (Jacob, 1977). In the literature of Tinkering and constructionism, Resnick's creative learning spiral (Resnick, 2017) models a child's process of exploring the adjacent possible within a microworld. As she sits down with wooden blocks, she *imagines* something to build, *creates* it, *plays* with it, *shares* it with friends, *reflects* and evaluates it before imagining the next change or refinement and creating it, etc. etc. It's not difficult to characterize this as a navigation of adjacent possibles. Resnick argues that this process is fundamentally analogous to what graduate students at MIT Media Lab are doing as they explore and develop new cutting edge technologies.

Figure 3: Resnick's *Creative Learning Spiral* (2017)

According to Tria et. al's definition (2015) as well as Kauffman's, movement through the adjacent possible often involves "incremental modifications and recombination of existing materials" (Tria et al., 2015) - i.e. the primitive lung becomes the swim bladder. This is very similar to the idea of bricolage, which the anthropologist Claude Levi-Strauss described in his famous book *The Savage Mind* (2000), and which had a great deal of influence on Seymour Papert's thinking. "The basic tenets of bricolage as a methodology for intellectual activity are: Use what you've got, improvise, make do" (Papert, 1993). This approach is at the core of constructionist thinking about learning experiences and tinkering.

Both tinkering and the navigation of the adjacent possible have strong similarities to the role of prototyping in design and design based research. As Lim et. al. (2008) describe it, "Prototypes are used as a means to frame, refine, and discover possibilities in a design space." This is particularly important when the objective is not just to solve problems, but to discover new problems to pose. Whereas prototyping in design often operates on a somewhat larger timescale of several prototypes per day, week, month, or year, tinkering involves modifying one's project several times a minute. Fundamentally, this is the same process operating at different scales. In tinkering and design, the goal is to bring an idea into being and reflect on it, and to see what new possibilities emerge. Prototyping makes an adjacent possible into an actual, which allows the designer to see what new, subsequent adjacent possibles become possible.

In the case of scribbling machines (*Tinkering Project: Scribbling Machines | Exploratorium*, 2023), a well established tinkering activity, the explorer of adjacent possibles might wonder what would happen if they move the motor 1 cm to the left, or what might happen if they move the weight on the motor. Many and perhaps most of these small changes don't lead to anything interesting, but some do. This leads to new ideas and explorations of further adjacent possibles. It's not necessary to have a specific goal or end-state in mind, although in general new goals and problems to solve tend to emerge out of the process of tinkering. [7]

For example, the sub-theme of "writing machines" - drawing machines that make repetitive marks that resemble writing, is an adjacent possible "realm" I have sometimes encountered in drawing machine workshops. If the builder stumbles upon drawings that look like writing and finds it interesting, they may decide to explore further adjacent possibles within this realm. For example, they may focus on making subtle changes to adjust the character of the script.

[7] It's worth noting that when asked if they had a specific plan in mind that led to an interesting result, most adults will admit that they did not apologetically, as though they felt they should have. This may be a result of Western culture's tendency to place higher value on intentional planning over exploratory tinkering. As Papert put it "The traditional epistemology is based on *the proposition*, so closely linked to the medium of text –written and especially printed. Bricolage and concrete thinking always existed but were marginalized in scholarly contexts by the privileged position of text."(1992) (emphasis mine)

Figure 4: Marks similar to writing that participants came upon during the *Drawing with the Sun* activity I ran in the EER *More than Human* workshop, September 2021

There are important implications to the idea that the act of tinkering is essentially the act of exploring adjacent possibles. For one thing, it implies that the concepts and methods used in one realm might be compatible with the other. That would suggest that we may be able to use the pedagogy of Tinkering to create the conditions for people to explore the adjacent possible individually, but also collectively. We may also be able bring to bear the tools and methods associated with the theory of the adjacent possible to better understand tinkering experiences. Kauffman's use of the evolution of the swim bladder as an example of the adjacent possible emerged from evidence in the fossil record (2014). If we accept Gregory Bateson's contention that cultural learning and evolution are fundamentally the same processes operating at different scales (2002), perhaps we can make a fossil record of ideas that emerge through collective tinkering. If we can map how species evolve over thousands of years in the fossil record, it might be possible to map how tinkering projects evolve over thousands of seconds in a Documentation record.

According to Kauffman, the nature of the movement between adjacent possibles renders the future fundamentally unpredictable. If we can accept that limitation, we can explore the other advantages the theory confers. For example, in retrospect the navigation of the adjacent possible is causal, rational, and systematic. So while we cannot use it to predict the future (in a strict sense), we can use it to better understand the past and the process behind the development of new ideas. That includes, potentially, understanding how to design environments for collective inquiry into the adjacent possible. We may not be able to predict the future, but we may be able to design systematic means of exploring the adjacent possible that will undoubtedly change it.

4.2 Theory in Practice: Design Based Research to Develop Contexts to support Collective Creativity

Although I was never a student during the six years I spent working in the Lifelong Kindergarten Group at MIT Media Lab, I learned a great deal about the methods they use. Friends and colleagues who were PhD and Master's level students took the "Demo or die" credo of the media lab seriously, perhaps even more so when it changed to "Deploy or die." To us it meant that in order to prove or disprove the value of an idea, it had to somehow be placed in dialog with the real world, in all its messy context.

This was essentially what we were doing with Scratch, MaKey MaKey, and the rest of the projects in various stages of development at that time: Reflecting on what we observed, proposing and implementing new ideas, trying them out in the world, and carefully observing what happened. Although we never spent much time on methodological semantics, what we were doing fits best in the domain of design-based research. Have an idea? Figure out a way to try it out in the world and see what happens.

Practitioners have been doing various forms of design-based research since long before it existed as a theoretical framework with a name. Even so, when researching something as complex as learning and creativity, things can quickly get complicated and un-focused in such a way that frameworks and clear definitions can be useful for managing the complexity. In design based research in education, part of this complexity is due to the nature of the work itself. An educator doing design research aims to create knowledge about children's creativity and learning by designing circumstances for it to occur. Each time they run their activity, they must wonder: Is what I observed a result of the circumstances I designed, some innate quality the child brought with them, or something else entirely? These can be difficult to tease apart.

Cobb et. al. put the problem this way:

> Prototypically, design experiments entail both “engineering” particular forms of learning and systematically studying those forms of learning within the context defined by the means of supporting them. This designed context is subject to test and revision, and the successive iterations that result play a role similar to that of systematic variation in experiment. (2003)

Just as they describe, in this research it is necessary to gather data on both the research question and the design of the experimental method itself. In other words, it’s necessary to collect data on both collective creativity and the design of activities and environments I have designed to create the conditions for collective creativity. When time and resources get tight, these two goals can easily get in competition with each other. This is something that research practitioners need to be wary of.

In Design Research in Education (2018), Bakker makes a related point.

> [Another] characteristic of design research is its interventionist nature. In many research approaches, changing and understanding a situation are separated. However, in design research these are intertwined in line with the following idea: If you want to change something you have to understand it, and if you want to understand something you have to change it (Bakker, 2004 in Bakker, 2018).

A similar argument has been made about the pedagogical value of tinkering with various phenomena in STEM: We can learn how things work by changing them and then observing what happens (Gutwill et. al. 2015). In this case, the work was to create a context for observing collective creativity - a context I could change and refine across iterations. As with any design-based process, quality comes through iteration, and for various reasons I was prevented from getting nearly as many iterations as I would have liked. Probably that’s the case for all researchers, but like many other things that problem gets worse during a pandemic. This matters because the more iterations one can do, the more changes one can make, and the better chances there are to understand the important variables in play.

Barab and Squire (2004) point out that design-based research can be a means of evaluating theory in practice - and that applies here as well. I am exploring the integration of ideas from very different disciplines. The adjacent possible comes from biology, constructionism comes from psychology, and then there is the world of design. The results thus far suggest some interesting possibilities.

Design based research may also generate new theory. Citing the work of Cobb et. al., Barab and Squire suggest that "It is through understanding the *recursive patterns* of researchers' framing questions, developing goals, implementing interventions, and analyzing resultant activity that knowledge is produced" (1999, in Barab & Squire 2004, emphasis mine).

McKenney & Reeves (2018) created a generic model to describe the process of design based research in education. The arrows between stages are intended to indicate the iterative, exploratory nature of the work. The work proceeds across three general phases to completion, with the understanding that elements of each phase can happen within all of the others, depending on the needs and insights that arise.

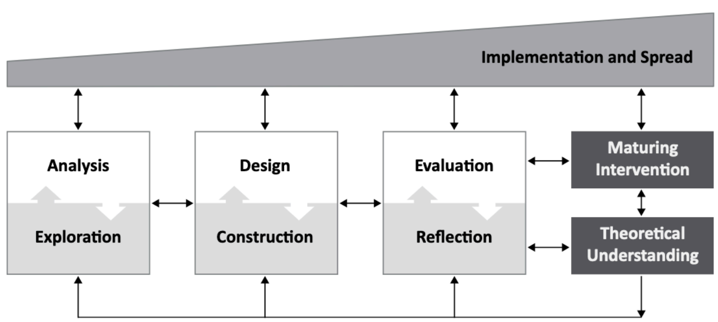


Figure 5: Generic model for conducting design research in education (McKenney & Reeves 2018)

It's important to note here that the process is both recursive and scale invariant. For example, in preparation for each workshop with learners that we ran, my collaborators and I would analyze, design, and evaluate, and then reflect together on the results. The same shaped pattern holds at the scale of the entire project itself (or at least the post Covid-19 pandemic portion of it). Like the recursive algorithms used to draw fern leaf like shapes with Logo in the 1980s (Papert, 1980), the full-scale fern leaf is drawn through the recursive drawing of the smaller, identically shaped elements.

Like Tinkering, design based research is an exploration of the adjacent possible and therefore path dependent, and this research is no exception. The method and the goals evolved to fit the circumstances, while I did my best to evolve the circumstances to fit the goals. Practice based research is dependent on the circumstances of the practice, which in this case is the design and facilitation of non-formal learning experiences within a library. Manipulating these circumstances into a form of research is itself a kind of bricolage.

4.2.1 Design Evolution at the Scale of the Project as a Whole

I have heard contemporaries of Seymour Papert describe him as a "real genius." Even if that was the case, he didn't do his design work in isolation. Without exception, all of the constructionist microworlds I admire - including softwares, hardwares, and construction kits - emerged out of collectively creative design processes by research practitioners. This isn't to say there aren't variations in ability or skills among individuals - there are. Perhaps that is the reason why good work in this field seems to require sustained attention and creativity from many different people. Within a healthy collectively creative community, the various weaknesses in one get compensated for by the strengths of others, ratcheting the aggregate result towards the better.

Being a constructionist educator and living and working in a foreign country with no pre-established team nearby, I needed to find or establish a group of educators to work with and an environment to work in. Having run several Tinkering workshops in Dokk1 Library for Aarhus Public libraries, I was impressed by the values and thoughtfulness of the people I'd met there. In discussing the possibility of this research with Sidsel Bech-Petersen (who later became one of my PhD supervisors) it became clear that Aarhus Public libraries was interested in developing their institutional knowledge about playful learning and in collaborating on this kind of research. We agreed that I would lead a design research project on collective creativity in collaboration with several members of the staff. In the process we would increase their repertoire of skills as librarian educators and lay a foundation for reflective practice on creative learning in the library. By hosting residencies for colleagues and friends from the world of Tinkering in science centers and Playful learning in schools, we could ensure that more than just my own views and perspectives were brought into the mix.

At the start of the PhD we founded the Creative Learning Research Group (CLRG), which consisted of 5 library educators from Aarhus Public libraries. Each educator brought a variety of skills and knowledge, including but not limited to experience design, the facilitation of creativity through crafting with small children, and the use of complex digital fabrication tools. All had some experience with Design Thinking for Libraries (IDEO, 2015), which in my view shares many if not most of the same core values as Tinkering. There is an argument to be made that the pedagogy of Tinkering is essentially a more playful form of Design Thinking for children and adults.

Originally the plan was to cycle through readings of basic texts of creative learning, run bi-weekly or monthly tinkering workshops with children, and practice collecting and reflecting on documentation. But the Covid-19 pandemic shut down the library and made in-person meetings impossible, so for more than a year we were only able to meet online. We managed to run and document one online workshop and one in-person workshop shortly after the library reopened. Both are described in the article titled *Experiments towards a Pedagogy of Creativity and Learning in the Library.* But for the most part during the lockdown we read and discussed theory in zoom calls, which was about all we could manage to do. In October of 2021 we visited Reggio Emilia together for 3 days to attend a seminar on practice based research. During this visit, Ben Mardell and I came up with the core concepts of the Playing with the Sun project. That part of the process is described in greater detail in the following chapter.

4.2.2 Methodology for the design of workshops and data collection

I use a workshop design methodology learned from developing and running workshops with colleagues from the Lifelong Kindergarten Group at MIT Media Lab, and refined from collaborating on workshops with the Tinkering Studio at the Exploratorium as well as designing and leading my own workshops in the LEGO Idea Studio.

Initially I make a detailed outline in a document shared with collaborators that describes the goal of the workshop, the research question, and the general logistical considerations, such as workflow for signing releases to collect data, attendees, etc.

This includes details about the prompt that will be used, the timeline, and the materials made available to learners. The outline generally includes the design of sample projects, which roughly define the design space for participants. Sometimes it will include the design of base models, which are pre-assembled starting points given to participants so that they can easily get started. Data collection in the form of documentation strategies gets a good deal of consideration. A research question is chosen by consensus and used to focus our shared attention in a particular area.

Even if I am running the workshop alone, I generally try to talk the outline through with an experienced colleague or collaborator to hear their opinion on the various strategies - especially new ones. For example, placing people in the role of "catalysts" was a new strategy, and the feedback I got from talking it through with Liam Nilsen caused me to simplify it as much as I could before the day of the activity.

I then make sure I have a few hours for setup / problem solving before the start of the activity, all the necessary materials, etc. We then run the activity. There are often times when reality interferes with my plans. For example, at the CES conference described in the Recursive Prompting article, I planned to encourage people to turn up the volume of the iPad displaying the drawing machine they were viewing in order to hear the brief interview with the project's creator. This turned out to be impractical in a large and somewhat noisy space - so I let it go.

After the workshop teardown and clean up, I hold an after action review session as soon as is practical with any collaborators, or if alone I write down notes. These after action reflection sessions are focused on the design of the activity and generally last from 20 minutes to (ideally) an hour or longer, and are usually organized around 3 categories: "Green / Yellow / Red." Green being something that worked very well and should be preserved in future iterations. Yellow is something acceptable but improvable. Red is something problematic that should be addressed before the next workshop.

Digital data like photos and videos are collected into a folder for subsequent analysis. During the analysis phase I review the research question and the data, trying to identify patterns and organize things in such a way that it answers the questions I want to ask. For recursive prompting workshops, that means organizing the videos in a Milanote virtual board that is the digital equivalent of the physical recursive prompting board. This allows the data to be analyzed based on relationship and chronology. I then discuss early impressions with colleagues and collaborators.

5 Outcomes and Implications

Abstract

Summarizes the research in two tracks, originally intended to be merged halfway through the research process. Track one consisted of developing a team of research practitioners in the library conversant with the design, facilitation, and Documentation of Tinkering experiences. Challenges encountered along the way are described for the benefit of future research practitioners. Track two describes the research's methodological contributions in the form of new methods for creating the conditions for and studying collective creativity. It summarizes the implications of the empirical data collected. Theoretical contributions in the form of the integration of the theory of the adjacent possible with Tinkering are briefly described.

> "I don't know how in the debate between pragmatism and idealism there came the separation between theory and practice. Why did this separation come about? What purpose did it serve? What kind of power relations does it express?"
>
> Carla Rinaldi (2006, p. 150)

In designing this PhD I set out to create the conditions for practitioners in the library to do research into collective creativity. In attempting this I took inspiration from the children and educators of the city of Reggio Emilia, Italy. Adherents of the Reggio Emilia approach have always been clear that the theory they create is rooted firmly in practice, even if it takes much of its inspiration from the sciences. Their methods, like so much of their work, are freely shared around the world. But the culture they create within their schools is local, as all culture at this scale ultimately is. Their institutional culture and their method of using Documentation are "interlocked" in the sense used by Gregory Bateson to describe how each sustains and shapes the other (Bateson, 2002).

In the film *An Ecology of Mind*, there is a brief clip of Bateson describing this kind of "interlocked" relationship in simple terms. (You can view it here: https://vimeo.com/573350180)

> The horse and the tundra, the grassy plains, are interlocked. It's an evolution in which now the grass needs the horse, as much as the horse needs the grass. And if you want grass, if you want what's called a lawn in the suburbs, you will first of all go and buy a mower, which will be the teeth of the horse – [to] cut that grass. You will then go and you'll buy a roller. And the roller crushes the grass down and makes it make turf. Then finally, you will end up going and buying a sack of manure, because you have to be at least the other half of the horse too, you see. (Bullfrog Films, 2011)

In other words, the grassy plain sustains the horse, who by clearing, trampling, and fertilizing the field sustains the grassy plains. According to such a model, the introduction of a new method is bound to be an iterative, evolutionary process of establishing a relationship to the surrounding institutional culture. If this can be done successfully, it would pave the way for thinking of the library not just as a place to access knowledge from elsewhere, but also as a place to create new knowledge - in this case, about collective creativity. In other words, practitioner research into play, design, and creativity could carve out its own niche in the library, and demonstrate its own value and perspective in ways that other institutions could begin to recognize.

Part of the value of this work is that it describes, in some detail, an attempt to establish a form of practice based research into play and creativity in the library. In addition to developing new insights tailored to non-formal learning environments, it was also intended to offer citizens the chance to be playful and develop their creativity through hands-on activities. While it did not unequivocally establish this new niche, it does describe the approach used and the challenges encountered in some detail. Part of the value of this account is that it will be useful to research practitioners interested in establishing the same or similar niches. In terms of meeting the goals for supporting playful creativity in the library world set out by Jochumsen et. al. (2010) in *The Four Space Model*, this is a step in the right direction. And a step that can be learned from and improved upon.

I had another motive for working with practitioners in the library. Designing constructionist play activities, environments, and materials is incredibly complex, so much so that quality requires collective creativity. While at MIT Media Lab's Lifelong Kindergarten group I witnessed (and in small ways contributed to) the growth of two famously influential constructionist learning tools: the Scratch programming language and online community, [8] and MaKey MaKey, a computer interface designed for tinkering now used in schools, libraries, and makerspaces around the world. Like nearly all inventions, both of these are (correctly) attributed to the work of a few individuals without whom they would clearly not exist. But witnessing their development gave me the sense that they were also a product of something much harder to attribute: the culture of collective creativity established and maintained by the people around them.

Mitch Resnick is the first to say he couldn't have made Scratch on his own. He inherited, maintained, and developed the culture of collective genius or "Scenius" out of which it emerged. If Scratch is the horse, it could only have evolved in the grassy plains of the Lifelong Kindergarten Group. The implications of this model is that if one wants "horses" in the form of high quality playful learning experiences, one has to work to establish grassy plains where they can evolve. Success comes not only from working *on* a product, but is also dependent on understanding its context and establishing processes to iteratively develop and sustain it.

At the start of this research, my intentions were to launch two separate tracks that would converge halfway through the 3 year PhD project, setting the stage for practice based research into collective creativity. The first was to create the conditions for doing practice-based research into collective creativity in the library. I would establish a small research group consisting of librarian educators interested in tinkering and playful learning. To do this we would read and discuss seminal ideas in constructionist pedagogy; design, run, and Document (in the sense of the word as used by Reggio Emilia) creative tinkering workshops with citizens; and host visiting experts in Tinkering for residencies. Once established, we would do design based research together on the creation of conditions for short-term collective creativity using tinkering activities within the library itself, and share our results with other practitioners as well as the broader academic community. In other words, we would use our newly established grassy plain to evolve some nice practitioner-research horses.

The second track, intended to run concurrently with the first, was my own research into collective creativity. This would include a broad review of the literature that

[8] Scratch 1.3 and the first version of the website was already released by the time I joined the team. But the invention of Scratch was (and is) an ongoing process.

seems most relevant to practitioners, and early experiments in developing new methods. It would continue with experiments in new methods done as part of the Experimenting, Experiencing, Reflecting research project. The hope was that after about a year and half I would have established a foundation in both knowledge, methods, and means for doing practice based research into collective creativity. I would then combine the two tracks to do many iterations of practice based research into collective creativity in the library, with the help and insight of my colleagues there.

It didn't work out like I planned.

The Covid-19 pandemic led to the closure of both the university and the library one week after my PhD officially started in March of 2020. Anyone who lived through it knows the chaos and uncertainty it created, as well as the various attempts to work around the limitations we all tried. We managed as best we could. Colleagues from the library and I met online instead of in person and discussed readings ad nauseam, as it seemed to be the only constructive thing we could do. In these meetings I was forced to become a lecturer, a role I've tried my best to avoid throughout my career by focusing on the design of hands-on workshops and learning environments. I made various attempts at building prototypes for video conferencing systems that could enable creative, hands-on play at a distance and perhaps make it possible to do tinkering research during lockdowns. And there was an online conference built around online playful learning activities co-developed with Ella Paldam from the Interacting Minds Centre. In the end, none of these were relevant enough to the original research focus to make it into this manuscript or the articles.

Instead of the nice converging lines of my original plan, we did what amounts to a relaunch halfway through. At time of writing I am part of a team of librarian educators skilled in the fundamentals of tinkering facilitation and design. They are beginning to be able to generate meaningful Documentation and to develop a shared language for making sense of what we observe during hands-on workshops. Together, the team and I developed and piloted several Tinkering activities based on the Playing with the Sun construction kit. This collaborative process contributed greatly to the design of the kit itself. We can and will share our construction kit and activities with other non-formal learning educators in libraries and science centers. But we cannot claim to have generated new knowledge together about collective creativity.

Below you will find a summary of what was learned from these two tracks. Though I wasn't able to form the synergy between the two that I originally envisioned, the results still have important implications – both for practice based research in the library, and for the study of collective creativity.

5.1 Track one: Practice-Based Research into Collective Creativity in the Library

My plan had real weaknesses and I ran into challenges I hadn't planned for. That in itself is not surprising: Like any decent tinkerer (or design researcher), I had planned to improvise – meaning I had planned to run into challenges I couldn't plan for in advance, and to have time to contend with them. But there was less time to address emergent problems than I needed to solve them.

I will describe a few of the challenges below so that future research practitioners who might wish to try something similar can benefit from them.

5.1.1 Challenges

5.1.1.1 Access to Participants for Design Experiments I chose *Playing with the Sun* and sustainable energy as the context for my research into collective creativity because I felt compelled to do my part as an educator to begin to address the climate emergency. It also fit reasonably well into the requirements and interests of the different stakeholders involved. The complexity of the issue and the technologies involved meant that we needed to work with kids age approximately 8 to 15, which is an age range I've always enjoyed working with.

Having run a few workshops at Maker Faire at Dokk1 Library in 2015, I had an internal picture of it as having a large flow of children of all ages constantly moving through it. I later learned that this really only happens during large events like Maker Faire. Most of the time, most of the children coming to Dokk1 are in the kindergarten or younger age range. We tried doing drop-in *Playing with the Sun* activities with these children on two occasions. While there was some interest and engagement, and enthusiastic parents, we ended up agreeing that the floor could not be made low enough for them to meaningfully engage and build with the construction kit and the activities.

This meant that most of our opportunities for observing children engaging with the activities and the construction kit required us to align with major events where kids 8 and older were present, or to import kids from school. Tinkering activities work best in the non-formal, drop-in environments out of which they emerged, like horses fit on grassy plains. These generally involve people passing by, seeing an interesting activity, joining it (out of their own choice and initiative), learning how to do the activity from seeing others do it, and participating for as long as they choose. For the purposes of iterating on the design of an activity or construction kit, drop-in Tinkering workshops can be run with as few as 2-4 participants at a time and still yield useful design insights and documentation. They can also be bounded at as low as 8 participants at a time in order to maintain an ideal ratio of facilitators and Documenters to participants. Attention is a finite resource, and drop-in workshops make it easy to tailor the number of participants to the research question and the observers who are Documenting.

Participation in drop-in workshop settings is nearly always intrinsically motivated, which means that passersby can self-select. As an educator running a drop-in tinkering activity, one does not have to spend time and energy figuring out how to work with or motivate disinterested participants, because disinterested participants have the freedom to not show up. [9] There is a simplicity and clarity to the proposition to the passerby that says, essentially: "We are experimenting with this activity with these elements. Would you like to try?"

In terms of design iteration potential, this is a very different kind of workshop than one with a group of students brought to the library from school. Most classes have 20 or more participants, which means the facilitators / documenters of the activity have a lot more learners to attend to at once. If one wishes to prototype a new element of a construction kit, one has to have enough working prototypes for everyone to use at once, instead of just a few, which is all that's necessary to sustain a drop-in activity.

Because all of the participants will begin and end the activity at the same time, documenters and facilitators get only one chance to observe each stage of the process. Whereas in a drop in activity, one can notice an issue encountered in the introductory

[9] Some may assume that a good learning activity should work for everyone. I don't agree. We would never hold a book or a piece of art to such a standard. Human beings are diverse across many dimensions, and should be accorded the freedom and respect to choose which learning opportunities to pursue and which not to.

stage and then watch for it to happen again and again as new participants join in and start throughout the day. The logistical costs to the team in terms of planning time and preparation are also much greater when working with school classes. This usually involves a good deal of coordination with the teacher, transportation considerations, lunches, snacks, bathroom breaks, etc.

It's also the case that children visiting the library as part of school classes may not feel intrinsically motivated to participate. In our experiments, almost all of the participants eventually became inspired to engage with the activities. But some started out with the resigned faces of children who expected to be told what to do (as they are, perhaps too often, in school), and also expected that what they would be told to do would be boring. In one workshop, to my great frustration, a few of the children had those resigned faces for the last 10 minutes because no one told them that they were free to experiment outside of our prompt. They clearly didn't expect to be offered this freedom. This raised an important question in our post-workshop reflections about how best to communicate to participants that they have agency, and that our learning context is different from school.

Some still argue that useful learning can happen without the learner's agency, willing participation, and curiosity - qualities that are not always present in learners in schools. But I would argue that creative learning activities cannot be pedagogically successful without authentic learner engagement. Though it may be all we have to work with sometimes, expecting something dull and being pleasantly surprised to find it interesting is not the same as encountering something interesting and freely choosing to join in. Intrinsic motivation matters (Kohn, 1999). That is very relevant both to the establishment of Tinkering in the library and especially to this research. Intrinsic motivation seems to be present in almost all examples of collective creativity I read about in the ethnographic literature. [10]

5.1.1.2 General Data Protection Regulation (GDPR) GDPR is a law pertaining to the collection of identifiable information about individuals. Compliance requires that librarians secure a signature on a long and complex legal form in order to collect identifiable information about an individual or their child. This information

[10] I would argue that this is true of the business literature as well, in spite of the fact that the people working in those environments are undoubtedly also extrinsically motivated by their salaries.

must then be stored in such a way that the individual may revoke their permission and all identifiable data can be found and destroyed.

When running drop-in events with parents and children, it is possible to have the forms ready and to ask a parent to fill them out. But when working with schools, this becomes much more difficult. It's necessary to first give the forms to the teacher, who then has to get them to the parents to be signed, and eventually they must get back to the librarian who must submit them to a local GDPR officer for addition into a database. This creates significant time and energy costs for everyone involved.

GDPR is a significant barrier to the collection of meaningful Documentation of learning experiences. By combining bureaucratic overhead with nebulous and potentially disastrous consequences for failure to properly comply, it creates a powerful chilling effect for practitioners. Many educators I spoke to in the library have responded to GDPR by resolving never to take photographs of children that are identifiable, which limits their documentation to the backs of heads and disembodied hands. Faces are the primary means for humans to communicate their emotional experience, as well as what they are doing or thinking. Without faces, it is much more difficult to interpret what a learner is thinking, feeling, or experiencing. This makes it that much harder to do what is essentially the goal of Reggio inspired Documentation: to make learning visible (Giudici et al., 2008). The fact that public institutions like libraries and universities are held to the same standards as billion dollar corporations whose business models are based on profiting from people's private data is puzzling to me.

Perhaps the most frustrating effect of the GDPR has to do with the prevention of serendipity. When running a Tinkering workshop, one never knows when an interesting learning moment will serendipitously occur. If one hasn't had everyone fill out onerous bureaucratic forms in advance, it's not clear if it is acceptable to pull out one's camera and take a photo of the moment, regardless of how important or meaningful to the research question it is.

Of course the GDPR was created with a laudable goal: to protect children's right to privacy. But it unintentionally makes it more difficult to capture Documentation that could be used to advocate for children's rights as learners, and to highlight the fact that they are capable of leading their own process of learning and inquiry. Librarian educators are resilient and have found ways to work around these challenges.

Many focus on written notes, gathering anonymized quotes, sketching, or gathering discarded products of creative processes for analysis. But doing research on creativity and learning that relies on evidence of learner agency and initiative is subtle and difficult work. GDPR makes it that much harder.

5.1.1.3 Time and motivation for practitioners to reflect on Documentation As described in the article *Experiments towards a Pedagogy of Creativity and Learning in the Library*, educators (and practitioners) of all kinds are extremely busy these days. Most all of them are involved in multiple projects, with multiple stakeholders, with multiple different criteria for success. Within the library world itself there are different views of what constitutes quality in a creative, hands-on workshop. That in itself is not a bad thing. But there is a risk that in the absence of a clearer consensus about quality in creative workshops, important stakeholders like politicians may evaluate them using easily "countable" criteria, like number of participants. As the saying goes, "We treasure what we measure."

Based on conversations with various librarian educators, the consensus seems to be that it will be very difficult to find time in their extremely busy schedules to spend collecting and reflecting on Documentation. The argument for doing Documentation is a difficult case to make, because it asks for a radical shift in priorities that costs a lot in terms of time and attention. It's also not always easy to show how evidence of learner creativity and intelligence in creative activities is even partly attributable to the educator.

Great Documentation puts the focus on the intelligence and creativity of the learner, and doesn't necessarily convey all the work that the educator did to make the learner's creativity possible. As with art, understanding and appreciation of the work sometimes go hand in hand. So there is a kind of chicken or egg problem in trying to establish Reggio Emilia inspired Documentation as a practice in places that have not already fallen in love with the subtleties of the medium. Ideally, quality Documentation inspires a local culture of appreciation for it, which in turn inspires more great Documentation, which creates more appreciation, etc. etc. I haven't figured out how to get that feedback loop going amongst library educators and their surrounding stakeholders. They are a very diverse group, many of whom are focused on things like literacy or book group discussions that don't naturally lend themselves to the method of Documentation, which tends to rely (at least to some degree) on aesthetics.

Libraries function under politicians who tend to ask for new projects and events. These politicians may not have a nuanced understanding of quality in non-formal educational contexts devoted to creativity and open-ended learning. Therefore many of the requests for information about projects from important stakeholders like these will tend to ask for numbers like attendees, time spent, etc. It can be challenging to see how to get politicians on board with a commitment to reflecting more and doing less countable (and more subtle) things.

Changing this system would likely require effort at many levels. Politicians would need to be educated by the practitioners themselves about the value of the educational approaches being developed and refined locally such that they could recognize relatively subtle definitions of quality. That's a big investment. But it is one that might be feasible alongside a commitment to use Documentation as means of evaluating non-formal and playful learning experiences of the sort described in the *Four Space Model* (Jochumsen et al., 2010).

Parents, also, would have to be educated about the value of what their children are doing in playful learning experiences so that they can better learn to recognize it. To do this well, the educators would have to propose, agree on, and refine a shared definition of quality, and learn how to communicate it. There are no external systems pushing for this kind of reinvention of process, and it would only bear fruit after a long investment in terms of time. The case for this kind of approach may have to compete for resources with a variety of other projects with a quicker path to quantifiable gains.

One path to solving this problem is to try and knock the socks off the educators, parents, and politicians by presenting Documentation of quality in learning experiences that is undeniable, and enrolling them in creating a shared articulation of quality that emerges out of it. (And getting a lot of enthusiastic attendees for creative learning activities in the process wouldn't hurt either.) For example, at some workshops the educators on the *Playing with the Sun* team have expressed a kind of thrill of recognition when seeing children engage deeply with the activities and begin to propose and lead their own creative experiments. If we could capture and communicate that well enough, perhaps others would be able to better see the value in it, and wish to be a part of creating it. We aren't there yet, but we have made a start.

5.1.2 The Fundamental importance of Iteration

In developing creative learning experiences, a healthy iteration of the design process entails reflection on the activity, prototyping of some new aspect of the activity, putting it in front of a learner, observing and documenting their interaction, and reflecting on it at the start of the next iteration. All of the challenges described above have the same fundamental effect on the design process: They increase the opportunity costs associated with some portion of the design iteration cycle. Because time and energy are both finite, the result is fewer effective design iterations. The cost of that is in both speed and quality in terms of the product or activity being designed, but also in terms of the insights and professional development of the research practitioner. The quicker one can meaningfully iterate (and the lower the cost per iteration), the better.

Although we haven't been able to move as quickly as I'd hoped, we have come quite far. There is now a small team of librarian educators in Dokk1 who have a good foundation in this methodology (as well as the accompanying theory). Among these team members there is enthusiasm and appreciation about tinkering and open-ended creative learning in general. One team member recently remarked "It's nice to have been part of the process of building an actual 'thing' (referring to the *Playing with the Sun* construction kit.)" Creating learning tools like construction kits involving electronics is not normally in the realm of possibility for librarian educators. We have proven that it is something that can be done in a library, by and for librarian educators. In a little over a year, we have managed to evolve a pretty good horse with our little grassy plain.

5.1.3 Ways Forward

The grassy plain is setup to make more horses. The participants in the Playing with the Sun project now have a shared language around tinkering design - including concepts like iteration, the importance of reflection, and how to perceive and support children's engagement. The design concepts of "Low floor" and "High ceiling" are no longer just abstractions from a book – they have seen the meaning and relevance in practice. And they know how to use this design language in post-workshop reflections designed to highlight what worked and what didn't in such a way that we can see what needs improvement in the road ahead. The key elements of the oral tradition around tinkering that I learned from working with constructionist learning designers at MIT's Lifelong Kindergarten Group and the Tinkering Studio at the Exploratorium have been passed on.

The prior work with the Creative Learning Research Group described in the first article also suggests that Documentation practices do lead to insights and framings that, in the aggregate over time, could lead to the development of practice-based theory about learning and creativity tailored for the library. The insights about the roles of parents and grandmothers in supporting children's creativity (described in Appendix 3 as well as in *Experiments towards a Pedagogy of Creativity and Learning in the Library*) seem particularly relevant here. If librarian educators can generate theory to explain how best to engage parents as co-facilitators in creative activities, such a theory would likely be useful in many different non-formal learning contexts.

Similarly, the idea of *handlemod* (similar to creative confidence) that emerged out of discussions in the Creative Learning Research Group seems applicable to all educators working with creative learning - inside or out of schools. The documentation of and reflection on various means of intervening with low-handlemod learners would likely lead to useful insights and techniques for intervening that could be broadly applicable. This might be a way to spark a reflective conversation in a larger network of library educators that would be a means of developing a shared sense of quality at a larger scale.

It may be that this experience of a different kind of attention about learning will bear fruit among the educators who participated in this research, perhaps even years later. But it may also get filtered out by the environmental conditions the educators are in. As with every grant driven organization, there is pressure to deliver outcomes according to each funder's definition of quality. This can easily crowd out the space and time for practitioner educators to develop their own emergent and subtle sense of what constitutes quality within their local context. To apply Bateson's metaphor to a level higher up in scale, the librarian educators themselves are interlocked with their funding landscape. As horses, they can try to evolve in a new direction, but only so far as they can convince their grassy plain to evolve with them. A practitioner researcher's method will always be interlocked with its institution, and its institution is always interlocked with its external stakeholders. Change requires complex orchestration at multiple scales.

The challenges described above do not seem insurmountable, but they are challenges. Would my plan to create the conditions for doing practice-based research into collective creativity in the library have worked if there hadn't been a Covid-19 pandemic? I don't know. Even if it failed, it would have been nice to be able to fail more clearly, under better circumstances. Nevertheless I will assert that this failure has generated a lot of useful knowledge is a contribution to the field. Librarian educators interested in developing a shared definition of quality can benefit from the work described herein as well as this description of challenges encountered along the way. If Jochumsen et. al.'s (2010) goals for supporting innovation and creativity in Danish libraries are to be achieved, it will require libraries and librarian educators who are willing to keep failing usefully, like this, until they succeed.

5.2 Track Two: Methods, data, and theoretical contributions for the Study of Collective Creativity

5.2.1 A New Method for Creating the Conditions for and Studying Collective Creativity

Though the two tracks never converged the way I'd planned, I was able to develop and pilot two new methods for generating new knowledge about collective creativity. The methods described in "Short-term ecology" article and the "Recursive prompting" article capture useful insights about the movement of ideas in collectively creative activities and how to design for collective creativity. Both offer a strategy for research practitioners to create the conditions of collective creativity on a short-time scale with general populations. As such, they show how practice based research of the sort described herein could be used by educators working in non-formal educational institutions. Such methods could satisfy both their primary purpose of offering meaningful learning experiences to citizens, as well as generating new knowledge about collective creativity. They show a path for changing from a practitioner to a research practitioner.

Each of the methods described can be iterated on and adapted to different purposes. For example, in a non-formal context like a science museum or library these could be a basis for ongoing practice-based research into different kinds of creativity. They are inexpensive in terms of resources and materials. Even if it does take more time than most library educators are used to allocating to a single area of inquiry, these methods are a lot less time intensive than ethnography. And they can yield different but complementary insights to ethnography.

The recursive prompting method in particular shows directions for future design based inquiry, and frames several problems in the design of the method that could be subsequently addressed. For example, there's a need for a change in the structure to allow participants to get familiar with the materials and practices before asking them to select a sub-prompt or area of the recursive prompting board in which to situate their further creative exploration. This is not a hard idea for other research practitioners interested in tinkering and play to begin to experiment with. Nor is it particularly difficult to try out different prompting strategies to better support collective exploration, and encourage people to see the documentation of past work done by others as useful sources of insight on which to build.

Recursive prompting points towards a strategy for applying shared collective inquiry by citizens into many different kinds of design problems. For example, it might be possible to invite participants in a focus group to debate a design question, summarize the three main conclusions that emerge, and then feed those forward to the next group of citizens for comment or prototyping. Recursive prompting illustrates a potentially generalizable means of both mapping and analyzing collective inquiry as exploration of the adjacent possible, and so has the potential to be applied in many different domains.

Neither recursive prompting nor the means of designing activities described in *A Short-Term Ecology for the Having of Wonderful Ideas* are repeatable in a strict sense. The laws of physics are the same everywhere, but culture, learning, and creativity are local. For that reason these kinds of collectively creative activities could be a means of exploring differences across cultures, populations, etc. which could lead to further useful insight. One possible research question could be: Do some populations or cultures find it easier to engage in collective creativity than others? If so, why? The answers will have implications for both anthropology, education, and creativity research.

If we view the creation of these methods as an ongoing design research project, then they are still in their early stages. But they are ready to be put into iterative practice and development by a small team of practitioner researchers, ideally based in a library.

5.2.2 Data gathered about collective creativity and implications

The experiment described in the *Short-term ecology* article suggests that ideas evolve through cross-pollination within collectively creative activities, and that we can create a "fossil record" used to map and retrospectively analyze their emergence using Documentation. For one thing, we can see the tributaries of an idea as it emerges across different people working in the same group. In some cases these people never directly encountered or communicated with one another, yet they all clearly contributed something to the process of an interesting creative outcome.

The role of the "Catalyst" can be described as a kind of engine of serendipity: They help cross-pollinate different ideas through the group. The goal of this process is not so different from the way Catmull describes the intent and purpose behind the design of Pixar's office space.

> Most buildings are designed for some functional purpose, but ours is structured to maximize inadvertent encounters. At its center is a large atrium, which contains the cafeteria, meeting rooms, bathrooms, and mailboxes. As a result, everyone has strong reasons to go there repeatedly during the course of the workday. It's hard to describe just how valuable the resulting chance encounters are. (Catmull, 2008)

The data described in *A short term ecology* provides an example of how Catmull might go about systematically describing those chance encounters: by mapping them. This could be a step towards better analyzing and describing their value. Both the design of Pixar's offices and the actions of the Catalysts describe different means of designing for serendipitous group reflection and cross-pollination of ideas. The evidence for the importance of serendipity can be found in many different places in the literature on collective creativity (Bakker 2018, Glăveanu, 2020, Von Hippel 2005, Sawyer & DeZutter 2009). The data collected from these methods and interventions adds to this chorus of voices.

As described by one interlocutor from *A Short Term Ecology for the Having of Wonderful Ideas*, the ability to assert one's own ideas while ensuring plenty of space for other's ideas in a collectively creative activity can be seen as a skill. A skill is distinct from a trait in that it can be (and may need to be) learned. If this is accurate, it follows that this could be an area for educators to begin to think more about and even to design for. There is no pedagogy of collective creativity that I'm aware of - although the Reggio Emilia approach and constructionism certainly have key elements of one. But this data raises the question: Should there be? If collective creativity really is the foundation for many of the breakthroughs which today we tend to attribute to individual geniuses, shouldn't we be designing learning experiences that support its development? How else will children learn how to identify and find the balance between asserting their own ideas and maintaining space for others that my interlocutor so eloquently described?

The data collected also suggests that people play many different roles in collectively creative experiences. The conventional framing of "so and so had an idea" is insufficient in these contexts. Rather, the evidence gathered suggests that "an idea" had by someone may instead be the result of a process that is larger than any individual. This would agree with evidence from both Sawyer (2014) and Von Hippel's (2005) work, which also highlights how collective creativity emerges out of diverse communities. This has implications for pedagogy, including the pedagogy of design.

The data in the solar drawing machines workshop shows people playing different kinds of roles in the collectively creative experience - many more roles than just the people who "have the idea." Some are in the assigned role of catalyst, but others are riffing on ideas, and still others are focused on prototyping, and still others are being skeptical. It is possible that good ideas generally have more kinds of "parents" than we are generally aware of, just as Kurt Vonnegut's character Billy in the novel *Slaughterhouse 5* is unaware of the crucial role that male homosexuals and women over sixty-five play in earthling sexual reproduction in the fourth dimension (Vonnegut, 2005). We do not yet have enough data to determine how best to characterize these different roles. But we do now have a method that could be used to create the conditions to explore that question further.

5.2.3 Theoretical Contributions

This research argues that the pedagogy of Tinkering can be used as a means of systematically exploring a design space framed as Kauffman's adjacent possible, an idea that has its foundations in biology. The implication is that the act of tinkering is fundamentally compatible with the notion of the adjacent possible, and that as Bateson argued (2002), the processes of learning and evolution are essentially the same patterns operating at different scales.

There is at least anecdotal evidence for the idea that tinkering is an effective means of exploring the adjacent possible in the form of stories of innovation in science and design. In his book *Where good ideas come from: the natural history of innovation* (2011), Steven Johnson describes accounts of important breakthroughs he characterizes as explorations of the adjacent possible, including a few very import accidental ones like the discovery of penicillin. This idea is explored further in his later book *Wonderland: how play made the modern world* (2016), in which he describes how playful tinkering has served as a means of inquiry into adjacent possibles that have often led to fundamental breakthroughs in science and engineering. Clearly this is not the only factor in creative breakthroughs - but there is an argument to be made that it may be an important aspect.

It is beyond the scope of this research to definitively prove or disprove Johnson's assertion, or such weighty contentions as those argued by the likes of Bateson and Kauffman. What it can do is suggest strategies for putting these ideas into practice to see what emerges. If there is a fundamental similarity, irrespective of the differences in time scales, between Tinkering and the movement between adjacent possibles that appears in the fossil record, then the means for studying one should be roughly applicable to the other. I have shown the utility of that theory by creating an artificial fossil record of emergent ideas in a tinkering workshop. I argue that this gives us a systematic way of understanding of how the exploration of the adjacent possible works in collectively creativity experiences.

The application of the adjacent possible to the ethnographic data about collective creativity collected by Shah in von Hippel's Democratizing Innovation (2005), described in the Discussion section of the Literature Review chapter, is also a theoretical contribution. The theory of the adjacent possible allows us to better understand the process through which high performance wind surfing emerged out of a collective inquiry. The implications of having a better theoretical grip on these phenomena are significant. The theory explains why innovation within communities of practice will depend on access to materials for prototyping, and storage of past prototypes. These are the essential nutrients out of which adjacent possibles can be found or formed, without which they can never become "actuals" from which to explore further adjacent possibles.

What does this imply about communities under stress, without access to resources? It suggests that rather than only offering aid in the form of necessities, it may be important to offer a library of ingredients that can be used to make prototypes and explore adjacent possibles — even if we cannot know in advance exactly how those ingredients will be used or to what purpose.

For example, it is obvious that people in refugee camps need shelters, and we should certainly provide these. But they may also need elements with which to construct local solutions that we cannot predict, model, or imagine. People who are not living in the camp (or who are outside of any local context) will lack the necessary contextual knowledge and experience of what is needed beyond the immediately obvious, and they probably always will. But it may be possible to provide elements — perhaps a set of "primitives" designed to be interoperable — that would likely prove useful for a local exploration of adjacent possibles by the people in the camp. Such a library of elements for exploring adjacent possibles in domains like these could provide powerful "objects-to-think-with" (Papert, 1980).

As described in the *Short Term Ecology* article, Constructionism positions learning and creativity as aspects of the same fundamental process of knowledge construction. That process benefits from objects-to-think-with in their role as a bridge between the concrete and the abstract, which supports the creation and refinement of the learner's internal schema, or models of how things work. Part of what this research shows is how objects-to-think-with (or in the language of design, prototypes) can work in a similar way for groups of people engaging in short-term collectively creative experiences.[11] This can inform new strategies for organizing people to both ask and

[11]Levi-Strauss' work and its influence on both Piaget and Papert is an area that could benefit from further scholarship, but is beyond the scope of this work. It would be useful to investigate how his description of how thinking can be influenced by totems evolved into Papert's objects-to-think-with.

answer questions that are meaningful to them together. It offers evidence of scale invariance: that the phenomena of tinkering as an individual learning experience can be generalized to groups while maintaining many of the same qualities. This is a small step towards validating Bateson's contention that learning in individuals and evolution at the scale of the planet are essentially the same processes operating at different scales (2002).

What are the implications of further evidence of the correspondence of Tinkering as a means of exploring the adjacent possible? In education, it would argue for greater emphasis on process and communication, and the exploration of open-ended possibilities. That itself would be contingent on a few things. First, collective creativity would need to gain greater recognition for its importance to the process of innovation. Second, the ability to usefully contribute to collective creativity would need to be recognized as a learnable skill (as opposed to an innate trait). Finally, the field of education would need to relax some of its goals that are measured in terms of content delivered, which tend to crowd out the space for less deterministic and measurable learning experiences. It would have to allocate more time and resources to activities with more creative, nebulous, and unpredictable outcomes (at least in the short term). A deeper description of creativity as a fundamental, scale invariant process occurring in all areas of the living world could be one way to bolster the argument for such a change. Recursive prompting activities that result in genuinely innovative design solutions, complete with descriptive evidence of the collectively creative processes that led to them, could be another.

6 Conclusion

It is strange to me that in the country where I grew up, the United States of America, practitioners like counselors and educators don't have a stronger voice in societal conversations related to the work they do every day. Who else can claim to have seen the major social issues of our time up close as they manifest themselves, through hundreds and sometimes thousands of people, over the course of years and even decades? The ever increasing workloads and bureaucratic requirements they are saddled with must be one reason for this. But the lack of structures to support and make time for collective reflection also play a part. Whatever the reasons, I am convinced that the perspectives of thoughful practitioners will invariably contain important insights, and deserve to be amplified for the good of us all.

One goal of this research was to create an example that educators working in non-formal learning environments anywhere might choose to borrow and adapt to their own purposes. There are drawbacks to being in the thick of the work of education, but there are also advantages. If we can take a page from Reggio Emilia, perhaps we can learn to integrate the work of education with the work of research. This would seem to be a viable path to an upgrade in status for practitioners. If we can generate theory - recognizable, comprehensible, and applicable theory to explain what we see and do – then our status can change from that of a technician maintaining an institutional machine to a designer capable of changing it. All of the institutions I've worked in as a counselor and an educator are in need of change informed by the voices of the practitioners within them. And we are entering an era in which all institutions must change, and quickly, to cope with a rapidly developing climate emergency.

This research provides evidence that running Tinkering activities in non-formal learning environments is a viable means of creating the conditions for and studying collective creativity. Despite the focus on research, the pedagogical value for learners participating in these activities appears to be preserved. It seems very likely that learners benefit from these experiences in the ways that Bevan et al. describe in *Learning through STEM Rich Tinkering* (2015). And there is an additional argument to be made that in order to learn how to participate in collective creativity, people need to enter a context where they have a chance to experience it.

One of my goals was to try and establish a positive feedback loop between research and the practice of education. Designing and facilitating creative learning experiences is subtle work. Processes that lead to quality require ongoing dialogs between educators and learners that is a form of design based research. Because success is defined as enabling the learner to manifest their unique intelligence and creativity, the work is deeply connected with local culture and exquisitely sensitive to the knowledge, skills, and curiosity of all the participants (Krechevsky et al., 2013). At least according to the research I read, the same is true of collective creativity. This is why I argue that this kind of highly local research is one of the best means of developing a general understanding of collective creativity.

But limitations and failures to achieve the original vision must be acknowledged. I was not successful in establishing methods for practitioner based research that will likely continue after this PhD is completed. That would have looked like children and adults returning to the library again and again, of their own free will, to participate and expand the realm of possibilities offered by the activities (similar to early adopters in the Scratch online community). It would require a team of educators and a project structure that would enable them to maintain an ongoing dialog with these learners that results in shareable insights. And it would require an audience - perhaps a network of practitioners - interested in reading and thinking about those insights. That's a very tall order, and there are a variety of reasons why it didn't work out. The Covid-19 pandemic costing us 18 months of iteration between me, our design team, and the public is one of them. Though I cannot prove it, I believe success in this area is possible, and that this research makes a good summary of what would be needed to achieve it.

What this does show is that it is within the scope and ability of non-formal educators in libraries to design creative learning experiences and construction kits, provided they are lucky (and / or perhaps assertive) enough to have the following:

- A practical, comprehensible theory to shape and guide their work.
- Time and resources to iteratively design and propose activities to the public.
- The epistemic confidence to assert interpretations and explanations, which are the precursors of theory-making. (Weick, 1989)
- Some means of group reflection on the process and whatever is observed.

In addition, the research suggests several new questions worth asking in the future:

- What can we learn about collective inquiry by collecting documentation of creative projects made by participants with similar prompts but varying geographic and cultural locations?
- What kind of framing, institutional support, and funding would be necessary to support similar research by non-formal educators involving creativity (collective or otherwise) and learning?
- What is the epistemic relationship between a practitioner's willingness to uncritically accept conclusions from scientistic or scientific research, and their hesitancy about their own observations, interpretations, and theory making?
- As we learn how to facilitate collective inquiry with tinkering activities like those created as part of *Playing with the Sun*, can we then make the shift to "real world" problems? For example, can we run a collective shared design inquiry on how to dry our clothes more efficiently, or how to redesign aspects of a city to better integrate local sources of sustainable energy, or solve other local sustainability problems? The advantage that might be leveraged here is the one Von Hippel (2005) identified as present in many of the innovation communities his research describes: Designing and prototyping *in situ*, with all the relevant context at hand, confers tremendous benefits to the process.

As we move into this new and perilous phase of human history, the only certainty we have is that there will be dramatic change, intentional and otherwise. Our future will depend on how we manage that change and uncertainty. The tremendous breakthroughs in science and technology over the past few centuries have led to the epistemic dominance of the objective over the subjective, the global over the local, and the genius of the individual over the intelligence and wisdom of the collective. In my view, these are all bundled together at the root of the crisis we are facing. If we are to find a new way of living that is compatible with the rest of life on earth, on which we manifestly depend, it will require new ways of thinking and being creative together.

We are going to need collective creativity.

7 References

Ackermann, E. K. (2010). Constructivism(s): Shared roots, crossed paths, multiple legacies. *Proceedings of Constructionism 2010 Conference, Paris.*

Adaptive radiation. (2022). In *Wikipedia.* https://en.wikipedia.org/w/index.php?title=Adaptive_radiation&oldid=1130431744

Bakker, A. (2018). *Design research in education: A practical guide for early career researchers.* Routledge.

Barab, S., & Squire, K. (2004). Design-Based Research: Putting a Stake in the Ground. *Journal of the Learning Sciences*, *13*(1), 1–14. https://doi.org/10.1207/s15327809jls1301_1

Bateson, G. (2002). Mind and nature: A necessary unity. Cresskill, NJ. Hampton Press.

Bateson, P. P. G., & Martin, P. (2013). Play, playfulness, creativity and innovation. Cambridge University Press.

Benkler, Y. (2017). Peer production, the commons, and the future of the firm. *Strategic Organization*, *15*(2), 264–274. https://doi.org/10.1177/1476127016652606

Bevan, B., Gutwill, J. P., Petrich, M., & Wilkinson, K. (2015). Learning Through STEM-Rich Tinkering: Findings From a Jointly Negotiated Research Project Taken Up in Practice. Science Education, 99(1), 98–120. https://doi.org/10.1002/sce.21151

Brennan, K. A. (Karen A. (2013). *Best of both worlds: Issues of structure and agency in computational creation, in and out of school* Thesis, Massachusetts Institute of Technology. https://dspace.mit.edu/handle/1721.1/79157

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. The Journal of The Learning Sciences, 2(2), 141–178.

Bullfrog Films. (2011). *An ecology of mind.*

Catmull, E. (2008). How Pixar Fosters Collective Creativity. (Cover story). Harvard

Business Review, 86(9), 64–72. Business Source Complete.

Cobb, P., diSessa, A., Lehrer, R., Schauble, L. (2003). Design experiments in educational research. Educational Researcher, 32(1), 9–13.

Computer Clubhouse History. (n.d.). Global STEM After School Program | The Clubhouse Network. Retrieved 9 April 2023, from https://theclubhousenetwork.org/about/history/

Cranky Contraptions | Exploratorium. (2023, April 12). https://www.exploratorium.edu/tinkering/projects/cranky-contraptions

Cybernetics. (2023). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Cybernetics&oldid=1134800481

Duckworth, E. (1972). The Having of Wonderful Ideas. *Harvard Educational Review*, *42*(2), 217–231. https://doi.org/10.17763/haer.42.2.g71724846u525up3

Fischer, G., & Vassen, F. (2011). Collective Creativity: Collaborative Work in the Sciences, Literature and the Arts. BRILL. https://doi.org/10.1163/9789042032743

Frere-Jones, A. (2014). Ambient Genius: The Working Life of Brian Eno. The New Yorker, 90 (82).

Gabaree, L., Rodeghiero, C., Presicce, C., Rusk, N., & Jain, R. (2020). Designing creative and connected online learning experiences. *Information and Learning Sciences*, *121*(7/8), 655–663. https://doi.org/10.1108/ILS-04-2020-0121

Giudici, C., Barchi, P., & Harvard Project Zero (Eds.). (2008). *Making learning visible: Children as individual and group learners ; RE PZ* (4. printing). Reggio Children.

Glăveanu, V. P. (2020). A Sociocultural Theory of Creativity: Bridging the Social, the Material, and the Psychological. *Review of General Psychology*, *24*(4), 335–354. https://doi.org/10.1177/1089268020961763

Gutwill, J. P., Hido, N., & Sindorf, L. (2015). Research to Practice: Observing Learning in Tinkering Activities. *Curator: The Museum Journal*, *58*(2), 151–168. https://doi.org/10.1111/cura.12105

Hart, Y., Mayo, A. E., Mayo, R., Rozenkrantz, L., Tendler, A., Alon, U., & Noy, L.

(2017). Creative foraging: An experimental paradigm for studying exploration and discovery. *PLOS ONE*, *12*(8), e0182133. https://doi.org/10.1371/journal.pone.0182133

Hippel, E. von. (2005). *Democratizing innovation*. MIT Press.

How Many Combinations Are Possible Using 6 LEGO Bricks? (2017, February 12). Mental Floss. https://www.mentalfloss.com/article/92127/how-many-combinations-are-possible-using-6-lego-bricks

Hrynkiw, D., & Tilden, M. W. (2002). *Junkbots, bugbots, and bots on wheels: Building simple robots with BEAM technology*. McGraw-Hill/Osborne.

IDEO. (2015). *Design Thinking for Libraries: A Toolkit for Patron Centered Design*. IDEO. http://designthinkingforlibraries.com/

Jochumsen, H., Skot-Hansen, D., & Hvenegaard, C. (2010). A new model for the public library in the knowledge and experience society. 5.

Johnson, S. (2011). *Where good ideas come from: The natural history of innovation* (1. paperback ed). Riverhead Books.

Johnson, S. (2016). *Wonderland: How play made the modern world*. Riverhead Books.

Kauffman, S. A. (2014). Prolegomenon to patterns in evolution. Biosystems, 123, 3–8. https://doi.org/10.1016/j.biosystems.2014.03.004

Kauffman, S. (1995). At home in the universe: The search for laws of self-organization and complexity. New York: Oxford University Press.

Kauffman, S., Pathak, S. D., Sen, P. K., & Choi, T. Y. (2018). Jury Rigging and Supply Network Design: Evolutionary "Tinkering" in the Presence of Unknown-Unknowns. *Journal of Supply Chain Management*, *54*(1), 51–63. https://doi.org/10.1111/jscm.12146

Kelly, K. (2008). Scenius, or Communal Genius. *The Technium*. https://kk.org/thetechnium/scenius-or-comm/

Kohn, A. (1999). *Punished by rewards: The trouble with gold stars, incentive plans, A's, praise, and other bribes*. Houghton Mifflin Co.

Learning Dimensions of Making and Tinkering: A professional development tool for educators | Exploratorium. (n.d.). Retrieved 10 April 2023, from https://www.exploratorium.edu/tinkering/our-work/learning-dimensions-making-and-tinkering

Lévi-Strauss, C., & Lévi-Strauss, C. (2000). *The savage mind.* Univ. of Chicago Press.

Lorenz, Edward Norton (1963). *Deterministic nonperiodic flow.* Journal of the Atmospheric Sciences. 20 (2): 130–141. Bibcode:1963JAtS...20..130L. doi:10.1175/1520-0469(1963)020<0130:DNF>2.0.CO;2.

Martin, F. (1988). Children, Cybernetics, and Programmable Turtles. *Massachusetts Institute of Technology Press.*

Martinez, S. L., & Stager, G. (2019). *Invent to Learn: Making, Tinkering, and Engineering in the Classroom.* Constructing Modern Knowledge Press. https://books.google.dk/books?id=gjjHwAEACAAJ

Maturana, H. R., & Varela, F. J. (1980). *Autopoiesis and Cognition: The Realization of the Living* (Vol. 42). Springer Netherlands. https://doi.org/10.1007/978-94-009-8947-4

McKenney, S., & Reeves, T. (2018). Conducting Educational Design Research (2nd ed.). Routledge. https://doi.org/10.4324/9781315105642

Minuchin, S. (1974) Families and Family Therapy. Harvard University Press, Cambridge.

Minuchin, S., & Fishman, H. C. (1981). *Family therapy techniques.* Cambridge, MA: Harvard University Press.

Monechi, B., Pullano, G., & Loreto, V. (2019). Efficient team structures in an open-ended cooperative creativity experiment. Proceedings of the National Academy of Sciences, 116(44), 22088–22093. https://doi.org/10.1073/pnas.1909827116

Octoverse 2022: The state of open source. (2022). The State of the Octoverse. https://octoverse.github.com/

OPEN SCIENCE COLLABORATION. (2015). Estimating the reproducibility of psychological science. *Science*, *349*(6251), aac4716. https://doi.org/10.1126/science.aac4716

Parjanen, S. (2012). Experiencing Creativity in the Organization: From Individual Creativity to Collective Creativity. Interdisciplinary Journal of Information, Knowledge, and Management, 7, 109–128. https://doi.org/10.28945/1580

Papert, S. (1982). Mindstorms: Children, computers, and powerful ideas (Reprint). Harvester Press.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer*. BasicBooks.

Papert, S. (2005). You Can't Think About Thinking Without Thinking About Thinking About Something. *Contemporary Issues in Technology and Teacher Education [Online Serial], 5(3/4)*. https://citejournal.org/volume-5/issue-3-05/seminal-articles/you-cant-think-about-thinking-without-thinking-about-thinking-about-something

Papert, S., & Harel, I. (1991). Situating Constructionism. In *Constructionism*. Ablex Publishing Corporation.

Petrich, M., Wilkinson, K., & Bevan, B. (2013). It looks like fun, but are they learning? In M. Honey & D. Kanter (Eds.), Design, make, play: Growing the next generation of STEM innovators. Routledge.

Resnick, M. (2017). *Lifelong kindergarten cultivating creativity through projects, passion, peers, and play*. https://doi.org/10.7551/mitpress/11017.001.0001

Resnick, M., & Rusk, N. (1996). The Computer Clubhouse: Helping Youth Develop Fluency with New Media. *Proceedings of the 1996 International Conference on Learning Sciences*, 285–291.

Resnick, M., & Silverman, B. (2005). Some reflections on designing construction kits for kids. *Proceedings of the 2005 Conference on Interaction Design and Children*, 117–122. https://doi.org/10.1145/1109540.1109556

Ritchie, S. (2022). *Rebuilding After the Replication Crisis—Asterisk*. Asterisk Magazine. https://asteriskmag.com/issues/1/rebuilding-after-the-replication-crisis

Robinson, K., & Aronica, L. (2015). *Creative schools: The grassroots revolution that's transforming education*. Viking.

Rogers, C. R. (1995). *On becoming a person* (2nd ed.). Houghton Mifflin (Trade).

Rosenberg, M., Noy, L., Tylén, K., & Gordon, G. (2022). Social Interaction Dynamics Modulates Collective Creativity. *Proceedings of the Annual Meeting of the Cognitive Science Society*, *44*(44), 10.

Ruttonsha, P. L. Z. (2017). The Many Faces of Design. FormAkademisk - Forskningstidsskrift for Design Og Designdidaktikk, 10(1). https://doi.org/10.7577/formakademisk.1458

Sawyer, R. K., & DeZutter, S. (2009). Distributed creativity: How collective creations emerge from collaboration. Psychology of Aesthetics, Creativity, and the Arts, 3(2), 81–92. https://doi.org/10.1037/a0013282

Sawyer, K. (2012). Extending Sociocultural Theory to Group Creativity. Vocations and Learning, 5(1), 59–75. https://doi.org/10.1007/s12186-011-9066-5

Sawyer, R. K. (2014). Group Creativity Music, Theater, Collaboration. Psychology Press.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. Basic Books.

Scratch—Imagine, Program, Share. (n.d.). Retrieved 9 April 2023, from https://scratch.mit.edu/statistics/

Sosa, R. (2019). Accretion theory of ideation: Evaluation regimes for ideation stages. *Design Science*, *5*, e23. https://doi.org/10.1017/dsj.2019.22

Tang, T., Vezzani, V., & Eriksson, V. (2020). Developing critical thinking, collective creativity skills and problem solving through playful design jams. Thinking Skills and Creativity, 37, 100696. https://doi.org/10.1016/j.tsc.2020.100696

Tinkering Project: Scribbling Machines | Exploratorium. (2023). https://www.exploratorium.edu/tinkering/projects/scribbling-machines

Tria, F., Loreto, V., Servedio, V. D. P., & Strogatz, S. H. (2015). The dynamics of correlated novelties. Scientific Reports, 4(1), 5890. https://doi.org/10.1038/srep05890

Triplo viso strano. (2020). *Scintillae*. https://scintillae.org/en/project/triplo-viso-strano-2/

Turkle, S., & Papert, S. (1990). Epistemological Pluralism: Styles and Voices within the Computer Culture. *Signs: Journal of Women in Culture and Society*, *16*(1), 128–157. https://doi.org/10.1086/494648

Vecchi, V. (2010). Art and Creativity in Reggio Emilia (0 ed.). Routledge. https://doi.org/10.4324/9780203854679

Vecchi, V., & Reggio Children Srl (Eds.). (2002). *Theater curtain: The ring of transformation* (1. ed). Reggio Children.

Vonnegut, K. (2005). *Slaughterhouse-five, or, The children's crusade: A duty-dance with death* (Dial Press trade pbk. ed). Dial Press.

Vossoughi, S., & Bevan, B. (2014). Making and Tinkering: A Review of the Literature. National Research Council Committee on Out of School Time STEM, 57.

Vygotsky, L. S. (1990). Imagination and Creativity in Childhood. Journal of Russian & East European Psychology, 42, 7–97.

Ward, M. (2001). Beyond chaos: The underlying theory behind life, the universe, and everything. New York: Thomas Dunne Books.

Weick, K. E. (1989). Theory Construction as Disciplined Imagination. *The Academy of Management Review*, *14*(4), 516. https://doi.org/10.2307/258556

Xanthoudaki, M., & Blanton, A. (2021). *Creative Learning in STEM: towards the design of an approach between theory and reflective practice. 17*(3), 10.

Yalom, I. D. (1980). Existential Psychotherapy. Basic Books.

8 Article: Experiments towards a Pedagogy of Creativity and Learning in the Library

Amos Blanton, MA EdS. Draft 15 August 2023 (Post PhD submission) Accepted for publication at the Journal of Creative Library Practice (with request for revisions, addressed in this draft)

8.1 Abstract

This describes a case study of efforts to create the conditions for library educators to engage in a dialog between theory and practice intended to enable them to eventually develop a pedagogy of creativity and hands-on learning for the library. Over 14 months of biweekly meetings, 5 librarian educators led by the author studied constructionist learning theory and a method of doing practice based research from the pedagogy known as the Reggio Emilia approach, and ran two hands-on workshops for adults and children. Documentation from those workshops is included as well as an analysis of the challenges that became evident during the process. Implications for libraries as non-formal learning institutions are discussed.

8.2 Introduction

In *A new model for the public library in the knowledge and experience society*, Jochumsen et al. (2012) articulate a need for libraries to support learning as "a dialogue-oriented process that bases itself on the user's own experiences and their wish to define their own learning needs." This kind of learning "takes place in an informal environment – it happens through play, artistic activities and many other activities." Towards this end, they describe a need to "translate the model's more abstract concepts into a concrete reality."

What Jochumsen et al. describe is not so much a set of discrete goals as it is a culture shift in the way libraries think about learning and how they serve their communities. Rather than facilitating the consumption of facts, they suggest that libraries could become a place where new ideas are created, playfully and in community. Many other libraries have been exploring a similar set of values about learning (Rasmussen, 2016), often involving giving citizens access to new creative technologies through makerspaces (Willingham & DeBoer, 2015; Einarsson & Hertzum, 2020). In terms of learning, this amounts to a tectonic shift - especially for the people working in the library. Instead of "shushing" to keep things quiet, this vision has them learning to elicit the citizen's creativity and self-expression through a collection of skills that are the opposite of "shushing."

Aarhus Public Libraries, co-sponsor of this research, have been working on developing "a library for people and not books" (Østergård, 2019) since their flagship library, Dokk1, was conceived a decade ago. Inspired by human-centered design, their vision states that "The library of the future should be co-created with the citizens" (Bech-Petersen, 2016). This is done through an ongoing dialog between the librarians and citizens, the principles of which are described in *Design Thinking for Libraries: A Toolkit for Patron Centered Design* (IDEO, 2015), which they co-authored with the design firm IDEO and Chicago Public Libraries.

This work describes investigations into the question of how to develop and facilitate hands-on playful and creative learning activities in the library, a subset of the broader challenge described by Jochumsen et al. 2012. The research question is: How can we create the conditions for a dialog between theory and practice that could enable library educators to develop a pedagogy of creativity and learning for the library? The goal here is to experiment with reflective processes that could create the conditions for practitioner educators working in libraries to ask and answer their own questions. These processes, as well as observations and challenges that emerged along the way, are described below.

One risk inherent to all project-driven organizations is that each project tends to generate ideas and insights that are tailored to its own needs. If there are many projects running concurrently, they can easily crowd out the space and time for reflection necessary for educators to convert specific insights into generalizable theory. I argue that what is required to meet Jochumsen et al.'s challenge in the long the run is a robust general theory of play and creativity *in the library* - a pedagogy. The goal of this research is to experiment with theory and methods for supporting reflective practice that could create the conditions for developing and refining such a pedagogy. These are drawn primarily from two traditions in progressive education: constructionism (Papert, 1980) and the Reggio Emilia approach (Guidici et al., 2008 and Krechevsky, et al. 2013).

As Dubin (1976) described it, “A theory tries to make sense out of the observable world by ordering the relationships among elements that constitute the theorist's focus of attention in the real world” (in Weick, 1989). A pedagogy is a theory of learning that clarifies what kind of learning is valuable and why, and how best to create the conditions for it to occur (‘Pedagogy’, 2022). Like any theory that is useful for practitioners, it must enable them to make sense of what they observe, guide their interventions, and help them articulate why they do what they do for the stakeholders around them. In addition, it should provide a shared language with which to communicate with other library educators, and to collectively ask and answer subtle questions that enable the continuing evolution of the pedagogy.

Many librarians have little if any coursework addressing learning theories of any kind, as these are rarely offered as part of library science education programs (Montgomery, 2015, p.19). Educators working with learners in library makerspaces sometimes lack a coherent pedagogical strategy for supporting learners at different skill levels (Einarsson & Hertzum, 2020). Most existing pedagogy is strongly tied to formal learning environments like school, where learning tends to be compulsory and planned around a predetermined set of standards and goals. As contexts for learning, libraries share more similarities with other non-formal learning institutions like science centers and museums than they do with schools (Rogers, 2014). Non-formal learning institutions receive learners of all ages, often in family groups, and must try to engage them in ways that they find relevant and meaningful, or they won't come back.

In exploring what sort of actions and structure could support the development of a pedagogy of creativity and learning in the library, my colleagues and I used a “try it and see” approach, utilizing inductive (Eisenhardt et al., 2016) and abductive reasoning, with the goal that theory would emerge from the practice through collective exploration and reflection. Over the course of 14 months I met biweekly online or in-person with 5 experienced library educators[12] in what was called the *Creative Learning Research Group* (hereafter referred to as the CLRG). Each educator brought a variety of skills and knowledge including experience design, the facilitation of creativity through crafting with small children, and the use of complex digital fabrication tools. All had experience with Design Thinking for Libraries

[12]In this article a library educator is defined as anyone who designs or facilitates in-person learning experiences. A learner is anyone interacting with them or a learning experience they have designed.

(IDEO, 2015).

In the course of those meetings, we explored content (in the form of readings about various learning theories) and processes (in the form of reflective discussions) which had the potential to be useful and relevant in the context of the library. On two occasions we facilitated open-ended playful learning experiences together, and would have done many more were it not for the Covid-19 pandemic. We collected Documentation to use as evidence in our theoretical discussions, adapting methods that emerged out of the work of the children and educators of the city of Reggio Emilia, Italy (Guidici et al., 2008 and Krechevsky, et al. 2013) known as the Reggio Emilia approach. Our Documentation took the form of notes, quotes, observations and photographs of learners in the process of being creative, curated summaries of which are included in the findings section. This Documentation served as the evidence on which our theoretical interpretations were based.

In the analysis section, I suggest that library educators already use a patchwork of elements from various learning theories, but they rarely have space and time to reflect on or attempt to synthesize them. The practice of reflective Documentation shows potential as a means for generating new theoretical questions, ideas, and answers - the building blocks of a pedagogy. The lack of a clear articulation of what quality in creative learning activities in the library looks like is a challenge, one that may be made more difficult by epistemic issues associated with the division between academic research and practice.

In the Discussion section I describe a strategy for positioning learning in the library in relationship to learning in schools.

This work accepts as axiomatic the following ideas which, while debatable, are beyond the scope of this work to defend: 1) Each learner's experience is idiosyncratic, a process of integration that is contingent on their own pre-existing knowledge, skills, and interests as well as the values of their surrounding culture. And 2) in order to be useful and effective, theories of learning must be reinterpreted critically by educators for use in their own cultural and physical context (Guidici et al., 2008). Librarian educators can of course take inspiration from a variety of learning theories. But in order to be successful along the lines that Jochumsen et al. describe, they must ultimately craft their own, tailored to their own local context. This research describes a small step down that path. In the longer term, success is not so much a specific outcome as it is an effective process through which librarian educators can continually develop and refine their approach to supporting learning and creativity within the local cultures that surround them.

8.2.1 Background

This research is part of my PhD research, titled *Experimenting, Experiencing Reflecting: Collective Creativity in the Library*, and is funded by Aarhus Public Libraries and the *Experimenting, Experiencing, Reflecting Research Project* (EER). EER is a science and art based research collaboration between the Interacting Minds Centre at Aarhus University and Studio Olafur Eliasson, which itself is funded by the Carlsberg Foundation. The goal of my PhD research is to explore collective creativity through the design of materials, activities, facilitation strategies, and environments that support it. The work described here was part of the process of laying a foundation for design-based research into collective creativity in the library.

Prior to beginning this PhD research, I worked as a designer of activities, environments, and materials to support open-ended playful learning at LEGO for four years. During that time I designed learning through play activities for LEGO House, founded a small design lab called the LEGO Idea Studio, and co-led research into play and technology with MIT Media Lab, the Tinkering Studio at the Exploratorium, and the Reggio Children Foundation. Prior to moving to Denmark in 2015 I ran the Scratch online community as a member of the Lifelong Kindergarten Group at MIT Media Lab for 6 years. Based around the first tile-based programming language developed at MIT, the Scratch website hosted the world's largest online programming community for children at the time.

8.3 Methodology

At the beginning of the research described here, my supervisor Sidsel Bech-Petersen and I formed the Creative Learning Research Group (CLRG)[13] consisting of myself and 5 library educators from Aarhus Public Libraries, during the Fall of 2020. The

[13] Description of the Creative Learning Research Group at Dokk1 Library: https://www.aakb.dk/nyheder/kort-nyt/the-creative-learning-research-group-at-aaarhus-public-libraries

educators were selected by Bech-Petersen on the basis of availability and interest, and the selection was confirmed by the author after one on one interviews. The mission of CLRG was written in advance by the author: to grow knowledge and expertise about creative learning in libraries by studying the theory and practice of creative learning experiences, spaces, and communities, to apply these ideas to our work as library educators, and to reflect on the relevance of these ideas for libraries. For a little more than a year the CLRG group met every two weeks for 2 hour sessions, mostly online due to the closing of the library during the Covid-19 pandemic. In our meetings we discussed readings and theory related to creative learning and progressive education. Each member was invited to present some of their work outside of the CLRG to the rest of the group for critical reflection.

Creative Learning is an approach to play-based learning described by Mitchel Resnick in his book *Lifelong Kindergarten* (2017), which is an elaboration of Seymour Papert's Constructionism (1993). Much of this body of work is concerned with programming and technology and is often applied in schools. *Tinkering* is also an elaboration of constructionism (Vossoughi, S., & Bevan, B. 2014). It was developed by the Tinkering Studio at the Exploratorium Science Musueum and is used by non-formal educators working in environments like science museums, makerspaces, libraries, and schools around the world. Theory related to these pedagogies formed the bulk of the readings, which were selected by the author with input from the participants. Some emphasis was placed on conceptual tools designed for direct use by practitioners, for example the *Learning Dimensions of Making and Tinkering* produced by the Exploratorium (Bevan et al., 2014). In choosing to create an encounter between library educators and these learning theories, I was asking: Can these theories provide a shared language that is useful for reflecting on the work of creativity and learning in the library?

In addition to readings and discussions, on two occasions[14] the Creative Learning Research Group facilitated tinkering activities - one online with adults, and one in person with children and adults. In both cases, CLRG members collected Docu-

[14] Our original plan was for the Creative Learning Research Group to co-design and co-facilitate between 6 and 10 hands-on tinkering workshops which we could observe, Document, and reflect on together, allowing for a much larger pool of data from which to theorize. The lockdowns and restrictions of the Covid-19 pandemic forced us to spend much more time reading and discussing theory and much less time running workshops and reflecting on Documentation.

mentation in the form of photographs, videos, and notes to create a record of the learner's encounter with the activity. Our method for collecting and reflecting on Documentation was directly inspired by the work of the children and educators of the city of Reggio Emilia in central Italy (Krechevsky et al., 2013), who over the past 80 years have developed a pedagogy known to early childhood educators around the world as the Reggio Emilia approach (Rinaldi, 2006).

The educator who practices the Reggio Emilia approach is also considered to be a researcher. Their research is about understanding and supporting the research of children. The "data" in that research consists of Documentation, which Krechevsky et al. (2013) defined as "The practice of observing, recording, interpreting and sharing through a variety of media the processes and products of learning in order to deepen and extend learning." By reflecting critically on Documentation of children's learning, Reggio educators develop theory to explain observations and guide their interventions. This process of critical reflection on Documentation is understood to be the engine that created (and continues to refine) the pedagogy of Reggio Emilia.

The Reggio Emilia approach takes the position that each child is unique, complex, and deeply interconnected with their surrounding culture and environment (Krechevsky et al., 2013). Reggio educators are careful to specify that any theory or understanding of learning that emerges from their own work is extremely contingent on the child's context - including the culture of their community, school, and family (Giudici et al. 2008). What is learned may be useful in other places, but it is unwise to apply it without first reinterpreting it within the local context. As a pedagogy, the Reggio Emilia approach is committed to embracing the idiosyncratic nature of each learner and each learning community.

In designing and leading the meetings with the CLRG, I attempted to apply key ideas from this approach to the context of the library, especially with regards to collection and reflection on Documentation. Prior to each activity in which the team planned to Document the learner's process, we began by collectively choosing a research question relevant to our discussion about theory. We then developed strategies for collecting evidence related to our question. After the activity, we spent time interpreting the Documentation we gathered together. Out of these discussions I made a draft blog post about our learnings which was then discussed and edited by various members until we reached consensus that it was finished.

In attempting to introduce reflective practice organized around Documentation to the library, my goal was to understand the following: Can we use these methods to create a context for library educators to generate interpretations and theory to explain what they have observed and documented in their practice? The reason for the experiment was to see if such a practice could become an engine for collective reflection among library educators which, over time and in the aggregate, has the potential to add up to a pedagogy of creative and playful learning in the library.

8.4 Findings

In the spirit of the Reggio Emilia approach to Documentation (Krechevsky et al. 2013), the findings section consists of brief case studies of two learning experiences facilitated by the CLRG. These were written by me with extensive input and feedback from colleagues in the CLRG, with an audience of library educators in mind. Both case studies omit information that could be used to identify the participants, but they use the facilitator's real names (with their permission[15]). Although they describe observations of a small number of individuals, each can be thought of as representative of circumstances and people that library educators encounter frequently, and can therefore serve as foundation from which to generalize (Flyvbjerg, 2006). In addition to the documentation, each case study provides a theoretical interpretation - a "proto-theory" - that emerged out of discussions in the CLRG. The goal here is to show Documentation and interpretations of it that emerged out of a conversation among practitioners shaped by the methods described above. It is not to make rigorous claims about the evidence or interpretations about it.[16]

[15]I chose to use facilitator's real names out of a concern that anonymity without a compelling reason reinforces the idea that the unique qualities and interests of different learners and teachers don't matter, and a facilitator is just a facilitator and a learner is just a learner. Every good facilitator I've known has their own way of doing things, just like every good learner has their own idiosyncratic approach to learning.

[16]While strong claims can be based on evidence from case studies (Welch et al. 2011), we would need to have run these activities many more times than we were able to in order to generate sufficient observational data to make a serious claim to rigor. That was not the goal of this research, which was focused mainly on experimenting with processes that could support theory making of the sort that could eventually lead to the establishment of a pedagogy.

8.4.1 Case Study #1: Creative Confidence or "Handlemod" in Creative Activities

"I will probably flunk this," said the workshop participant.

Jane, the facilitator, had just finished giving the prompt for the online tinkering activity she was facilitating to the two participants in her Zoom breakout room. Developed by the Tinkering Studio at the Exploratorium, Shadow Remix (*Shadow Remix | Exploratorium*, 2023) invites the learner to point a flashlight at something that casts a shadow, and then create a drawing that integrates and is inspired by that shadow. The participant afraid of flunking was not being ironic. He seemed genuinely afraid that he would fail.

Jane had encountered something similar many times while working as an educator in library Makerspaces. Prior to the workshop, our 5 person team of library educators called the *Creative Learning Research Group* had set our focus on working with people with little confidence in their own creativity. We had all encountered people like this before - mostly adults - so we made no special effort to screen participants, trusting that at least a few would fit this description. In our discussions we began to refer to the condition as low "handlemod," a Danish word which roughly translates to "courage to act." In our preparatory discussions prior to the beginning of the workshop, we arrived at the following research question: "How can we support people with low creative-confidence (handlemod) to help them engage meaningfully with a creative activity?"

When invited to join a playful, open-ended activity, participants with low creative confidence tend to throw their hands up and say something to try to mitigate the expectations they are afraid will be placed on them. For example, they might say "I'm not a creative person!"

"You can't flunk this," Jane replies.

Jane tries to make clear that this is not a situation in which the learner will be judged or ranked on their performance. From our discussions afterward it was clear that she recognized that people who feel nervous in this way usually have little experience with the creative process, and even less confidence in it. So she begins to lend him some of her own confidence. She invites him to try to see what kind of shadow the

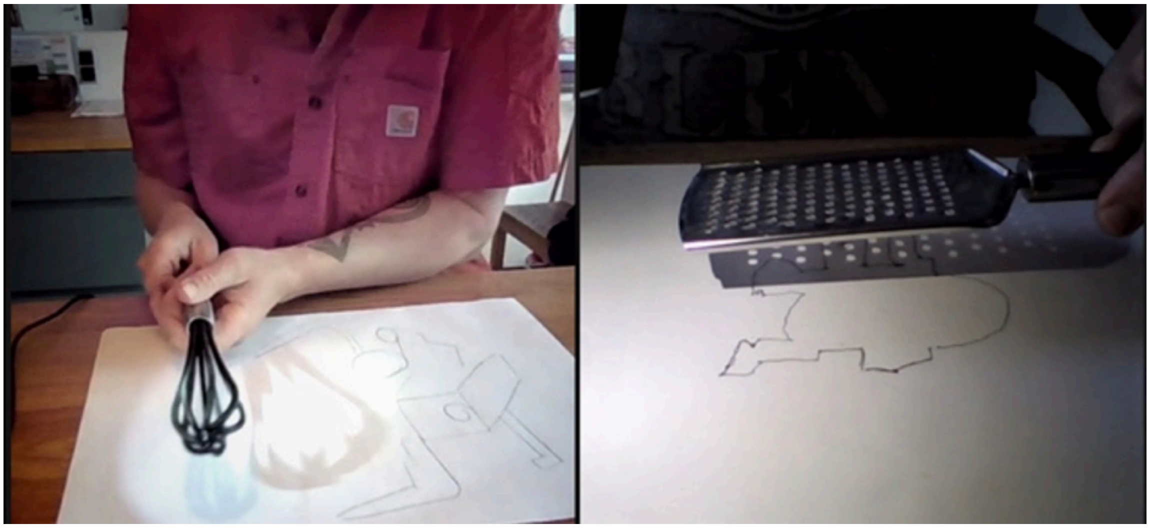


Figure 6: Article Figures 1A and 1B Screenshots from the Shadow Remix Zoom workshop.

light makes through a whisk he got from his kitchen. As he explores the different patterns formed by the shadows, she keeps up a light chatter, following along with what he is doing.

"I see the shadow looks interesting when you hold the light that way."

"Oh, that looks nice. What if you try rotating it?"

"Why don't you trace that line and see where it goes?"

Her speech is mostly unremarkable in terms of content and meaning conveyed, but it establishes her presence with him across the distance of the video call and helps set a casual tone. Once he has started to engage with the activity, she checks in on him periodically for the rest of the workshop.

Over the span of 30 minutes the learner gradually relaxes and becomes more and more focused on drawing and experimenting with the shadows. To an experienced facilitator of creative learning, this kind of transformation is fairly common when the right kind of support is given, though little has been written about it. It could be that having accepted the facilitator's emphasis on play and process over outcomes, he is able to set aside the fear that prevents him from engaging playfully. Perhaps there is a role played by the aesthetics of whatever is being explored (in this case the light and shadows). From the outside, it looks like he falls in love with the process of exploring and drawing with the different shadows. It's as if he forgets to feel afraid.

The Creative Learning Research group chose to document and reflect on the experience of working with learners with "low handlemod," or low creative confidence, because this kind of fear is a common barrier to playful and creative learning, especially for some adults. Anyone facilitating a creative design experience for citizens will need strategies for helping some portion of them to work around their anxiety and begin to build trust in the creative process. Such strategies could be an important aspect of a pedagogy of learning and creativity for the library.

Tinkering activities are open-ended design provocations, which means the variety of possible outcomes is functionally infinite. Unlike building a birdhouse or a Lego set by following step-by-step instructions, the final product of an open-ended activity cannot be known at the beginning. It requires a willingness to explore different possibilities, reflect on feedback (both from other people and the materials themselves), and make choices about which direction to take and which new problems to pose throughout the design process. In this way, a Tinkering activity resembles a long-term design process in miniature, running at the scale of minutes instead of days, weeks, and months. Creating the conditions in which a learner can practice these skills is part of the pedagogical value of Tinkering (Petrich et al., 2013).

8.4.2 Case Study #2: Learning from the Facilitation Strategies of Parents and Grandparents

In November of 2021, the Creative Learning Research Group observed parents working with their children on an open-ended marble run activity in the large public area on the ramp leading to the second floor. Designed by the artist's collective "The Secret Club" (https://schhh.net/), 'Papalapap' provides several open-ended provocations involving cardboard. We focused on observing and documenting families as they designed, built, and tested stackable sections of vertical marble runs. They built these using cardboard and basic crafting tools like hot glue and scissors. In preparing for the workshop, our goal was to look for indicators of creativity and self-expression as described in the Tinkering Studio at the Exploratorium's *Learning Dimensions of Making and Tinkering* (Bevan et al., 2014). But as we discussed the notes, photos, and quotations we'd collected afterwards, we decided to refocus our reflections on the different facilitation and support strategies we observed parents and grandparents using with children.

One family we observed appeared to have parents who were very comfortable with the creative process. From the way they dressed, we thought it was likely that they work in a creative field. Having abandoned our prompt to build a marble run, their daughter instead built an ornate and sophisticated dragon with cardboard tubes, a cup, and hot glue. When she expressed uncertainty as to what sort of legs she should make for her dragon, one of her parents suggested she sketch out different possible designs on post-it notes. With the families' permission, we collected these sketches and added them to our documentation board, which formed a shared record of what happened that day that we referred to in later discussions.

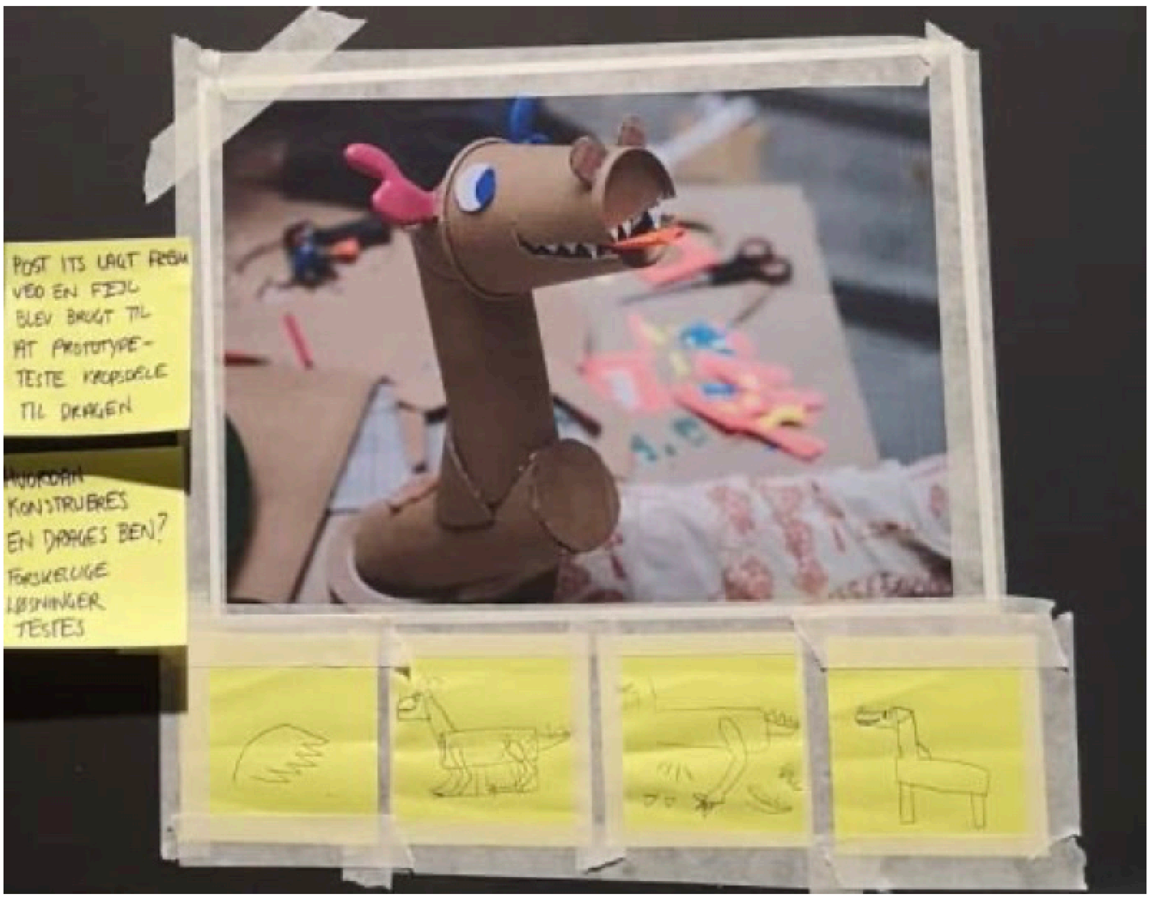


Figure 7: Article Figure 2 Photo of the dragon, and the post-it note sketches for its legs.

Suggesting that their daughter sketch out different possibilities was a sophisticated facilitation move on the part of the parents. If you don't know where to go next in a design process, it's often useful to sketch out different ideas, and then use these sketches to reflect on which direction to take. This is a design practice that often saves resources in the long run. Investing a lot of time building legs that she later decides aren't the right fit would be costly in terms of time and effort.

Donald Schön described something similar in his book *The Reflective Practitioner* (Schön, 1983). Though many people still think of creativity as a 2 step serial process of mental inspiration followed by execution, artists and creative practitioners often see that approach as expensive and potentially risky (at least at a gross scale). Picking an idea, building it to completion, and only then evaluating it (and potentially abandoning it) takes far more time and energy and involves greater risk than the more iterative approach of sketching out different possibilities and reflecting on them in order to "feel out" the right direction to take.

Though it may seem elementary to those familiar with the tenets of Design Thinking (IDEO 2015), such basic knowledge about the creative process is valuable. But not all citizens have the same level of access to it. We observed several parents who were critical of their children's exploratory efforts, and seemed worried that the direction they took would not lead to a satisfactory outcome. Both my colleagues in Dokk1 and the designers of the Papalapap activity were careful to avoid anything in the design of the space or our facilitation strategies that would suggest that evaluation, ranking, or competition would be involved. In spite of this, some proportion of citizens tend to assume that their creations will be ranked and judged critically.

In another observation we noticed a parent who seemed particularly unsatisfied with her daughter's exploratory efforts. At one point she took the project from her daughter's hands and began changing it herself, explaining that what the child was doing wouldn't work or look good. In this case, the child didn't seem to mind and began playing with something else. She seemed mostly unphased or perhaps used to shrugging off this expression of parental anxiety.

In terms of the pedagogy of creativity, what the parent was doing in this case could be described as the opposite of what Jane was doing for the learner who was afraid of flunking the "Shadow remix" activity. Instead of lending her confidence in the creative process, she was interacting in a way that seemed more likely to instill anxiety and distrust in the creative process. As we discussed in subsequent Creative Learning Research Group meetings, this puts the facilitator in a difficult position that requires careful ethical consideration. Is it appropriate to try to constructively intervene in these situations? If so how can this be done in a way that is respectful and sensitive to both the child and the parent?

8.5 Analysis

In discussions of the documentation described above, members of the Creative Learning Research Group (CLRG) engaged in critical reflection and theory making based on evidence observed and documented together in practice. The evidence for this critical reflection lies in the interpretations, described above and below, which emerged out of those discussions. Both the concept of "handlemod," and the discussion about techniques and guidelines for working with parents are examples of exploration of the theoretical space that have the potential to inform practice.

Generally speaking, this suggests that theory and reflective practices from the Reggio Emilia approach and constructionism can serve as a framework for a dialog between theory and practice among librarian educators. Whether or not this could eventually lead to a pedagogy of learning and play tailored for the library remains to be seen. Such an experiment would undoubtedly require a long term commitment in terms of time and resources. Below are four observations relevant to further work in this area.

8.5.1 Reflecting on Documentation of learning experiences leads to new questions and new ideas.

In the case study about parents and children described above, we planned to observe children's creativity and self-expression using the *Learning Dimensions of Making and Tinkering* (Bevan et al., 2015). But upon further reflection, the most interesting aspects of the Documentation we gathered had to do with the relationship between adults and children. In our discussions it became clear that this is a particularly rich and interesting area for librarian educators to explore, since libraries welcome interaction within families and across generations in ways that schools do not.

Our reflective discussions afterwards surfaced several interesting and important issues for further consideration. Is it appropriate, ethically speaking, to intervene in family dynamics that seem likely to limit the child's learning experience? For example, if we see a father grab the cardboard project out of his child's hands while judging it in a negative light, can we try to constructively intervene? How can we use our authority as educators to effectively communicate our pedagogical values to parents? If we can better articulate our vision of what quality in creative learning in the library looks like to them, will it help us to engage them as allies?

Out of this conversation, one member proposed that we create a "Dogma" - a collection of rules and constraints that frame the work we're doing in creative spaces in the library. We also debated possible slogans to place on the walls of an activity space which we could refer parents to when they enter, as a means of setting the frame for the type of playful creativity we hope to see. None of these made it past the draft stage before the CLRG group ended shortly after. But they suggest that a process of reflective documentation has the potential to lead to innovative ideas in the form of both new problems to solve and new solutions to solving them. Explored systematically, such ideas could form the basis for further practical and theoretical insights.

8.5.2 The Librarian educators observed already used a patchwork of ideas from various learning theories, but they rarely had space and time to reflect on them.

In the process of working with the Creative Learning research group I made notes and observations in order to be able to reflect critically on the goal of understanding what it would take to develop a pedagogy of creativity and learning in the library. From these observations, it was clear that each of my colleagues in the CLRG already had a good deal of knowledge built from experience facilitating creative learning. To name one example, Jane's ability to soothe and support the learner who was afraid of flunking was perhaps "primed" by the discussions we had about "handlemod" and creative confidence prior to the workshop. But she had already intervened in this way many times before.

But while Jane had already developed these skills and insights on her own, she mentioned that she had never discussed them with any of her colleagues. Prior to joining the CLRG, she was busy with numerous projects and had little time for individual reflection and even less for reflecting with peers on pedagogical questions. So while she knew how to work with people who lack creative confidence, there was no shared language with which to discuss or refine these ideas with colleagues. By "shared language," I mean a collection of concepts that experts in a field use to discuss and reflect together on subtle issues associated with their craft.

As we discussed the concept of creative confidence in English, we debated how best to express it in Danish. Danish is the first language of all members the CLRG group except for me, an American, and at the time I had very little understanding of Danish. So part of developing a shared language for use in a Danish library involved choosing the right Danish word to represent the concept we were discussing in English. The group explored different options, including "kreativ selvtillid" (creative self-confidence) and "handlemod" (courage to act) - finally settling on the latter.[17] In this case the choice of words for translation was an explicit and literal form of creating or defining a shared language, a building block for pedagogical theory.

In our ongoing discussions about creative confidence and how to constructively intervene to support its development in learners, a member of CLRG whose work is focused on children and crafting had a lot to contribute. She described a variety of different strategies she used to help children who were nervous or otherwise self-critical about their crafting abilities. As with Jane, she had an expertise developed over years which she rarely discussed with colleagues. Mostly this was due to lack of time and context for such discussions, but also perhaps due to the lack of a shared language with which to do it.

CLRG was composed of library educators from two organizationally distinct departments: adult learning and children's learning. This meant that there was less opportunity for shared reflection between members of different departments than there was within each department itself. At least in the realm of hands-on creative learning, the consensus seemed to be that there was more overlap in terms of useful knowledge across those working in different age ranges than most had initially imagined. In our small but developing pedagogical conversations, educators working with children had a lot more in common with adult educators than either initially imagined.

Time for reflection, it was universally acknowledged by members of the CLRG, is the first thing that gets sacrificed when the schedule gets tight. And the schedule is

[17]It's worth noting here an interesting cross-cultural issue. The English "creative confidence," as heard by Danish CLRG members, would be something one would attribute almost exclusively to geniuses or well-established artists like Picasso. Whereas "Handlemod" could be understood as a quality anyone would possess to varying degrees, and which could be more or less supported by different actions on the part of the facilitator.

usually tight. It is easy to assume that this is because of the demands of management – and surely in many cases it probably is – although this did not seem to be the case in our situation. In the CLRG team there was recognition that time for reflection was sometimes sacrificed by the library educators themselves, some of whom mentioned they often underestimated time costs and took on too much out of a desire to get involved in interesting or exciting projects. But the recognition that most projects were evaluated by politicians who are more interested in the number of participants than the quality of their learning experiences also seemed to play a role.

In general, much of the time, effort, and attention of many library educators appears to be structured and funded by grants. In the absence of a commitment from leadership to developing a distinct pedagogical stance, it's difficult to imagine a coherent pedagogy of learning and creativity in the library emerging by itself.

8.5.3 Proposing theory in the form of explanations of Documentation requires a firm epistemic stance.

In our discussions, I was most active in proposing explanations and theories to try to explain what we had observed and documented. Partly this was intentional in that I wanted to see if others would follow my example and assert explanations for what they observed. While there were elements of interpretation from all participants in our discussions, only one member attempted to apply this approach to her work outside of the CLRG group. This led to the creation of a set of pedagogical guidelines by the IRIS team, a project that focuses on developing new opportunities for technological literacy. They used these to frame their ongoing work with children.

There could be many personal and cultural reasons for what felt to me like a reluctance to assert new explanations to explain observations from practice. One explanation is that my librarian educator colleagues see themselves as "only" practitioners, and not academic researchers. Therefore, proposing explanations for what they observe is not in their job descriptions, which tend to focus more on actions than interpretations. There appeared to be a readiness to defer to formal and experimental research, even though there was also skepticism about its relevance to their work. Here I found a somewhat paradoxical situation: They had great respect for academic research which, by their own admission, was almost never relevant or useful to them as practitioners. It is possible that this willingness to defer to the expertise of academia accounts for some of their hesitancy to propose their own theories about what they observed in their work.

Carla Rinaldi, professor, author, and advocate for the Reggio Emilia approach to education, has written and spoken about the relationship between theory and practice in ways that are relevant to these epistemic challenges.

> Theory and practice should be in dialogue, two languages expressing our effort to understand the meaning of life. When you think, it's practice; and when you practice, it's theory. 'Practitioner' is not a wrong definition of the teacher. But it's wrong that they are not also seen as theorists. Instead it is always the university academics that do theories, and the teachers…they are the first to be convinced of it. In fact, when you invite them to think or to express their own opinions, they are not allowed to have an opinion. (Rinaldi, 2006)

She goes on to suggest an alternative:

> It's not that we don't recognise your [academic] research, but we want our research, as teachers, to be recognised. And to recognise research as a way of thinking, of approaching life, of negotiating, of documenting. It's all research. It's also a context that allows dialogue. Dialogue generates research, research generates dialogue. (Rinaldi, 2006)

My own view, which I shared with colleagues in CLRG, is that no academic researcher in the university has access to the wealth of contextual knowledge that library educators are swimming in. The fact that they are in situ, engaging with the work of facilitating learning in a context that differs fundamentally from that of schools, makes them the best equipped to propose explanations for the things that they observe. These explanations are the precursors of theory.

If the reluctance I observed is explained by Rinaldi's description of the hierarchical relationship between practitioners and academics, then it presents a significant challenge to the goal of developing a pedagogy of the library. For such a pedagogy to develop, practitioners must assert that their insights are worthy of consideration - both by other practitioners and by academics in related fields. They then must be described, shared, and discussed with other practitioners and researchers, again and again, over the course of years. This would require practitioners to take an epistemic stance that asserts both the value of their local, experience-based knowledge and their right and ability to generate theory to explain it. But my interlocutors seem to believe that the value of generalized academic knowledge about human learning far outweighs any potential contribution of their own. This is in spite of my impression that most would be hard pressed to think of even a single practical insight from the world of academic research on learning from the past few decades.

8.5.4 In the absence of a shared definition of quality in learning experiences, it's difficult to know where to begin.

Learning is incredibly complex and difficult to measure - especially when it is improvisational and creative (Resnick, 2017). Developing a pedagogy that explains how to design and facilitate towards it is a difficult undertaking. It benefits from at least some initial agreement as to what quality learning experiences look like in order to sustain movement towards that goal.

My impression was that there was a good deal of agreement about quality learning in the Creative Learning Research Group, much of which stemmed from their shared culture. Danish educational values are a cherished part of the Danish cultural heritage. But when I inquired in greater detail as to how these values could be enacted, answers tended to be somewhat general and difficult to base clear actions upon. It wasn't always clear what the expression of those values in a real learning experience would look like. At one point, one member of the group stated that while there was general cultural agreement at the level of values about learning, he felt that the practice of education in Denmark didn't always live up to those values. I had hoped that Documentation, because it provokes a conversation between theory and evidence gleaned from practice, might help to concretize what these values do or do not look like in action, but I don't think we reached that level. It may be something that can only emerge from repeated iterations of facilitating activities and reflecting on them.

Like cultural institutions worldwide, libraries in Denmark are evaluated by how many citizens make use of them. There is a risk that in the absence of a clearly articulated definition of quality learning, "the numbers" of people who show up for a given activity will be viewed as the primary measure of success. But as is true in schools, the number of participants who attend something, even when they have the freedom to choose whether they will attend it, is not in itself a good indicator of learning.

Reflective documentation could be a means for describing what quality learning looks like in the library - both for other educators and for outside stakeholders. But a clearer description or set of examples showing what quality learning in a library looks like would help to calibrate the compass such that library-educators could work towards a specific direction, as well as try to address the problem of how best to gather evidence relevant to that goal.

8.6 Discussion

Generally speaking, each citizen's use of the library is unique. Learning in a library tends to be non-linear and idiosyncratic: A child checks out a dinosaur book, an engineer looks for a reference on a manufacturing process, etc. While the structure of school asks learners to have the same or similar experiences, the goal of the library is to support the learner in having whatever experience is meaningful to them *at that moment*. Rather than following a pre-defined path, the learner arrives seeking to understand something relevant to their own interests, interests which may evolve and change even during the course of their visit.

Libraries often collaborate constructively with schools. But the fact that most people identify learning as something that mostly happens in school makes this relationship potentially risky for libraries. As Gopnik (2011, in Björneborn, 2017) puts it, "Adults often assume that most learning is the result of teaching and that exploratory, spontaneous learning is unusual. But actually, spontaneous learning is more fundamental." For some, learning in the library may be seen as an accessory to learning in school, where "real" learning happens. Without a clear articulation of its own distinct learning goals, values, and pedagogy, the library risks becoming irrelevant in the popular conception of learning. The position of libraries is made more precarious by the digital age, which renders at least one of its previous functions - the warehousing of physical books - obsolete.

In the course of discussions with colleagues from the IRIS (formerly Film X) project in Aarhus Public libraries, I created a Venn diagram to describe a way to think about the relationship between learning in libraries and schools. To varying degrees, schools around the world tend to be curriculum driven, compulsory, and dependent on lecturing to achieve the goal of information transfer and successful recall in students. Learning in the library is largely interest-driven, so the learners have a high degree of agency and freedom to choose and shape their own experience. In our discussion one librarian educator pointed out that the literal translation of the Danish word for teaching - *undervisning* - is "showing wonders." She suggested that this would be a good way of framing the role of library educators interested in facilitating creative explorations of STEM phenomena. Another referenced a quote by the famous American intellectual Ta-Nehisi Coates which describes his affection for the library and criticism of school.

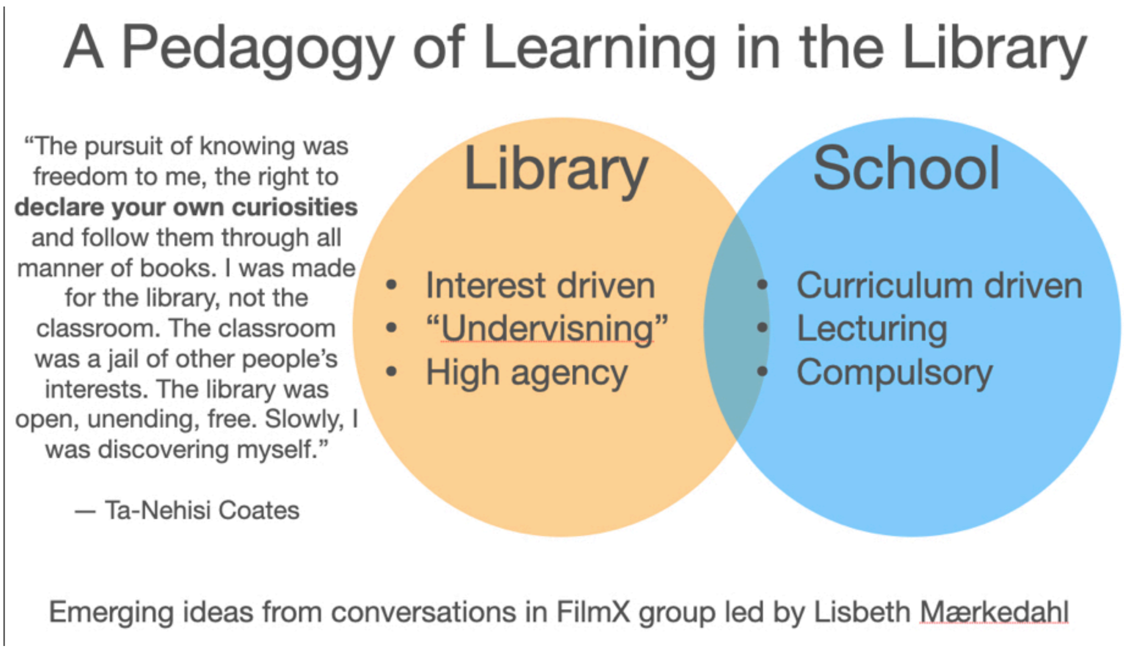


Figure 8: Article Figure 3 Venn Diagram that emerged out of discussions with the IRIS group (formerly FilmX), 2021.

This is not to say that the library should try to replace or actively criticize schools, or that schools are never interested in things like agency and interest-driven learning. Many schools share similar goals and aspirations which I attribute in this diagram to libraries. The specific content is tentative, and less important than the structural idea of the Venn diagram as a means of framing (and shaping) a relationship between two different institutions. If a library articulates a clear stance about the kind of learning it values, then it can recognize where that kind of learning does and does not overlap with the school's agenda. It can use this to shape its interactions with schools to grow and develop in whatever way it wishes to.

To give an example based on the cursory bullet-points shown in the slide, if the school would like to collaborate with the library on an open-ended programming activity in which children can design their own games based on their interests, the library would respond with an enthusiastic “yes!” Such an activity falls clearly into the shaded area where the pedagogical values of the school and the library overlap. It also presents an opportunity for the library to develop its own educator’s expertise in an area aligned with its pedagogical goals. But if the school invites the library to assist with rote memorization of vocabulary terms to satisfy requirements of the curriculum that don’t connect meaningfully to children’s interests, the library (in this example) should politely decline.

In order to make possible a productive dialogue between theory and practice, libraries must make choices about the kind of learning they will or will not focus on developing their capacity to support. Just as no one can become an expert in everything, no library can hope to develop expertise in every pedagogical approach. Expertise takes time and focus to develop, and this requires that practitioners have a clear view of the kinds of learning they are cultivating and the kinds of learning they are not cultivating. Libraries need to create an institutional identity around learning that citizens can recognize as both distinct from schools and valuable in its own right. Failure means being seen as merely an “accessory” to school learning, and accessories are the first to go when times get tough.

8.7 Conclusion

The claims of this research must be limited, as it reflects impressions formed from working with a small group of library educators in a well-known and well-resourced library. Most librarian educators would likely encounter much greater challenges doing this work in their libraries, many of which have little to no budget for running learning activities. Still, I hope that at least some of the ideas here could be useful to librarian educators in diverse contexts.

Any reflective dialog between theory and practice that is to yield useful insights for practitioners will take a significant amount of time and energy. The approach to Documentation as developed in the Reggio Emilia tradition, when reinterpreted in the library, is one viable means for organizing an ongoing conversation that meets Weick’s (1989) definition of a theory making process “designed to highlight relationships, connections, and interdependencies in the phenomenon of interest." Organizing teams around pedagogical focus, rather than age of the library patrons or other categories, could be another way to help facilitate such a conversation. Inviting library educators into a dialog about what the library sees as a quality learning experience, and providing concrete examples, is another.

Many more questions remain open. What sort of rhythm and proportion would be most effective for supporting library educators in encountering and digesting existing pedagogy, documenting in-person practice, and reflecting on documentation afterwards? Should one spend a few hours per day on each topic successively each week? My own attempts at asking this question were foiled by the uncertainty and interruptions of the Covid-19 pandemic.

It seems probable that an effective pedagogy for libraries would have to be developed in a conversation among library educators that extends beyond any single library or library system. What would be the best medium for sharing insights and ideas about creativity and learning across libraries around the world? Many of the librarian educators I've encountered don't read much theory or keep up with the latest research. This might be because they don't often find things to read that are relevant and meaningful to their work as practitioners. What medium would be the right medium through which to have an ongoing conversation as research practitioners, and not just practitioners? What sort of network would be able to support this kind of ongoing conversation, and help to justify the time and expense associated with it?

As Jochumsen et al. (2012) recognized, open-ended creativity and playful, interest-driven learning can be incredibly engaging for citizens of all ages. In my view, this is due to the improvisational, open-ended, and joyful nature of play. What gets created depends on the unique ideas and interests of the people who show up. But designing and facilitating this kind of playful learning is challenging. This is why educators working in this area benefit from an ongoing reflective conversation with their peers.

8.8 Acknowledgements

Many of the ideas presented come from extensive discussions with library educators in Aarhus Public Libraries, especially the Creative Learning Research Group, which included Sofie Gad, Rasmus Ott, Marie Pasgaard Ravn, Jane Kunze and Lisbeth Mærkedahl.

Many thanks to my advisors for their help and patience, including Andreas Roepstorff, Sidsel Bech-Petersen, and Peter Dalsgaard. Thanks to Klaus Thestrup and Lennart Björneborn for thoughtful feedback.

Thanks to the Carlsberg Foundation and Aarhus Public Libraries for making this research possible.

8.9 References

Bateson, G. (2002). Mind and nature: A necessary unity. Cresskill, NJ. Hampton Press, p. 141.

Bevan, B., Petrich, M., & Wilkinson, K. (2014). TINKERING Is Serious PLAY. Educational Leadership, 72(4), 28–33.

Bevan, B., Gutwill, J. P., Petrich, M., & Wilkinson, K. (2015). Learning Through STEM-Rich Tinkering: Findings From a Jointly Negotiated Research Project Taken Up in Practice. Science Education, 99(1), 98–120. https://doi.org/10.1002/sce.21151

Björneborn, L. (2017). Three key affordances for serendipity: Toward a framework connecting environmental and personal factors in serendipitous encounters. Journal of Documentation, 73(5), 1053–1081. https://doi.org/10.1108/JD-07-2016-0097

Dewey, J. (2015). Experience and education (First free press edition 2015). Free Press.

Dumit, J. (2014). Plastic neuroscience: Studying what the brain cares about. *Frontiers in Human Neuroscience*, *8*. https://doi.org/10.3389/fnhum.2014.00176

Einarsson, Á. M., & Hertzum, M. (2020). How is learning scaffolded in library makerspaces? *International Journal of Child-Computer Interaction*, *26*, 100199. https://doi.org/10.1016/j.ijcci.2020.100199

Eisenhardt, K. M., Graebner, M. E., & Sonenshein, S. (2016). Grand Challenges and Inductive Methods: Rigor without Rigor Mortis. Academy of Management Journal, 59(4), 1113–1123. https://doi.org/10.5465/amj.2016.4004

Giudici, C., Barchi, P., & Harvard Project Zero (Eds.). (2008). Making learning visible: Children as individual and group learners ; RE PZ (4. printing). Reggio Children.

Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. *Qualitative Inquiry*, *12*(2), 219–245. https://doi.org/10.1177/1077800405284363

Gray, P. (2010). The Decline of Play and Rise in Children's Mental Disorders | Psychology Today. https://www.psychologytoday.com/us/blog/freedom-learn/201001/the-decline-play-and-rise-in-childrens-mental-disorders

Gopnik, A. (2011). "Why preschool shouldn't be like school", Slate, November 16, available at: http://www.slate.com/articles/double_x/doublex/2011/03/why_preschool_shouldnt_be_like_school.html (accessed 9 August).

IDEO. (2015). Design Thinking for Libraries: A Toolkit for Patron Centered Design. IDEO. http://designthinkingforlibraries.com/

Jochumsen, H., Hvenegaard Rasmussen, C., & Skot-Hansen, D. (2012). *The four spaces – a new model for the public library.* New Library World, 113 (11/12), 586–597.

Kohn, A. (1999). Punished by rewards: The trouble with gold stars, incentive plans, A's, praise, and other bribes. Houghton Mifflin Co.

Krechevsky, M., Mardell, B., Rivard, M., & Wilson, D. G. (2013). Visible learners: Promoting Reggio-inspired approaches in all schools. Jossey-Bass.

Montgomery, M. (2015). Pedagogy for Practical Library Instruction: What Do We 'Really' Need to Know? Communications in Information Literacy, 9(1), 5.

Olson, K. (2009). Wounded by school: Recapturing the joy in learning and standing up to old school culture. Teachers College Press.

Papert, S. (1993). The children's machine: Rethinking school in the age of the computer. BasicBooks.

Pedagogy. (2022). In Wikipedia. https://en.wikipedia.org/w/index.php?title=Pedagogy&oldid=1105947430

Petrich, M., Wilkinson, K., & Bevan, B. (2013). It looks like fun, but are they learning? In M. Honey & D. Kanter (Eds.), Design, make, play: Growing the next generation of STEM innovators. Routledge.

Rasmussen, C.H. (2016). The participatory public library: The Nordic experience. *New Library World*, *117*(9/10), 546–556. https://doi.org/10.1108/NLW-04-2016-0031

Resnick, M. (2017). Lifelong kindergarten cultivating creativity through projects, passion, peers, and play. https://doi.org/10.7551/mitpress/11017.001.0001

Rinaldi, C. (2006). *In dialogue with Reggio Emilia: Listening, researching and learning*.

Robinson, S. K. (2010). Sir Ken Robinson: Changing education paradigms | TED Talk. Retrieved 6 August 2022, from https://www.ted.com/talks/sir_ken_robinson_changing_education_paradigms

Rogers, A. (2014). *The base of the iceberg: Informal learning and its impact on formal and non-formal learning*. Barbara Budrich Publishers.

Schön, D. A. (1983). The reflective practitioner: How professionals think in action. Basic Books.

Shadow Remix | Exploratorium. (2023, April 15). https://www.exploratorium.edu/tinkering/projects/shadow-remix

Vossoughi, S., & Bevan, B. (2014). Making and Tinkering: A Review of the Literature. National Research Council Committee on Out of School Time STEM, 57.

Weick, K. E. (1989). Theory Construction as Disciplined Imagination. *The Academy of Management Review*, *14*(4), 516. https://doi.org/10.2307/258556

Welch, C., Piekkari, R., Plakoyiannaki, E., & Paavilainen-Mäntymäki, E. (2011). Theorising from case studies: Towards a pluralist future for international business research. *Journal of International Business Studies*, *42*(5), 740–762. https://doi.org/10.1057/jibs.2010.55

Willingham, T., & DeBoer, J. (2015). *Makerspaces in libraries*. Rowman & Littlefield.

Østergård, M. (2019). Dokk1 – Re-inventing Space Praxis: A Mash-up Library, a Democratic Space, a City Lounge or a Space for Diversity? In D. Koen, T. E. Lesneski, & International Federation of Library Associations and Institutions (Eds.), *Library design for the 21st century: Collaborative strategies to ensure success*. De Gruyter.

9 Article: A Short-term Ecology for the Having of Wonderful Ideas: Collective Creativity and Cross-Pollination

Amos Blanton, MA EdS. Draft 7 June 2023. Under review as a chapter for a forthcoming EER Book Project.

A good idea has emerged. Five people are standing in the sun around a table on which two solar powered drawing machines are spinning. They've spent the last 40 minutes tinkering together in pairs, chatting and playfully riffing on different designs with one another. At the start of the workshop they were given acrylic mirrors which they use to reflect additional sunlight onto their machines, which makes them go faster. One pair has a small section of mirror, about the size of an index card, taped onto their machine. Instead of making it go faster, their idea is to have their machine reflect sunlight onto the other machines around it. When asked why they've done this, one of them explains with an African proverb.

"If you want to go fast, go alone. If you want to go far, go together."

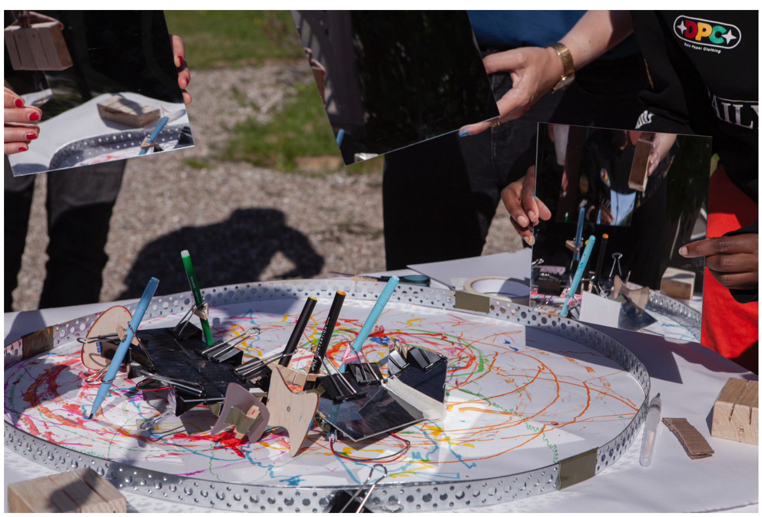


Figure 9: The drawing machine with mirror attached, visible at low center.

This prototype with its attached mirror has opened up the possibility of communication between machines, a domain of potential that did not exist before this moment. That the machines might become interactive, reflecting sunlight onto and influencing one another, is an idea that has never occurred to the designer of the activity. It suggests a whole new realm of possibilities.

It's a good idea. Where did it come from?

The conventional answer to the question of who "had" the idea doesn't make for much of a mystery, and anyway its on video. It was Joe. Acting in his assigned role as *catalyst*, Joe, an anthropologist in his fifties, was riffing on ideas with six tinkerers at the shared drawing table.

At the start of the activity, six of the twenty participants, a collection of artists and academics from the Experimenting, Experiencing, Reflecting project (EER) (http://EER.info), were assigned the role of *catalyst*. Catalysts were given a phone with a video camera and asked to attach themselves to one of the seven pairs of tinkerers building drawing machines together. They were told to record a brief video of any idea that arose and ask their tinkerers to say a few words about it. If they felt the idea was a good one, they could show it to another catalyst and, if both agreed the timing was right, play it for the second catalyst's pair of tinkerers as inspiration. In addition to these instructions, the catalysts were invited to do whatever they thought might be conducive to supporting and documenting cross-pollination and the emergence of new ideas.

The video shows a brief pause in the interaction at the shared drawing table. And Joe says:

> "I just had this vision of like putting the mirror on one of them and so as it moves around then it shines on another one who moves around who shines on…"

Joe had the idea.

When we use the English construction "Joe had the idea," we are referring to an idea in the same way we refer to a physical object. We use "Joe had the pen" or "Joe had some nachos," to describe possession of something. [18] But an idea is not the same as an object, even if intellectual property law says that an idea can be owned.

[18] If Joe were a woman we might say "Joe had a baby," and perhaps this would correspond a bit better to Joe's having had an idea, since it clearly came out of him. But the implied temporality of words for posession is misleading at larger timescales. Joe's ancestors and Joe's species and Joe's ecology had plenty to do with Joe's idea (and babies) in all but the most immediate time scales.

The idea that a good idea can be "had" by someone is important in Western culture. It's supposed to be both an engine of social mobility and a justification for wealth disparity. We grant immense wealth and power to people who have good ideas. But where exactly are the borders of an idea that allow it to be had by some *one*? Where is an idea's skin, the place where the idea ends or begins depending on if we are moving into or out of it? Did the idea of attaching mirrors to the drawing machines leap fully formed out of Joe, like Athena leapt full-grown out of Zeus' forehead? Or is it more realistic to say that the existence of a good idea is proof of some past relationship, the same way the existence of a baby is?

To answer this question in this experiment we can begin by examining the ancestry of Joe's idea in the evidence collected during the first 40 minutes of the activity. If there is more than one antecedent (and there is), who came up with those ideas, and how did they get into Joe? The conventional whodunnit mystery of who "had" the idea is already solved. But this was a stakeout to get to the bottom of a bigger question, one which we must borrow the grammar of the American South to ask: Who-all dunnit?

The musician and producer Brian Eno has stated that many good ideas are the product of what he calls "Scenius" — the collective form of "Genius" used to describe the creative intelligence of a music or art scene (Frere-Jones, A. 2014). If this is true, how can we create the conditions for studying how the collective form of genius works? And what methods can we use to analyze it? If the research pointing to the importance of collective creativity is correct, then it is a powerful means of creating conditions that are conducive to creativity and innovation (Hippel, 2005; Sawyer 2014). We are entering a phase of human history in which we're going to need more of that.

9.1 Design

Collective creativity is the emergence of innovative ideas from a group of individuals working with a shared purpose. Different disciplines have attempted to grapple with the complexity of collective creativity in different ways. Business research tries to describe the key practices of organizations that cultivate it (Catmull, E. 2008; Parjanen, S. 2012). Von Hippel (2005) studied how it emerges in sub-communities of enthusiasts that drive innovation in various domains. And in psychology, Sawyer

(2014) described the interactions between individuals and the group that lie at the foundation of collaborative creativity in improvisational theater and music. Each of these researchers gather data on collective creativity in the ethnographic "wild," which they use to describe the qualities of a process that is as complex as it is sensitive to subtleties of context.

While the ethnographic literature contains many trenchant observations about collective creativity, it also shows an area of untapped potential. Most of it comes out of relatively long-term study of communities of skilled enthusiasts. The approach used here is inspired by the Experimenting, Experiencing, Reflecting project (http://EER.info), and seeks to discover what can be learned by turning each of these factors on its head: What can we find out by inviting un-skilled enthusiasts to be creative together in a short-term activity? Rather than design a laboratory experiment that attempts to quantify effects by excluding confounding variables, this method proposes that we embrace contextual richness in all its complexity, and observe what happens as the process unfolds.

The goal of this case study was to create the conditions for collective creativity and to explore strategies for documenting and analyzing the interplay between individuals and the group. Creativity is defined as novel actions or ideas, particularly those that emerge from recombination in different ways or applications to new situations (Bateson & Martin 2013). The first research question is aimed at a foundational aspect of collective creativity: the cross-pollination of ideas.

- (RQ 1) How can we catalyze the cross-pollination of ideas through group reflection in a tinkering activity, and is there evidence that this leads to the emergence of new ideas through collective creativity?

The goal of this experiment was to boost cross-pollination via two interventions: 1) putting people in the role of catalysts, already described above, and 2) by creating a shared space for collective reflection at the shared drawing table, which will be described below. The emergence and movement of ideas was captured by the catalysts and an additional camera pointed at the shared drawing table.

Once the experiment was complete a second question soon emerged. The original goal was to create artificial conditions for an extremely brief and unusually dense ethnography — a "reduction" more in the spirit of cuisine than psychology. But the analysis soon came up against the limitations of the medium. Writing requires serialization that lends itself to narrative. But to see where the narrative of a single idea emerges requires a record of the movements of many different ideas through the group. This led to the second research question, which pertains to the analysis and presentation of the data.

- (RQ 2) How can we represent the collected data in a way that shows the interaction between participants in order to foreground collective creativity as an object of study?

Such a record of data collected should provide more than just the evidence used in the ethnographic narrative that (eventually) emerges. If we are making up stories to try to explain observations (as, arguably, all researchers of complex human phenomena are), it behooves us to provide more than just the data that supports our own story. It should be possible for others to view the same data and provide alternative interpretations. This data should be not only available, but accessible in such a way that requires little to no technical expertise to understand.

9.2 Run

> *Karsten: "This particular guy or girl is not strong enough in other positions. So this is the position where it can flourish."*

Karsten and Julie have been working on their drawing machine for about ten minutes. Their impression is that it's weaker than the other drawing machines they see around them. They try re-positioning the motor and drive-wheel in different ways, but it remains sluggish until they move the wheel to a perpendicular position, parallel to the solar panel. With the wheel acting as a base around which the machine rotates, and a soft brush pen in place of a stiff marker, it begins drawing big orange circles.

They mention the weakness of their machine to one of the facilitators, and he gives them a spare device held in reserve as a replacement. Instead of discarding their original machine, they begin attaching the two machines together to make one large drawing machine. Peter, their catalyst, starts filming, and asks how this idea came about.

> *Karsten: "The idea was that we first had a weak drawing [machine], and*

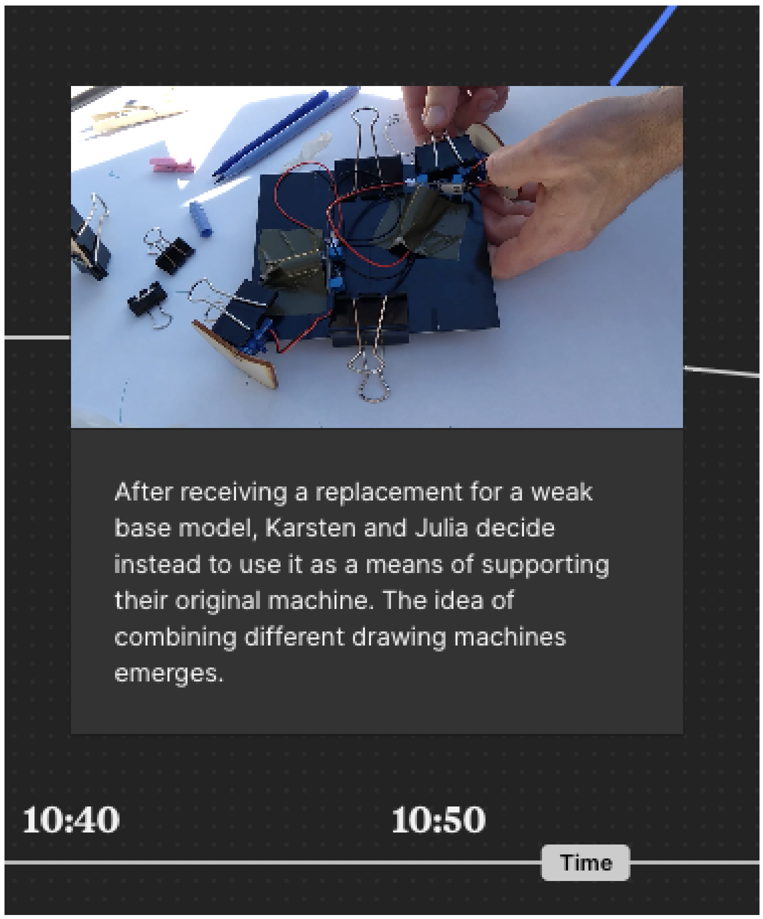


Figure 10: Karsten and Julie's idea to attach two drawing machines together emerges in the timeline.

then we got a stronger one. And then we liked the weaker one better. So now we wanted to see if maybe they are just better together."

A little later, a catalyst from a different group comes by to offer them the idea of naming one's machine. He explains how his pair of tinkerers named their machine "Bonkers," because they liked to make it "freak out" and "go bonkers" by reflecting extra sunlight onto it with mirrors. Peter, their catalyst, asks for their reaction to the idea of naming, and to the name "Bonkers."

> *Karsten: "I thought it was the opposite of our relationship because we've been very caring... Making it freak out is the furthest away from my mind-set right now..."*
>
> *Peter: "So you are susceptible to the idea of naming, but your relationship is different? More about maybe caring or nurturing?"*
>
> *Julie: "We are definitely not that inspired by 'Bonkers,'...we wouldn't choose that."*

Peter takes the video of Karsten and Julie's two drawing machines grafted together over to the shared drawing table, where he presents the idea of combining two machines together to three pairs of tinkerers working there. One of the catalysts there is called Joe.

9.2.1 Cross-Rejection of Ideas

When we think of cross-pollination, we might imagine an idea moving from one group to another, like a beautiful dandelion seeds floating across the landscape. It is welcomed in its new home as something foreign and exciting, something that inspires new possibilities, and new ways of thinking.

This moment with Karsten and Julie also involves the introduction of new and foreign ideas, but with a different result. To them, this new idea is notable not for its exciting new potential, but for its contrast to their way of thinking. Later on, Karsten and Julie describe their relationship to their machine as "curling parents"[19] — a pejorative Danish idiom similar to the American "helicopter parents," used to

[19]Curling is a game played on ice in which players frantically sweep in front of the path of a moving puck in order to smooth its way and influence its direction.

describe parents who are overly involved and attentive to their children. To them, the idea that someone named their drawing machine "Bonkers" is distasteful, like hearing that someone named their child "Bonkers," and liked feeding them sweets to make them "freak out." Watching the video, one gets the sense that by rejecting the cross-pollinated idea, they are both articulating and affirming their own position, playful as it is.

9.2.2 Theory for Creating a Short-Term Ecology of Wonderful Ideas

"The role of the teacher is to create the conditions for invention, rather than provide ready-made knowledge." - Seymour Papert

Eleanor Duckworth, professor at Harvard School of Education and author of the seminal essay *The Having of Wonderful Ideas*, framed her view of learning this way.

> "The having of wonderful ideas is what I consider to be the essence of intellectual development. And I consider it the essence of pedagogy to give [the child] the occasion to have his wonderful ideas, and to let him feel good about himself for having them" (1972).

Duckworth's *wonderful ideas* are not confined only to creative or novel insights. The child may have wonderful ideas in the form of concepts that have long been understood by science. But the phrasing "having of wonderful ideas" reflects a fundamental tenet of constructivist learning theory: that the child builds their own understanding through a process of observing, experimenting, reflecting, inventing and refining their ideas. The teacher's goal is therefore "to give [the child] the occasion to have his wonderful ideas."

Building on the work of Duckworth and Seymour Papert's Constructionism (1982), the pedagogy of Tinkering is a means of creating the conditions for invention in non-formal learning environments like science museums, makerspaces, and libraries (Vossoughi & Bevan, 2014). Inspired by artistic processes (Wilkinson & Petrich, 2013), Tinkering educators specialize in the design and facilitation of short-term, open-ended learning experiences that enable the creative exploration of various scientific and aesthetic phenomena.

The word *tinkering* itself refers to creative exploration that is open to emergent goals and encounters with new ideas.

> Sometimes, tinkerers start without a goal. Instead of the top-down approach of traditional planning, tinkerers use a bottom-up approach. They begin by messing around with materials (e.g., snapping LEGO bricks together in different patterns), and a goal emerges from their playful explorations (e.g., deciding to build a fantasy castle). Other times, tinkerers have a general goal, but they are not quite sure how to get there. They might start with a tentative plan, but they continually adapt and renegotiate their plans based on their interactions with the materials and people they are working with. (Resnick & Rosenbaum, 2013)

While there are elements of design for cross-pollination in the (mostly oral) Tinkering and constructionist tradition (Resnick & Rusk, 1996), most of the focus is on supporting individuals leading their own learning experiences. The educational approach developed by the children and educators of Reggio Emilia, Italy, while sharing many of the same fundamental values and thinking around learning, tends to think more about the collective (Rinaldi, 2006). In discussions with teachers and pedagogistas adept in the Reggio approach, one will often hear the 'class' (meaning everyone in the classroom) discussed as though it were an entity, one with its own unique interests, curiosities, and foibles. The class-as-entity is in dialog not only with the teacher (who is a leader as well as a member), but also with each student as an individual.

Tinkering, Resnick's creative learning (2017), and the Reggio Emilia Approach are all approaches to learning that are driven by practitioner researchers, but the tradition from Reggio Emilia is the only one to have created and exported its own research methodology. What is referred to as "Documentation" (Giudici et al., 2008) in Reggio Emilia is defined as "The practice of observing, recording, interpreting and sharing through a variety of media the processes and products of learning in order to deepen and extend learning" (Krechevsky et al., 2013). Collecting Documentation puts educators in a role similar to that of ethnographic researchers, gathering evidence of how the children use different activities to develop and refine their knowledge and creativity. Documentation is the evidence that grounds conversations between educators in Reggio Emilia as they reflect on what is happening in the classroom, and informs their subsequent interventions with the children. Though the means of Documenting collective creativity developed and used in this research would be considered far outside the orthodoxy, they do take their inspiration from Reggio.

The design of the solar drawing machines activity itself relies on a foundation in Tinkering, learned in practice from other non-formal educators via an oral tradition. The prompt given to the learners at the beginning was: "Begin by seeing what your machine draws. Then change it to make it make drawings that you find interesting." For those who may feel nervous or don't know how to begin, this prompt gives a clear starting point, something to do and to observe: "Begin by seeing what your machine draws." The next sentence invites the learner to follow their own agency and choice. Good prompts tend to follow this pattern of first grounding the learner and then inviting them to explore something interesting.

Aside from the prompt, there are many other factors that are important to running a successful Tinkering activity.

- the tone of the introduction
- the choices about materials to work with
- the design and "tinkerability" of the drawing machine "Base models" given as starting points
- the character and goals of the facilitation strategy
- the setup of the surrounding environment

These and other elements too numerous to mention have been honed over thousands of workshops by Tinkering practitioners, and passed on as part of a (mostly) oral tradition. This is not a casual undertaking. Some educators have spent most of their working lives honing the craft of Tinkering design and facilitation. There is far more to it than can be described here and perhaps, since it is mostly an oral tradition, more than can be contained in the medium of writing. But there are practitioners experienced in running interest-driven creative activities like these in science museums, makerspaces, and schools all over the world. All that is required for doing more of this kind of research is finding one to collaborate with.

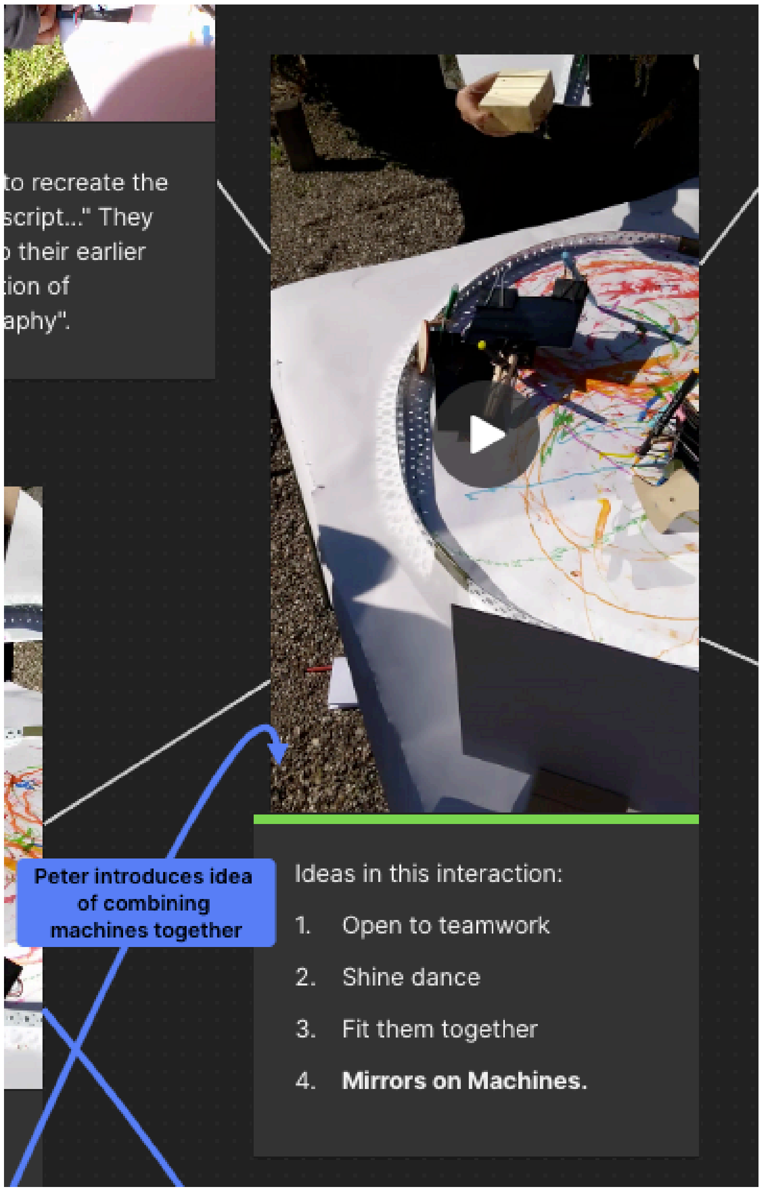


Figure 11: The interaction at the shared drawing table after Peter introduces the idea of joining two drawing machines together.

9.3 Learn

Peter introduces the idea of combining drawing machines together to the group standing around the shared drawing table. A few minutes after the tinkerers begin, the facilitator makes a brief interruption to introduce the shared drawing table.

> "When you have your machine making a drawing that you like, bring it to the shared drawing table and let it add your contribution to our shared drawing."

One of the aims is to have everyone's drawing machine contribute to a shared drawing, representing the creativity of the entire group. Another is to create a space where tinkerers can encounter and take inspiration from one another's creations. In the Tinkering tradition this is sometimes called a "watering hole," and it functions as a space for cross-pollination of ideas in a large group of tinkerers.

The three pairs of tinkerers at the shared drawing table find Peter's description of Karsten and Julie's "togetherness" interesting, but get distracted for a moment. Two of them discuss if they should join their models together or keep exploring their projects separately, and the consensus for the moment is to keep working separately. But the theme of togetherness continues and takes different forms in the ensuing conversation.

> *Liz: "….my characters they start out very alone, but then open.. open to teamwork."*

> *Amy: "…is there a way that we can work together by shining on rhythmically, like on the count? Like if we all shine on and off?"*

> *Joe: "Sounds like a song: If we all shine off… If we all shine…"*

> *Liz: "…. would it make sense to like fit them together, like I wonder if Bonkers would.."*

> *Joe: "I just had this vision of like putting the mirror on one of them and so as it moves around then it shines on another one who moves around who shines on…"*

Several, maybe all: "Oohhh.. that's coool!"

Liz: "That's a good idea!"

Amy: "Maybe we should be in the circle, and they should be holding mirrors."

Helene, who hasn't said much previously, asks "Do we have smaller mirrors?", and then goes off camera, apparently to find the necessary tools to cut out a small piece of acrylic mirror. Moments later she returns, and she and Neema begin working out how to attach it to one of the drawing machines. Meanwhile, Liz and anna have joined two machines together to form "Franken-Bonkers," the second combined drawing machine of the day.

9.3.1 Mapping Collective Creativity

Sawyer & DeZutter (2009) analyzed transcripts of conversations in improv groups in order to unpack the process of collective creativity. But tinkering is a different kind of improvisation, and presents a different kind of problem in terms of how to go about studying it. The group as a whole is never all together working on the same thing at the same time, as they often are in improv theater or music settings. Instead they operate in small pairs, each one a subgroup of the whole. Most of the ideas were generated in those pairs and then transmitted to other pairs, either by the catalysts, encounters at the shared drawing table, or simply as a result of working in the same general vicinity. A methodological problem soon emerges in that the data needs to be rendered tractable at two levels: the "fine scale" level of the filmed interactions, and the "gross scale" level of the workshop as a whole. Only at this gross scale can we see the movement of ideas between pairs of participants. This problem led to the second, more methodological, research question.

- (RQ 2) How can we represent the collected data in a way that shows the interaction between participants to foreground collective creativity as an object of study?

This study uses Milanote, a software designed to support artists and other creatives in visually managing their ideas, to make a gross scale map / timeline hybrid of the workshop that situates the fine scale video data. By creating timelines for each pair of participants showing notes and video of their experiments and situating them within a two dimensional map, we can look for evidence of ideas moving between the sub-groups.

One of the ways maps convey information differently than writing is that they present information in a searchable two dimensional space rather than in a serialized "start to finish" form. Whereas the writer of articles hopes that the reader will read through all or most of her words, the maker of maps accepts that the reader will use only a fraction of the information the map offers – whatever it takes to get from point A to B. The rest is not relevant. As a means of providing a lot of information without overwhelming the reader, the method of constructing timeline maps makes it possible to highlight the emergence of an interesting idea, and work backwards to find its antecedents. This is a bit like starting from the mouth of a river and traveling upstream to map the tributaries that feed into it.

Lots of interesting and novel ideas emerged out of this workshop, as is reliably the case with any Tinkering workshop that is reasonably well designed and executed. The problem of how to render the glut of data collected is solved by choosing one idea and generating a map that shows how it came to be.

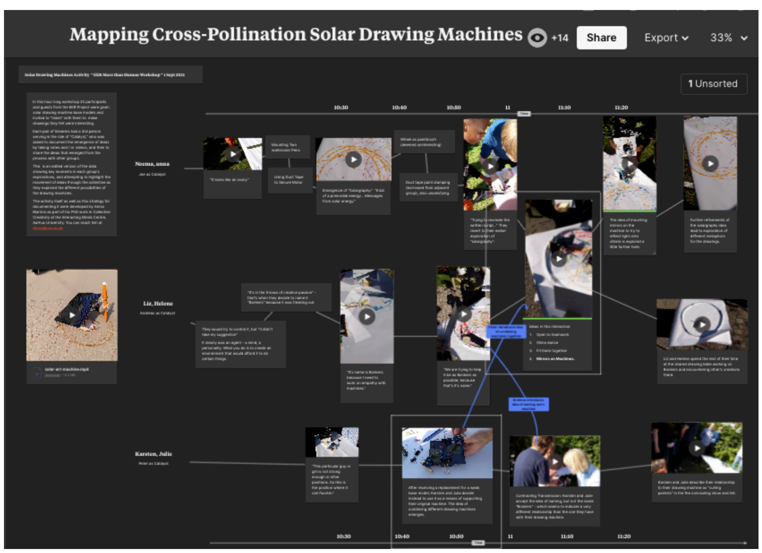


Figure 12: The milanote board containing data from the Solar Drawing Machines workshop, September 2021.

This map consists of embedded, playable video and field notes collected by catalysts, each laid out according to time on the X axis. There are three timelines from three separate pairs of participants shown (out of 7 total pairs tinkering that day). When viewed on the Milanote page, the videos can be seen and heard at the discretion of the viewer, providing a window into what was occurring at that moment as well as the tonal qualities of the interaction.

To tell the story of the emergence of the idea of attaching mirrors to the machine, I made small screen captures of the part of the map corresponding to the transcripts and events described above. These two sections are outlined as white rectangles in the overall map shown above. The viewer is free to browse all of the collected data from the participants involved on the map, even that which is not directly relevant to the narrative, in order to make their own interpretation or to criticize mine.[20] This ease of accessibility is an important aspect of Documentation for practice-based research. It is done in the belief that the conclusions and explanations will generally benefit from more practitioners viewing and sharing their own interpretations of the data. [21]

A live version of the Map can be found here: https://app.milanote.com/1N5Oxi1L7tMr8Y?p=7qEZrvV8sun

9.3.2 From Who-dunnit to Who-all dunnit

From the data collected, we can see how our view of who "had" the idea of attaching mirrors to the machines is dependent on how wide of a lens we use to view the interaction. If we set a narrow focus, as we did in the beginning, it is Joe's idea. But the stakeout on collective creativity reveals that there is more to the picture.

The idea of joining two machines together, as well as the conceptual theme of *togetherness*, was introduced to the tinkerers at the shared drawing table by Peter, who brought it from Karsten and Julie. Karsten and Julie had no direct interaction with the other players. Nevertheless, the theme of togetherness that emerged out of their

[20]This method could be used to create a shared corpus of data that could be used by different researchers to make different interpretations and conclusions. It would also be possible to share the entire dataset as well as a "zoomed in" view tailored to the idea under study.

[21]Too often research makes itself inaccessible to criticism from practitioners by placing questionable conclusions and relationships on a foundation of abstruse mathematical formulae. A little digging will often expose a formula's weakness or irrelevance to the question under study. But because the math looks impressively complicated, and because of the glorified epistemic position of mathematics and "the numbers" in our culture, many practitioners will assume that it doesn't make sense to them because they can't understand the math, instead of recognizing that it just doesn't make sense, full stop.

work clearly influenced the conversation that led to the good idea.

The idea of attaching mirrors to solar drawing machines is itself part of an ongoing, rapid fire conversation — one which we might best describe as "riffing" on the theme of togetherness, in the same way musicians might riff together on a musical theme. It comes hot on the heels of another idea, and is quickly followed by a third. It is Joe's voice that says it out loud. But would our idea have been remembered if Helene had not gone off to cut out the piece of mirror, so that she and Neema could tape it onto a drawing machine? This is important, because it changes the idea from just another utterance into a physical prototype, which then becomes an anchor for further conversation about the ideas.

As Lim et. al. (2008) describe it, "Prototypes are used as a means to frame, refine, and discover possibilities in a design space." Just as Karsten and Julie's combined drawing machine becomes both an anchor and a vehicle for the idea of "togetherness," the prototype mirrored drawing machine becomes the physical avatar of a big idea: that the machines might interact with and influence one another through the reflection of light.

Prototypes often serve as what Papert called an "object to think with" (1982), which Yasmin Kafai described this way:

> According to Papert, physical objects play a central role in this knowledge construction process. He coined the term "objects-to-think-with" as an illustration of how objects in the physical and digital world (such as programs, robots, and games) can become objects in the mind that help to construct, examine, and revise connections between old and new knowledge. (Kafai, 2005)

Papert was influenced by the work of the famous anthropologist Claude Levi-Strauss. In his seminal book *The Savage Mind* (2000), Levi-Strauss contrasts the analytical, abstract approach of Western Science with what he called bricolage, a "science of the concrete" used in primitive societies. Bricolage involves the recombination of existing materials to create new form and function, and is very similar to what Kauffman describes as evolution through exploration of adjacent possibles, evident in the fossil record (2014). Along with Latour (1999), Papert argued that many elements of the kind of thinking that Levi-Strauss characterized as concrete and primitive remain in and are important to Western science.

> "The bricoleur scientist does not move abstractly and hierarchically from axiom to theorem to corollary. Bricoleurs construct theories by arranging and rearranging, by negotiating and renegotiating with a set of well-known materials." (Turkle & Papert, 1991)

If bricolage and 'negotiation and re-negotiation with a set of materials' seems familiar, it's because it is precisely what this experiment was designed to do. The same can be said of all Tinkering activities, and the reason for this has to do with the way Papert though about learning. Objects-to-think-with represent a bridge between the concrete and the abstract. This bridge makes possible an ongoing, iterative conversation between the concrete and the abstract within the mind of the learner. It is through this conversation that the learner constructs their own hand-made, artisanal generalizations that they subsequently use to understand how the world works and how to interact with it.

It may appear as though we have now started speaking about two different things: learning and creativity. But constructivists and constructionists see these as manifestations of the same underlying process operating in the learner. The *Having of Wonderful Ideas* (Duckworth, 1972) is as much about learning as it is about creativity. Resnick's rebranding of constructionism as a more generalized approach he calls "creative learning" (2017) is an intentional blurring of a boundary he sees as artificial and outmoded. It's all knowledge construction. Creativity is just the word we use to refer to the stuff that happens to be novel or fresh in one dimension or another.

According to Constructionists, objects-to-think-with play an important role in knowledge creation for individuals. Our evidence suggests they may have a similarly important role in collective creativity. Let's try framing the interaction as a conversation between the concrete and the abstract.

Abstract: Two people form a kind of **affection** for their machine.

Concrete: A prototype of *two drawing machines joined together.*

Abstract: The catalyst shows a video of the prototype to another group, describing it as kind of **togetherness.**

Concrete: A prototype of a *mirrored drawing machine.*

Abstract: A new domain involving **communication** between drawing machines emerges.

And this takes us to our African proverb.

"If you want to go fast, go alone. If you want to go far, go together."

This is a further articulation of the idea of togetherness that describes still another way of thinking about the interaction of the drawing machines, one that stuck firmly in the author's mind.

9.3.3 The Tralfamadorian Sex Hypothesis of Collective Creativity

The way the word "conception" is used to describe the origin of both people and ideas is reminiscent of a passage from a famous Kurt Vonnegut novel called *Slaughterhouse 5*. Billy, the hero of the book, is living among the Tralfamadorians, a race of inter-dimensional aliens who experience reality in four dimensions, giving them complete access to past, present, and future all at once.

> One of the biggest moral bombshells handed to Billy by the Tralfamadorians, incidentally, had to do with sex on Earth. They said their flying-saucer crews had identified no fewer than seven sexes on Earth, each essential to reproduction. Again: Billy couldn't possibly imagine what five of those seven sexes had to do with the making of a baby, since they were sexually active only in the fourth dimension.
>
> The Tralfamadorians tried to give Billy clues that would help him imagine sex in the invisible dimension. They told him that there could be no Earthling babies without male homosexuals. There could be babies without female homosexuals. There couldn't be babies without women over sixty-five years old. There could be babies without men over sixty-five. There couldn't be babies without other babies who had lived an hour or less after birth.
>
> It was gibberish to Billy. (Vonnegut, 2005)

Our general tendency is to ascribe the having of good ideas to individuals. But the data collected in this experiment suggests that, like Billy in his fictional universe, we may be missing key elements of the story. The conception of ideas in collectively creative experiences might require different kinds of people, playing different kinds of roles, at different points in time.

Going forwards in time from the birth of our idea, we can see that the person who says the idea out loud, Joe, is an important contributor. But so is everyone who "coo's" in affirmation even before he's finished saying it, and so is Helene who leaves shortly after to find the parts necessary to prototype it. After Helene and Neema build the prototype, Neema articulates her thinking behind it with an African proverb, which shapes the reflective conversation around it and sticks in the mind of the author, who brings the idea to it's latest concrete manifestation, the page (or the screen) you are reading.

Moving backwards in time from the moment of birth back into the gestation phase, we see Liz, Amy, and anna contributing to the playful, reflective environment and "riffing" on ideas. We can see Peter the catalyst bringing (and, crucially, generalizing) the idea of togetherness, and showing the video of the two machines grafted together. And several meters away there are Karsten and Julie, the curling parents who refused to give up on their handicapped drawing machine, and chose instead to graft it on to its helper.

They all have something to do with the birth of this idea. From this we can see that our initial description of the event, "Joe had an idea," has about equal grounds for plausibility as does an immaculate conception. [22] Yet when we look out into the world, we are surrounded by specters of the Genius Joe. Plenty of people know Watson and Crick discovered DNA, but they probably don't know Rosalind Franklin, the X-ray crystallographer whose work made their discovery possible, or any of the other members of the scientific "Scenius" that surrounded and informed their work (Maddox, 2003). As more and more scholars begin to look critically at colonial narratives about innovation and creativity, we begin to see that the cracks running through their foundations may extend all the way down to the idea of individual genius itself (Fischer & Vassen, 2011, Weisberg 1993 and Arendt 2013 in Sosa, 2019).

But one thing that Joe, Watson and Crick, Elon Musk, Einstein and the rest of the geniuses have going for them is the simplicity of their narrative. It would be

[22]Following our metaphor to its logical conclusion, a person having an idea by themselves is perhaps similar to a person having sex by themselves. It's all well and good, but not something to be particularly proud of.

tiresome to have to recite a list of 47 names every time we speak about the discovery of DNA. If Vonnegut's Billy can't handle the relatively straight-forward seven sexes it takes to conceive an Earthling, how will we ever understand and describe what it really takes to conceive a good idea? One approach is to try to reconceptualize a "good idea" as just the localized, temporal manifestation of a larger process, one that spans across more people and more time than we are used to thinking about. More (practice-based) research is needed.

9.4 References

Bateson, P. P. G., & Martin, P. (2013). Play, playfulness, creativity and innovation. Cambridge University Press.

Bevan, B., Gutwill, J. P., Petrich, M., & Wilkinson, K. (2015). Learning Through STEM-Rich Tinkering: Findings From a Jointly Negotiated Research Project Taken Up in Practice. Science Education, 99(1), 98–120. https://doi.org/10.1002/sce.21151

Bevan, B., Ryoo, J. J., Vanderwerff, A., Petrich, M., & Wilkinson, K. (2018). Making Deeper Learners: A Tinkering Learning Dimensions Framework. *Connected Science Learning*, *1*(7). https://www.nsta.org/connected-science-learning/connected-science-learning-july-september-2018-0/making-deeper-learners

Catmull, E. (2008). How Pixar Fosters Collective Creativity. (Cover story). Harvard Business Review, 86(9), 64–72. Business Source Complete.

Coles, A., & Sinclair, N. (2019). Re-thinking 'concrete to abstract': Towards the use of symbolically structured environments. *Canadian Journal of Science Mathematics and Technology Education*, *19*(6), 1–16. https://doi.org/10.1007/s42330-019-00068-4

Dewey, J. (2015). *Experience and education* (First free press edition 2015). Free Press.

Duckworth, E. (1972). The Having of Wonderful Ideas. *Harvard Educational Review*, *42*(2), 217–231. https://doi.org/10.17763/haer.42.2.g71724846u525up3

Fischer, G., & Vassen, F. (2011). Collective Creativity: Collaborative Work in the Sciences, Literature and the Arts. BRILL. https://doi.org/10.1163/9789042032743

Frere-Jones, A. (2014). Ambient Genius: The Working Life of Brian Eno. The New

Yorker, 90 (82).

Giudici, C., Barchi, P., & Harvard Project Zero (Eds.). (2008). *Making learning visible: Children as individual and group learners ; RE PZ* (4. printing). Reggio Children.

Hippel, E. von. (2005). *Democratizing innovation.* MIT Press.

Kafai, Y. B. (2005). Constructionism. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 35–46). Cambridge University Press. https://doi.org/10.1017/CBO9780511816833.004

Kauffman, S. A. (2014). Prolegomenon to patterns in evolution. Biosystems, 123, 3–8. https://doi.org/10.1016/j.biosystems.2014.03.004

Krechevsky, M., Mardell, B., Rivard, M., & Wilson, D. G. (2013). *Visible learners: Promoting Reggio-inspired approaches in all schools.* Jossey-Bass.

Latour, B. (1999). Pandora's hope: Essays on the reality of science studies. Harvard University Press.

Lévi-Strauss, C. (2000). The Savage Mind. Univ. of Chicago Press.

Maddox, B. (2003). The double helix and the 'wronged heroine'. *Nature*, *421*(6921), 407–408. https://doi.org/10.1038/nature01399

Papert, S. (1982). Mindstorms: Children, computers, and powerful ideas (Reprint). Harvester Press.

Parjanen, S. (2012). Experiencing Creativity in the Organization: From Individual Creativity to Collective Creativity. Interdisciplinary Journal of Information, Knowledge, and Management, 7, 109–128. https://doi.org/10.28945/1580

Resnick, M., & Rusk, N. (1996). The Computer Clubhouse: Helping Youth Develop Fluency with New Media. *Proceedings of the 1996 International Conference on Learning Sciences*, 285–291.

Resnick, M. (2017). *Lifelong kindergarten cultivating creativity through projects, passion, peers, and play.* https://doi.org/10.7551/mitpress/11017.001.0001

Resnick, M., & Rosenbaum, E. (2013). Designing for Tinkerability. In M. Honey & D. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM* *innovators*. Routledge.

Rinaldi, C. (2006). In dialogue with Reggio Emilia: Listening, researching and learning.

Sawyer, R. K. (2014). Group Creativity Music, Theater, Collaboration. Psychology Press.

Sawyer, R. K., & DeZutter, S. (2009). Distributed creativity: How collective creations emerge from collaboration. *Psychology of Aesthetics, Creativity, and the Arts*, *3*(2), 81–92. https://doi.org/10.1037/a0013282

Sosa, R. (2019). Accretion theory of ideation: Evaluation regimes for ideation stages. *Design Science*, *5*, e23. https://doi.org/10.1017/dsj.2019.22

Turkle, S., & Papert, S. (1991). Epistemological Pluralism and the Revaluation of the Concrete. In S. Papert & I. Harel (Eds.), *Constructionism*. Ablex Publishing Corporation.

Vonnegut, K. (2005). *Slaughterhouse-five, or, The children's crusade: A duty-dance with death* (Dial Press trade pbk. ed). Dial Press.

Vossoughi, S., & Bevan, B. (2014). Making and Tinkering: A Review of the Literature. National Research Council Committee on Out of School Time STEM, 57.

Wilkinson, K., & Petrich, M. (2013). *The art of tinkering: Meet 150+ makers working at the intersection of art, science & technology*. Weldon Owen.

10 Article: Recursive Prompting: A Method for Collectively Exploring a Design Space

Amos Blanton, MA EdS and Peter Dalsgaard, PhD. Draft 8 June 2023. Under review at *LearnX Design 2023: Futures of Design Education* conference.

10.1 Abstract

Describes a new design method called Recursive Prompting in which participants collectively explore the possibilities of a design space in non-formal learning environments. Based on a pedagogical foundation in Tinkering and inspired by Kauffman's adjacent possible, Recursive Prompting feeds forward ideas from past learners so that future learners can build on them. The goals are 1) to invite participants to an authentic experience of open-ended design as a context for developing their design skills and 2) to use this process to develop the method as a strong concept in design. A case study describing the current status is described as well as future directions for improvement of the method.

Keywords: recursive prompting; Strong Concept; Tinkering; Collaborative Design; non-formal education

---

10.2 Introduction

This paper describes a new design method called *Recursive Prompting* in which participants engage in a playful, collective design process in non-formal learning environments like libraries and science museums. Recursive prompting was inspired by a theory of evolution and innovation called the adjacent possible developed by the biologist and complexity theorist Stuart Kauffman (2014), and on the educational theory and practice of constructionism (Papert 1982), specifically as it pertains to Tinkering (Bevan, Petrich, and Wilkinson 2014). It is informed by years of practice designing and facilitating collective design activities, both in formal and nonformal learning environments. Recursive Prompting is designed to scaffold collective creativity, which for the purposes of this paper is defined as the emergence of innovative ideas from a group of individuals working and communicating together towards a shared purpose, similar to what Von Hippel observed in *innovation communities* (2005) and what Sawyer and DeZutter called distributed creativity (2009). In this paper we describe the pedagogical and scientific theories behind the method, its core elements, and position it as a strong concept in design as described by Höök and Löwgren (2012). It includes a case study in which recursive prompting was applied as a design method and evaluated against three criteria: progressive growth in complexity, clustering, and novel applications, and concludes with ways forward.

In recursive prompting activities, participants (adults or children age 10+) are prompted to create new prototypes inspired by documentation of prototypes made by past participants. These are in turn documented and fed forward to successive generations of participants as inspiration for their prototypes – hence the use of the term *recursive*. This distributed process broadens the range of individuals involved in the prototyping process and scaffolds the exploration of multiple generations of ideas. It is intended to demonstrate value both as a learning experience for the participants and a method for exploring a design space.

The pedagogical goals of the method are: 1) to invite learners into an authentic design experience to give them an opportunity for hands-on learning (Bevan, Gutwill, Petrich, and Wilkinson, 2015) , and 2) to enable them to experiment with and experience what it is like to be part of a collective exploration of a design space that spans both time and participants. In addition to their functional purpose, documentation of the prototypes is intended to stimulate learner reflection and awareness of the exploratory, open-ended, and iterative nature of the process of collective design.

The conclusion suggests ways forward to improve the method.

10.3 Background

10.3.1 Constructionism and Tinkering

Constructionism (Papert and Harel, 1991) is an educational theory that emphasizes the importance of actively creating knowledge with and through artifacts. Constructionism was developed by Seymour Papert on the basis of the constructivist theory of Jean Piaget (Piaget 1973), which asserts that people create their own understanding of the world through experiences and interactions with it. By extension, the constructionist perspective suggests that it is possible to design circumstances for learners to develop their understanding of the world through hands-on, project-based activities in which they use their creativity to design, build, and create something tangible. As open-ended learning experiences they are designed to be supportive of epistemological pluralism (Turkle & Papert, 1990). The aim is for learners to gain a deeper, systemic understanding of the subject matter that can be applied across different domains. Because constructionism has always argued for the importance of both epistemological pluralism and learner agency, we see it as a good pedagogical foundation for efforts to develop pluriversal design education (Noel, 2020).

Recursive prompting has its practical foundations in the pedagogy of Tinkering. A comparatively recent outgrowth of constructionism developed at the Exploratorium Science Museum in San Francisco, tinkering refers to the act of playfully engaging with and learning about phenomena through exploratory hands-on project-based creative design processes (Bevan, B., Gutwill, J. P., Petrich, M., and Wilkinson, K et al. 2015). The pedagogy of Tinkering is an approach to designing and facilitating learning experiences that invite interest-driven learning using open-ended but carefully constrained provocations (Vossoughi and Bevan 2014). It is regularly put into practice in science museums, libraries, and makerspaces around the world.

The argument for the pedagogical value of Tinkering rests on the idea that doing what is essentially design in a tinkering activity is a means of developing important design skills (Martinez & Stager, 2019). The success of a Tinkering workshop can be evaluated by observation and documentation of the learners engaging with the experience. The Tinkering Studio at the Exploratorium developed a framework for evaluation called the Learning Dimensions of Making and Tinkering (Gutwill et al., 2015), which describes five learning dimensions and associated indicators, which has since been updated and made publicly available to Tinkering educators (Bevan, Ryoo, Vanderwerff, Petrich & Wilkinson 2018). Research suggests that the presence of these indicators is associated with the development of design skills and STEM learning (Bevan et al., 2015).

10.3.2 The adjacent possible

> The adjacent possible consists of all those things (depending on the context, these could be ideas, molecules, genomes, technological products,

> etc.) that are one step away from what actually exists, and hence can arise from incremental modifications and recombinations of existing material (Tria et al. 2015).

The adjacent possible is a theory for understanding the exploration of a space of possibilities which the biologist and complexity theorist Stuart Kauffman first proposed as an explanation for speciation in the fossil record. Simply put, the adjacent possible is what's next door to whatever state something is in now. Before the Post-It note existed, it was an adjacent possible of the plain paper note taped to a wall. Once invented, the Post-It note became an "actual" from which new adjacent possibles could emerge, from making fish scales in kindergarten craft activities to tools for organizing and reorganizing collections of thoughts in design meetings.

Each time an adjacent possible transitions into an "actual," it changes the space of possibilities not only for itself but also for the entire system of which it is a part. As a result, each movement into an adjacent possible is not only a potential optimization within the current context, but also has the potential to be the introduction of a new evolutionary niche from which new adjacent possibles can emerge. Kauffman (2014) provides an example from the evolution of the swim bladder, which allows fish to maintain neutral buoyancy at different heights within the water column. Believed to have evolved from the primitive lungs of a lungfish, the swim bladder made possible a new ecological niche in the oceans which thousands of species soon evolved to fit into.

Design can be framed as an exploration of the adjacent possible. If one were to design a pedagogy for teaching people to navigate the adjacent possible, it would likely share many qualities with the pedagogy of Tinkering. Tinkering activities are open-ended within a carefully designed set of materials and constraints. The frame is set (i.e. build a drawing machine), but what will be created is unknown at the start and dependent on the learner's curiosity, interests, and knowledge. Facilitation strategies are designed to help learners engage with the process of tinkering, which Resnick & Rosenbaum (2013) describe this way:

> Instead of the top-down approach of traditional planning, tinkerers use a bottom-up approach. They begin by messing around with materials (e.g., snapping Lego bricks together in different patterns), and a goal

> emerges from their playful explorations (e.g., deciding to build a fantasy castle). Other times, tinkerers have a general goal, but they are not quite sure how to get there. They might start with a tentative plan, but they continually adapt and renegotiate their plans based on their interactions with the materials and people they are working with.

Like evolution, tinkering proceeds step-by-step in the direction of greater complexity, but without a pre-defined end state or plan in mind (Jacob 1977).

10.3.3 Recursive Prompting as a Strong Concept

In their influential 2012 paper, Höök and Löwgren propose the notion of “strong concepts” as a type of intermediate-level knowledge that is generative for design and can be applied in a range of design situations (Höök and Löwgren 2012). Strong concepts reside at a level above singular cases such that they are applicable in multiple cases and potentially across domains, are concerned with interactive behavior, can be embedded into or inform the design of artifacts, and reflect the practice and use of artifacts. In a similar vein, Dalsgaard and Dindler (2014) propose the notion of bridging concepts as a solution to the challenge of connecting theory and practice. Bridging concepts are defined three constituent components: a theoretical basis, a set of design articulations for how the concept may be expressed, and a range of examples that illustrate their potential use. Whereas conceptual constructs are primarily informed by and seeks to further contribute to the development of theory, bridging concepts build on and seek to further develop both theory and practice.

While the concept of recursive prompting can be said to embody characteristics from both of the above mentioned constructs, we consider it primarily as a strong concept under development, with a particular emphasis on the generative potentials it holds for informing collaborative development and exploration of design spaces. While most prior examples of strong concepts pertain to the design of interactive artifacts, recursive prompting stands out in that it concerns a way of orchestrating a collective design process.

10.4 Methodology

In order to put recursive prompting to the test in practice, we ran a recursive prompting case study, which we report on in this paper. The research question was: *Can the method of recursive prompting enable unspecified participants to contribute to an open-ended exploration of a design space that results in progressive growth in complexity, clustering around the emergence of valuable ideas, and novel applications?*

We documented this session via video recordings (Penn-Edwards 2004), field notes (Patton 2005), and unstructured interviews (Kvale 1994) in response to the emergent actions of study participants. Moreover, the development of all prototypes in the experiment were documented on a physical recursive prompting map (see figure 1). Participants were recruited by setting up the recursive prompting map and worktable with materials in the social / coffee area of a medium sized academic conference in [University redacted] called [conference name redacted] with approx. 200 attendees. Any conference attendee who approached and showed interest was invited to participate. No specific data on attendees was collected aside from release forms for to enable us to collect field notes and make recordings. The approximate age range of participants was estimated to be 20-65 with roughly equal gender participation. There was a wide range of technical experience, with some showing familiarity with the electronic elements and others for whom it was likely their first encounter with these technologies.

Upon completion of the experiment, we carried out an analysis of the collected data, including video recordings, field notes, and the structure of influences documented on the recursive prompting map. In our analysis, we examined the data for evidence of three phenomena which we consider indicators of successful recursive prompting: progressive growth in complexity, clustering, and novel applications. We describe these indicators in more detail in the findings section.

10.5 Method of Recursive Prompting

The pedagogical value of Tinkering as an individualized learning experience aimed at citizens in non-formal learning environments has been established (Bevan et al., 2015). The goal is to build on that foundation to develop a method to invite learners into a collective design experience. Such a method could make clear how collective design processes benefit from diversity in terms of knowledge and perspective of participants (Hoever, van Knippenberg, van Ginkel, & Barkema 2010; Bercovitz & Feldman 2011). We believe it is important that such a method should demonstrate design utility as well as educational value. At this stage we are utilizing practice based research in non-formal learning environments to offer 1) an engaging design learning experience to participants, while 2) attempting to develop the method itself.

As Schön describes in the Reflective Practitioner (Schön 1983), sketching is an iterative process in which the sketcher receives feedback from their own sketch, which then informs the subsequent ideas that emerge. They are engaging in what Schön described as a "conversation with the material." Recursive prompting is a strategy of using documentation to extend that conversation to more people, and with it create a map of adjacent possibles in the design space that should prove useful in subsequent design work. The map of documentation serves as a kind of public sketchbook, showing the different design ideas and emergent domains explored by the collective.

Once the recursive prompting activity is complete, the documentation can be analyzed and archived for future analysis. It can also be used as the starting prompt for future learning activities.

10.5.1 Participant Experience Flow in Recursive Prompting Activities

10.5.1.1 Introductory Phase The introductory phase begins when participants first encounter the activity in an informal space. Often the first thing they see is the ongoing map of documentation of the recursive prompting process. When approaching the map of documentation, the viewer should be able to quickly understand where the different regions of the design space lie, and where the present moment in time is represented. This constitutes the frontier of the design process. The eye can then track backwards from the present moment in what amounts to a (short term) historical tour of what came before and the relationships between the various prototypes across time.

Facilitators (approximately 2 for every 10 participants working simultaneously) greeting new potential participants should give a brief tour of one evolutionary line of prototypes to explain a few of the ideas already developed by past participants. If they choose to participate, this is followed by an introduction to the tools and building materials, and stating the prompt. Tools and materials for prototyping must be easy for participants to understand and to use, along the lines of what Papert and Resnick referred to as a "low floor" (Resnick 2017).

10.5.1.2 Build Phase Participants build creative prototypes for as long as they wish to in a collegial, lightly facilitated, and low-stakes social environment in which they can see, reflect on, and discuss what one another are doing. They should feel welcome to borrow and repurpose any ideas from the map or from one another, and to ask for help anytime.

During the build phase the map of documentation of previous prototypes serves as a source or information about past ideas and iterations one might learn from or copy, as well as showing what has not yet been explored within the space of possibilities. It should be visible and close by.

10.5.1.3 Outro Phase Once a prototype is completed, it is documented and added to the map of documentation in such a way that future participants can easily understand its qualities and evaluate it as a potential starting point for their own explorations. It should be recorded and presented in such a way that makes it easy for a viewer to borrow or repurpose ideas from it to use for their own creative exploration. Information gathered should help the facilitator see where to place the project on the map in relation to other projects, so as to make those relationships clear.

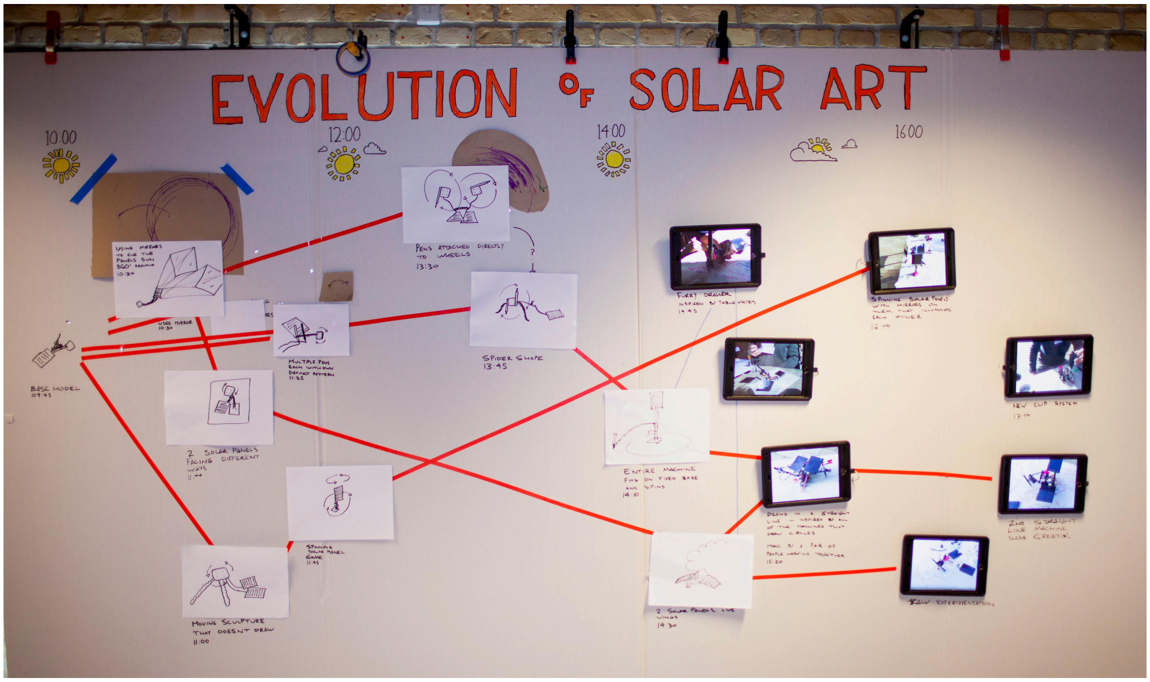


Figure 13: (Article Figure 1) The live recursive prompting map at the end of a daylong workshop. iPads shown on the right were playing video loops of prototypes. An Interactive digital representation is available at: https://app.milanote.com/1Pq3fa1EpTdz6L?p=d8NEXrOl73g

10.6 Case Study: Recursive Prompting at the CES Conference

The case study of a recursive prompting activity described here was run at the Cultural Evolution Society conference at Aarhus University in 2022, by two facilitators, one of them an author of this paper. A digital version of the recursive prompting map, including all of the video data collected of the prototypes described below, can be viewed on Milanote at this URL: (https://app.milanote.com/1Pq3fa1EpTdz6L?p=d8NEXrOl73g)

Prior to the opening of the conference, we made a large cardboard map titled *Evolution of Solar Art*, with time marks on the horizontal axis, and mounted it in the coffee area of the conference where we knew many passersby would see it (Figure 1). Next to this we placed a work table large enough for 6 people to work at a time with prototyping materials from the *Playing with the Sun* construction kit (https://resources.playingwiththesun.org/Const-Kit-Overview/), developed by one of the authors as part of research developing tinkering activities in collaboration with Aarhus Public Libraries. Materials included 1 watt solar panels, solar-engines that store solar energy until there is enough to make a pulse that will drive a motor, patch cables, gear motors with attached 3D printed hubs, markers, binder clips to act as pen holders, and small mirrors. Short sections of bendable plumber's strap and removable push rivets were provided as an open-ended framework for building structures. We made a simple example project and made a brief video of it with the first of 8 iPads we had in reserve, and then placed the iPad playing the video in a loop in the left most position of the recursive prompting board.

Figure 14: (Article Figure 2) Participants at the worktable at the start of prototyping session.

Throughout the day, participants approached the board or the worktable out of curiosity (Figure 2). A facilitator explained that we were doing research about how ideas build on one another in open-ended activities, answered any questions, and invited them to participate (Figure 3). Those that chose to join were asked to sign a release to permit filming and use of gathered data for research. We introduced them to the building materials and demonstrated how to make basic connections to make the motor turn. Then we invited them to build something interesting that draws using solar power.

There were 20 participants across the day between the opening hours of 10 to 17:00, with busier times clustered around conference mealtimes and coffee breaks, and slower times around keynotes. Most participants worked alone with a few working in pairs. Many more people viewed the activity than could participate due to limits on space.

When each participant or pair of participants finished (ranging between approx. 10 to 50 mins), we recorded a brief video of their creation in which we asked them 1) to name it, 2) to say a little about it, and 3) asked them if they were inspired by anything else they saw. We then placed the iPad on the map at the corresponding time on the X axis with the video playing on a constant loop. (The Y axis position was not indicative.) We wrote a brief description of the prototype next to the iPad. If they indicated that a previous prototype on the map inspired theirs, we placed a line of red tape between the two prototypes. Once all iPads were up on the map we took the left-most on the X axis (which had been on the map for the longest time) and replaced it with a sketch before using it to record and display the next prototype. At the conclusion we uploaded the videos to a “virtual” version of the map in software called Milanote (Figure 4).

10.6.1 Findings from the case

We examined the data from video recordings, field notes, and unstructured interviews for evidence of three phenomena that we consider to be indicators of a successful recursive prompting activity:

10.6.1.1 Progressive Growth in Complexity Progressive growth in complexity suggests that there has been an accretion of valuable ideas over time in the prototypes collected, with later ones showing a greater degree of complexity or sophistication (in any domain) than earlier ones. This would be an indication that the method of recursive prompting supports or encourages the feeding forward of valuable ideas from past prototypes such that they are worth integrating in future

Figure 15: (Article Figure 3) A facilitator demonstrates how the construction materials work for a new participant.

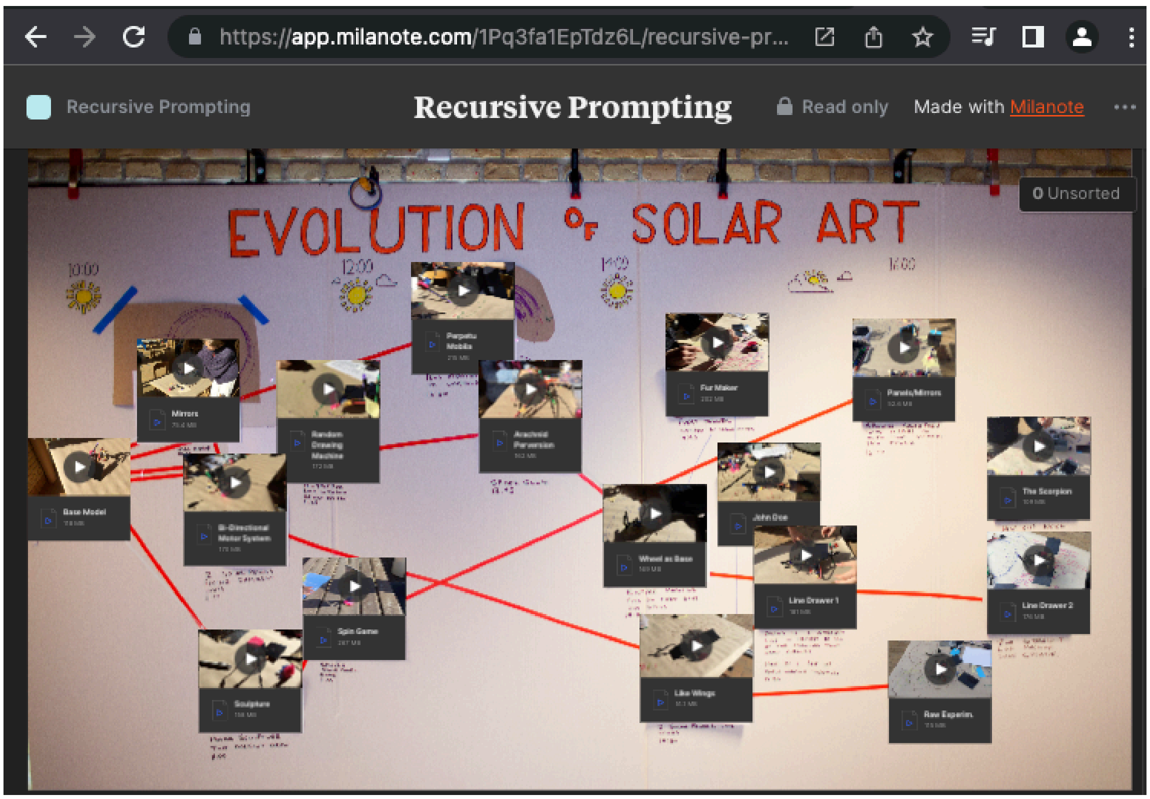


Figure 16: (Article Figure 4) The completed milanote board with video data for each prototype, visible at: https://app.milanote.com/1Pq3fa1EpTdz6L?p=d8NEXrOI73g

ones, forming a foundation for progressive explorations of the adjacent possible in the design space.

There is little evidence of progressive growth in complexity in the case study data. Such evidence would take the form of one or more ideas appearing in one prototype that form the foundation for further exploration of adjacent possibles, appearing in at least 2 generations of subsequent prototypes. Of the 17 video recordings, three contain references by participants to inspiration coming from others working alongside them at the worktable, something which is common in tinkering activities. But this inspiration does not appear to span multiple generations of prototypes.

10.6.1.2 Clustering Clustering is indicated by the emergence of prototype(s) that serve as a common ancestor from which many subsequent projects took inspiration, and are therefore linked back to it in the map of documentation. Clustering is caused by many participants finding value in some quality of the prototype at the center of the cluster. This may come from perceived value in any domain, from aesthetic, to engineering, to anything else. A project around which clustering has occurred serves as a common ancestor of future designs, as well as indicating a domain that participants value.

Our analysis revealed no clear evidence of clustering in this case study. On the map of documentation, only a single prototype is marked as inspiration to two subsequent prototypes (excepting the starting "base model," which is excluded from our analysis). Judging from impressions of facilitators during the event and statements made by a few of the participants, the most plausible explanation for why there was no clustering is that most of the participants were primarily interested in exploring their own ideas of what they could make with the construction kit.

10.6.1.3 Novel Applications One of the criteria for success used to evaluate the design of tinkering activities is referred to by tinkering educators as *solution diversity*, meaning that one sees a wide variety of different projects that come from the activity. Such variety indicates that different participants have been able to integrate their own ideas and interests into the process, shaping the results in varying ways, enabling each of them to experience what Eleanor Duckworth referred to as "the having of wonderful ideas" (1972) . In addition to the argument that this makes the participant's experience pedagogically valuable, it also suggests that the activity design has enabled the expression of the diversity that exists in the group.

Novel prototypes demonstrate a unique or unexpected purpose, application, or aesthetic. In order to meet our success criteria, novel prototypes should also suggest a new domain of design exploration. Three prototypes from our case study met this criteria.

The fourth participant of the day created a simple rotating sculpture on a base instead of a drawing machine. Two facilitators found this interesting and began playing with a simple motor and solar panel combination on a fixed base. This prototype rotated when oriented towards the sun and stopped once it rotated out of the sunlight. They could then reflect additional light onto its solar panel with mirrors. This became a two person cooperative game in which each player reflected light onto the panel when it rotated towards them (see *Spin Game* in the Milanote map data linked above).

Subsequently, a co-facilitator [name removed] made multiple versions of this prototype, attached mirrors to the back of the panels, and then placed them in relation to one another so that each machine would at times reflect light onto another machine (see *Panels / Mirrors* on the Milanote Map). By breaking the frame of the prompt, the rotating sculpture made possible the subsequent sculptural builds, which then explored the novel idea of each prototype giving feedback to others in the form of reflected light.

The *fur Maker* is another novel prototype that meets the criteria described above. It uses the motion of the wheel to draw repeated parallel lines that look like animal fur. As it is hand held, it can be used to draw these lines anywhere on the paper. It suggests the possibility of hand-held drawing devices that convert solar energy into a means of agitating the pen and creating different patterns, a new aesthetic and practical application.

The third novel prototype emerged early on when a participant made a prototype called *Bi-directional motor* system that demonstrated a means of orienting two solar panels in such a way that the machine maintains its power through most of its degrees of rotation with respect to the sun. Normally solar drawing machines lose power the more they rotate their panel away from perpendicular to the sun's rays. The builder of *bi-directional motor system* noticed this and chose to develop an engineering strategy for working around this inherent limitation of the materials.

These three prototypes define three distinct domains for further exploration in the design of the construction kit and activities: 1. Interactive games (the *rotating sculpture*) 2. Aesthetics (the *fur maker*), and 3. Engineering (the *bi-directional motor system.)* Moreover, this speaks to the third criteria for strong concepts set forth by Höök and Löwgren (2012), namely *substanticity*, the concept's relevance and potential for use in designing new instances.

10.7 Discussion

François Jacob argued that the process of evolution was more like tinkering than engineering (1977). Kauffman's adjacent possible (2014) builds on that idea by providing a descriptive model of how that process works. Recursive prompting is an attempt to develop a method for applying these ideas in the context of design and design education by creating a context for playful tinkering, reflective selection of where to invest energy in exploring adjacent possibles, and the shaping of emergent ideas into prompts for successive generations of participants.

Because it is a drop-in activity designed to welcome diverse, intrinsically motivated participants in a non-formal learning space, we see recursive prompting as potentially useful to efforts to develop pluriversality in design education (Noel, 2020). By highlighting the diversity of prototypes and perspectives from different participants, we hope to show the value of a broad range of epistemic perspectives (Turkle & Papert, 1991) and how these can lead to new and valuable domains of design exploration through methods that value collective creativity. There is already evidence that diversity in the composition of teams increases the chances of innovation (Johansson, 2004; Paulus, 2000 in Parjanen 2012), perhaps methods like this one can one day be used to explore that question further.

During the activities, participants demonstrated a range of indicators of learning, described under each of the Tinkering Studio's *Learning Dimensions of Making and Tinkering* (Bevan et. al. 2018), especially those associated with the Learning Dimensions *Initiative and intentionality* and *Creativity and Self-expression.* We can infer the likelihood of pedagogical value in this learning experience from the presence of these indicators, and the established literature on the pedagogical value of Tinkering

(Bevan et. al. 2015). We argue that using Tinkering as a foundation for developing new design methods is likely to confer baseline value as a design learning experience in addition to what the method itself offers.

In addition to the pedagogical value offered by an engaging and playful Tinkering experience, we believe recursive prompting has the potential to become a useful method for designers to involve citizens in non-formal learning environments like libraries and museums in the exploration of a design space. It opens up the possibility of inviting a large, diverse group of participants to drop-in and engage with a design process without requiring specialized skills. The documentation collected and displayed on the recursive prompting map is likely to show not only novel concepts and emergent domains, but also to provide evidence of which domains a population of participants is interested in.

10.8 Conclusion and future work

The recursive prompting case study described herein proved to be highly generative and led to prototypes that define interesting new domains. The *fur maker*, for example, could easily be used as a sample project for the prompt "Build a tool you hold in your hand that helps to draw interesting designs." Similarly, one could imagine inviting successive generations of participants to explore the engineering problem of how to provide constant power irrespective of their machine's angle to the sun (as shown by the prototype *Bi-directional motor system).* Neither of these possibilities were identified in the design space prior to this recursive prompting session. Each novel prototype suggests a different domain with potential for further exploration - an adjacent possible. It should be possible to run the activity again using each of these novel prototypes as a starting point, inviting future participants to prototype further within the design domains they describe. Perhaps the same could be done with the output from this next workshop.

The recursive prompting case study did not show evidence of two out of three success indicators: clustering and progressive growth. In future experiments we will make changes to the method to try to design towards these goals. We may try to highlight emergent sub-prompts as potential starting points for future participants by writing them clearly on the map. Should something like a *fur-maker* emerge, we might write a specific sub-prompt inspired by it on the recursive prompting map next to it, i.e.:

"Make a handheld solar-powered drawing device." We would do this in order to more directly position emergent ideas as potential sub-prompts for new participants. This may help to encourage both clustering and greater progressive growth in complexity over time.

In subsequent iterations we will try giving new participants a longer orientation period - perhaps 3-5 minutes - in which they are given an opportunity to get used to the building materials before we give the prompt. Alternatively, we may try offering them a closed-ended task to complete first, such as assemble a pre-determined structure or base model to work from. Afterwards we can invite them to leave the worktable and take a closer look at the recursive prompting board to select a prototype or sub-prompt from which to take inspiration. More familiarity with the building materials and how they work should enable them to better understand the information presented on the board, and its relevance to the shared exploration.

10.9 References

Bercovitz, J., & Feldman, M. (2011). The mechanisms of collaboration in inventive teams: Composition, social networks, and geography. *Research Policy, 40*, 81-93.

Bevan, B., Gutwill, J. P., Petrich, M., and Wilkinson, K. (2015). Learning Through STEM-Rich Tinkering: Findings From a Jointly Negotiated Research Project Taken Up in Practice. Science Education, 99(1):98–120. Publisher: John Wiley & Sons, Inc.

Bevan, B., Petrich, M., and Wilkinson, K. (2014). TINKERING Is Serious PLAY. Educational Leadership, 72(4):28–33. Publisher: Association for Supervision & Curriculum Development.

Bevan, B., Ryoo, J. J., Vanderwerff, A., Petrich, M., & Wilkinson, K. (2018). Making Deeper Learners: A Tinkering Learning Dimensions Framework. *Connected Science Learning*, *1*(7). https://www.nsta.org/connected-science-learning/connected-science-learning-july-september-2018-0/making-deeper-learners

Dalsgaard, P. and Dindler, C. (2014). Between theory and practice: bridging concepts in hci research. In Proceedings of the SIGCHI conference on Human Factors in Computing Systems, pages 1635–1644.

Duckworth, E. (1972). The Having of Wonderful Ideas. Harvard Educational Review, 42(2):217–231.

Gutwill, J. P., Hido, N., & Sindorf, L. (2015). Research to Practice: Observing Learning in Tinkering Activities. *Curator: The Museum Journal*, *58*(2), 151–168. https://doi.org/10.1111/cura.12105

Hoever, I.J., van Knippenberg, D., van Ginkel, W., & Barkema, H.G. (2010). Fostering team creativity: perspective taking as key to unlocking diversity's potential. *The Journal of applied psychology, 97 5*, 982-96 .

Höök, K. and Löwgren, J. (2012). Strong concepts: Intermediate-level knowledge in interaction design research. ACM Transactions on Computer-Human Interaction (TOCHI), 19(3):1–18.

Jacob, F. (1977). Evolution and Tinkering. Science, 196(4295):1161–1166.

Kauffman, S. A. (2014). Prolegomenon to patterns in evolution. Biosystems, 123:3–8.

Kvale, S. (1994). Interviews: An introduction to qualitative research interviewing. Sage Publications, Inc.

Martinez, S. L., & Stager, G. (2019). *Invent to Learn: Making, Tinkering, and Engineering in the Classroom.* Constructing Modern Knowledge Press. https://books.google.dk/books?id=gjjHwAEACAAJ

Noel, L.-A. (2020). Envisioning a pluriversal design education. *Pivot 2020: Designing a World of Many Centers.* DRS Pluriversal Design SIG Conference 2020. https://doi.org/10.21606/pluriversal.2020.021

Papert, S. (1982). Mindstorms: children, computers, and powerful ideas. Number 14 in Harvester studies in cognitive science. Harvester Press, Brighton, reprint edition.

Papert, S. and Harel, I. (1991). Situating constructionism. constructionism, 36(2):1–11.

Parjanen, S. (2012). Experiencing Creativity in the Organization: From Individual Creativity to Collective Creativity. Interdisciplinary Journal of Information, Knowledge, and Management, 7, 109–128. https://doi.org/10.28945/1580

Patton, M. Q. (2005). Qualitative research. Encyclopedia of statistics in behavioral science.

Penn-Edwards, S. (2004). Visual evidence in qualitative research: The role of video-recording. The Qualitative Report, 9(2):266–277.

Piaget, J. (1973). Psychology and epistemology.

Resnick, M. (2017). Lifelong kindergarten cultivating creativity through projects, passion, peers, and play. OCLC: 1227489657.

Resnick, M. and Rosenbaum, E. (2013). Designing for Tinkerability. In Honey, M. and Kanter, D., editors, Design, make, play: growing the next generation of STEM innovators. Routledge, New York, NY.

Sawyer, R. K. and DeZutter, S. (2009). Distributed creativity: How collective creations emerge from collaboration. Psychology of Aesthetics, Creativity, and the Arts, 3(2):81–92.

Schön, D. A. (1983). The reflective practitioner: how professionals think in action. Basic Books, New York.

The Tinkering Studio at the Exploratorium. (2023). *Learning Dimensions of Making and Tinkering: A professional development tool for educators | Exploratorium.* https://www.exploratorium.edu/tinkering/our-work/learning-dimensions-making-and-tinkering

Tria, F., Loreto, V., Servedio, V. D. P., and Strogatz, S. H. (2015). The dynamics of correlated novelties. Scientific Reports, 4(1):5890.

Turkle, S., & Papert, S. (1990). Epistemological Pluralism: Styles and Voices within the Computer Culture. *Signs: Journal of Women in Culture and Society*, *16*(1), 128–157. https://doi.org/10.1086/494648

Turkle, S., & Papert, S. (1991). Epistemological Pluralism and the Revaluation of the Concrete. In S. Papert & I. Harel (Eds.), *Constructionism.* Ablex Publishing Corporation.

Vossoughi, S. and Bevan, B. (2014). Making and Tinkering: A Review of the Literature. National Research Council Committee on Out of School Time STEM, page 57.

11 Project: Playing with the Sun

Abstract

This section describes the overall structure, goals, and contributions of the Playing with the Sun project, and is submitted along with the articles as part of this PhD dissertation. It explains where and how the products of Playing with the Sun have been published and made accessible to other educators in libraries and other non-formal learning environments. It describes the process used to develop the Playing with the Sun activities and construction kit, which were created in collaboration with librarian educators in Aarhus Public Libraries and Mark Moore.

Playing with the Sun is a project to develop a construction kit, tinkering activities, and pedagogy that invites children and adults to develop an intuitive sense of how sustainable energy works through playful tinkering. It was conceived by Amos Blanton and Ben Mardell in October of 2021 during a seminar in Reggio Emilia. The activities were developed in collaboration with educators from the Teknologiforståelse (Technological Literacy) team at Aarhus Public Libraries, who also gave input into the design of the construction kit. The user experience design of the kit was developed in collaboration with Mark Moore, who did all of the circuit design. The brief writings about pedagogy were made in collaboration with Ben Mardell.

The contributions of Playing with the Sun are as follows:

- An open-source construction kit consisting of elements designed to support open-ended, playful creative learning with sustainable energy. Other librarian educators (or anyone who is interested) are free to build and / or modify the elements of the kit. If they wish to they may suggest improvements and offer them back to the project.
- A set of activities designed to invite children 8 and up and their families to play with sustainable energy and explore how it works. These are described in activity guides hosted on the resources site.
- Some early steps towards a pedagogy of creative learning and collective inquiry in the realm of sustainable energy. This is described in the Playing with the Sun working paper, written with Ben Mardell.

- A documented design process that demonstrates how library educators can can develop activities and a construction kit, described in this chapter.
- Library educators who were members of the Playing with the Sun design team gained valuable experience and knowledge about designing playful and creative learning experiences.

Figure 17: Slide from a presentation by the author about Playing with the Sun, NEXT Library Conference 2023.

Playing with the Sun is a product of collective creativity, integrating input from many different collaborators. The activities and construction kit are important elements of the activities and materials I used to try to elicit and study collective creativity in my research. In designing and co-leading the project with colleagues Aarhus Public Libraries, I have tried to maintain awareness of the importance of learner agency at two levels: The librarian educators co-creating the kit need to feel empowered to experiment and try new ideas, so that when they facilitate the activities they will offer the same freedom to the learners.

As many teacher educators have observed, the way one works with teachers has a strong influence on the way they work with students (Brennan, 2013). If we want them to create contexts for children to lead playful, open-ended design explorations within some set of constraints, then we need to create contexts and constraints for educators to do the same. If we continually instruct them with expertise from above, rendering them fractious, exhausted and without agency, they will very likely recreate that relationship with the students. I have written more about this idea in a paper coauthored with Maria Xanthoudaki on the *Future Inventors* project (Xanthoudaki & Blanton, 2021).

At the beginning of this process my goal was to define a set of constraints and broadly defined objectives, and then to invite fellow members of the team to play and explore within those constraints together. It was important that they felt invited to bring whatever skills, talents, knowledge and resources they had to bear on the problem. This required significant time and effort designing workshops, leading discussions, and hosting seminars intended to give my colleagues in the library a foundation in tinkering pedagogy and design. In addition we explored the use of Reggio Inspired Documentation as a research practice. The results was an iterative design process in which we imagined new ideas together, put them into practice in the form of activities and workshops with learners, and reflected on the results.

Due to the the Covid-19 pandemic, there wasn't as much time to make use of this foundation to do research on collective creativity as I had originally planned. That and the logistical challenges of finding children in the target age range in the library resulted in us running only about 12 workshops, whereas the original target I set was 25 or more. If circumstances had permitted I would have liked very much to reach 50, even if they had fewer participants and were briefer than the 12 we did run, which were mostly with school classes.

The reason that more workshops is better in this kind of research is that there is only so much design feedback that can be absorbed from each workshop before the designers reach saturation. And there is only so much that can be usefully reflected on between workshops before the lack of feedback from experience becomes the limiting factor. So it follows that the ideal circumstances for this kind of work are those that permit just enough time to reflect and make modifications to an activity between trying it out with, and getting design feedback from, the learners. [23]The possibility of many design iterations in a non-formal learning environment was one of my reasons for proposing that this PhD research be done in the library, and I had hoped to make a high number of iterations the foundation of my argument for rigor in the methodology. That will have to wait.

[23]I suspect one reason for the very high quality of Tinkering activities developed at the Tinkering Studio is the fact that they have a museum "floor" just outside their workshop door with a near constant supply of new tinkerers to test their ideas with. An activity designer can have an idea for an improvement, walk outside and try it, and come back in to reflect on and chat about the results all in less than 20 minutes with almost no logistical time costs. It is a paradise for activity design iteration that tinkering designers like me can only dream of.

In spite of these challenges, I would still call the experiment to develop a construction kit and set of activities with librarian educators a success. There are numerous contributions from everyone on the team in the project at many different levels - from the physical design of elements and environment, to the logo design, to the design of the activities and emerging pedagogy. Readers will find a timeline below that highlights some but not nearly all of these collectively creative contributions. More may eventually be published as part of my colleague Minke Nouwens-Bromann's ethnographic research on our design process.

It is clear that libraries have tremendous potential as spaces for doing design-based research on play, creativity, and the development of creative learning experiences. The interest-driven nature of learning in the library makes them ideal laboratories. Many of the challenges identified are solvable with relatively modest staffing and resources. It may be easy to mitigate some of the logistical challenges by siting the research in libraries closer to residential areas with populations of children who have more unscheduled time to engage in drop-in activities. This would make it easier to establish a local community of practice, which would enable faster iteration loops on both design and research.

The Playing with the Sun activities and construction kit also served as an important part of the context for experiments designed to elicit collective creativity. The two PhD articles titled *Recursive Prompting* and *A Short-Term Ecology* describe research in which the construction kit serves the role of open-ended play material that participants used to build and explore their ideas. Had I used a pre-existing collection of play materials or a ready made construction kit - Lego bricks for example - I would have had a great deal more time to study the phenomena of collective creativity (at least at the level of direct experimentation on it). However, that would have confined the research to the level of learners engaging with activities and materials. I felt there was more value in exploring how to structure a collectively creative design research process at the level of practitioner educators, and then to run and collect data on the activities with them. And this aligned with the goal of establishing an example of how to do practice based research on play and learning in the library.

What we were doing as a design team was fundamentally analogous to what we are inviting the learners to do in the activities with the kit, only on a longer time scale. The idea for the project itself was based in some part on Mitchel Resnick's contention that what children do in kindergarten with building blocks is fundamentally analogous to what graduate students do at MIT Media Lab with technology (2017): playfully explore new possibilities, and see what can be learned in the process.

We are used to thinking of libraries as places of research. But that research often consists of accessing and analyzing ideas developed elsewhere. Through Dokk1 and *Design Thinking for Libraries* (2015), Aarhus Public Libraries demonstrated that the library can also be a place to build new knowledge through design thinking. This knowledge is often local, rather than universal. But adherents to the Reggio Emilia approach believe that in realms as complex as learning and education, all knowledge must be interpreted locally to be relevant and meaningful to the learner (Guidici et. al. 2008).

As we are forced to reckon with the global crisis brought on by the developed world's over-reliance on fossil fuels, we will have to learn to think locally. Both Design Thinking and Tinkering represent good pedagogical foundations for people to practice doing just that, and local libraries are the ideal setting. Playing with the Sun is a way of putting these ideas in practice.

11.1 Areas of Focus for Playing with the Sun

The Playing with the Sun project has been structured around three areas, each with its own set of collaborators.

11.1.1 Activity Design

Activities were developed in a collaboration between Amos Blanton and the Teknologiforståelse (Technological Literacy) group in Aarhus Public libraries. The group consists of Jane Kunze as project manager, Henrik Viking Hansen, Mathias Kær Helge, Sara Petrat-Melin, and Matilda Ejgreen Tjelldén. It was formed and overseen by Sidsel Bech-Petersen, my PhD supervisor at Dokk1. We worked together most of every Tuesday beginning March of 2022 through June of 2023.

During this time the team at Aarhus Public Libraries hosted two design residencies from visiting tinkering designers: Ryan Jenkins of Wonderful Idea Co. the week of May 9th, 2022. And Sebastian Martin of the Tinkering Studio at the Exploratorium, the week of October 3rd 2022. Both of these residencies focused on activity design, facilitation, and the pedagogy of Tinkering and playful learning, and involved several days of collaboration with the Playing with the Sun team. Each included a half-day hands-on workshop on Tinkering with 20-30 Danish librarians from surrounding regions, which Jane Kunze and the Teknologiforståelse team organized and ran along with the resident.

The third and final residency was in May of 2023 with Ben Mardell of Harvard Project Zero, and focused on reflective documentation as a means of making learning visible. This included two Playing with the Sun workshops run with children from local schools. Documentation from this residency was presented as part of Ben's keynote at the 2023 NEXT Library conference titled *Supporting Playful Learning in Libraries: A Pedagogy of Play*.

The two activities documented and described on the website are drawing machines and cable crawlers. Drawing machines involves building a solar or handcrank powered machine that makes marks with a pen or by moving itself through sand. Cable crawlers invites children to build a small cable car that can travel across strings that are set up in the play environments.

Many more activities have been discussed as possibilities, and a few have been prototyped. But these are yet to be fleshed out, tested, and fully designed.

11.1.2 Construction Kit Design

The Playing with the Sun construction kit was co-developed by Amos Blanton and Mark Moore, with input and feedback from the Teknologiforståelse team in Aarhus Public Library. Celeste Moreno, Andrew Sliwinski, Sarah Trahan, Ole Caprani, Mike Petrich, and Liam Nilsen contributed important advice and feedback along the way.

In terms of this research, the construction kit serves as a set of "primitives" - not unlike Scratch blocks - with which children can begin to explore the realm of sustainable energy through first-hand experience. Like all constructionist play materials it is designed to enable bricolage, or the recombination of elements to form new and different ideas (Papert & Harel, 1991). It is entirely open-source, and the instructions necessary to source parts and build each element are made available on the resources website.

The kit consists of the following elements at time of publication:

Figure 18: The elements of the open-source Playing with the Sun construction kit at time of publication.

- Solar panels generate power from sunlight
- Gear motors output power generated from various sources. They have a switch to change their direction of rotation, and a hub that can attach to a variety of different wheel shapes as well as form a drive-pulley for cable crawlers.
- Solar Engines store energy until there is enough to briefly pulse the motor, allowing for solar powered activities in less than optimal lighting conditions.
- Hand crank generators allow learners to generate their own power to drive motors or charge powerpacks.
- Power Packs can store enough energy to drive a motor for a few minutes when charged with hand crank generators or solar panels.
- Structural Elements consist of PPA coated Plumber's strap (Danish: Patentbånd or Hulbånd) which can be bent into a variety of shapes. Snap rivets allow pieces of strap to be secured together or to other elements of the kit.

The need for a construction kit emerged out of our design process from the recognition that the technical barriers presented by bare electronic elements like solar cells and various circuits were simply too high of a bar for most educators. Most of the "kits" available to explore sustainable energy sources like solar panels are closed-ended, meaning that they are designed in such a way that the learner builds a single project, usually advertised on the front of the box, by following step-by-step instructions. So there is a need for construction kits designed for open-ended play with sustainable energy, allowing children to build anything they can imagine in the spirit of what Seymour Papert described as a "microworld" (1982).

The design of the kit simplifies the complexity of working with solar cells and other elements by using a set of standard, relatively easy to use connectors, and a range of other standards designed to maintain electrical compatibility. Any element can be combined with any other element, and though the results may be unexpected, they won't cause damage. In terms of design philosophy, the kit draws heavily from the work and experiences of constructionist educators affiliated with the Lifelong Kindergarten group at MIT Media Lab and the Tinkering Studio at the Exploratorium.

In designing the kit, inexpensive and easy to source low-tech components have been preferred over difficult to source expensive ones. Whenever possible, we have tried to design elements that can be easily fabricated with a laser cutter or 3D printer out of commonly available stock. Our intention is to make it as easy as possible for an interested library, makerspace, school or similar organization to build their own kit and begin running their own workshops. At time of writing we have yet to invest in any promotion. Thus far one engineering professor from Columbia and one unschooler cooperative in Colorodo have expressed an intention to build their own kits. And one library Makerspace in Aabenraa, Denmark was inspired to build their own version.

The kit itself is an open source project. This means it is open to outside contributions in the form of new or improved designs for various elements. The Contributor Guide on the Resources site describes design values and technical requirements necessary to do so. It is hoped that when an organization builds (instead of buys) its own construction kit, the builders will become better able to modify, hack, and evolve the elements than they would otherwise be. But we recognize that building the kit will require a significant amount of technical expertise and time investment. Currently we suggest any non-technical organization (like a library or school) who wishes to build a construction kit should do so in collaboration with a makerspace or maker community of some kind. Once the kit is built, it doesn't require much technical knowledge to run or engage in tinkering activities with it. We hope it will make a good foundation for pedagogical experiments to learn how children make sense of the relationship between energy generation and its use, which we hope will in turn inform the design of future activities and elements.

The source code necessary to fabricate all the elements - from the 3D printed wheel hubs to the electronic circuit boards - is available on the project's public Gitlab repository: https://gitlab.com/playing-with-the-sun/, which is described in greater detail below. Instructions for sourcing parts and assembly are available on the Playing with the Sun Resources website: https://resources.playingwiththesun.org/

11.1.3 Pedagogy

The third leg of Playing with the Sun centers around the pedagogical approach to designing learning experiences for children around sustainable energy. We aspire to develop a means of collective inquiry and creativity with participants spanning multiple locations across the globe. This is still in the early stages of development. The pedagogical ideas described thus far can be read in the Playing with the Sun working Paper #1, written by Ben Mardell and Amos Blanton, and included in the Playing with the Sun appendix.

The idea of recursive prompting, described in the article of the same name, is an early experiment in organizing collective creativity as part of Playing with the Sun. The idea is that if we can design documentation strategies, activity designs, and methods that allow us to collectivize the exploration of a design space with a playing with the sun activity, then we will be closer to being able to do it with other projects. For example - we might ask citizens in several libraries to prototype new ways of drying clothes sustainably, and organize the collective inquiry as a recursive prompting activity in which everyone contributes to the same design exploration. Instead of standing on the shoulders of giants, perhaps we can create a method for standing on the shoulders of other interested people in one's own community. How high we can get that way remains to be seen.

The inquiry into pedagogy will continue after the completion of this PhD project in a conference designed by Ben Mardell and Amos Blanton in Watertown, Massachusetts (US) on July 6th and 7th of 2023 called *Playing towards sustainable energy practices: A 2-day conversation about playful learning and the climate crisis.* The goal for the two days is to explore attendees individual and collective thinking about these two questions:

- What responsibility do we, as educators, have in engaging people of all ages in an examination of the climate crisis?
- How can play and playful learning be part of an exploration of sustainable

energy practices?

We have invited 40 educators, artists, tinkerers, and engineers to attend.

Pursuant to this early effort to conceptualize collective inquiry in Playing with the Sun, I worked with designer Nick Bromann in February of 2023 to develop design strategies for managing and representing this data, especially with regards to recursive prompting. This work was delayed about nine months by various bureaucratic issues, so it isn't featured in any of the publications. But it will be explored further in the coming years.

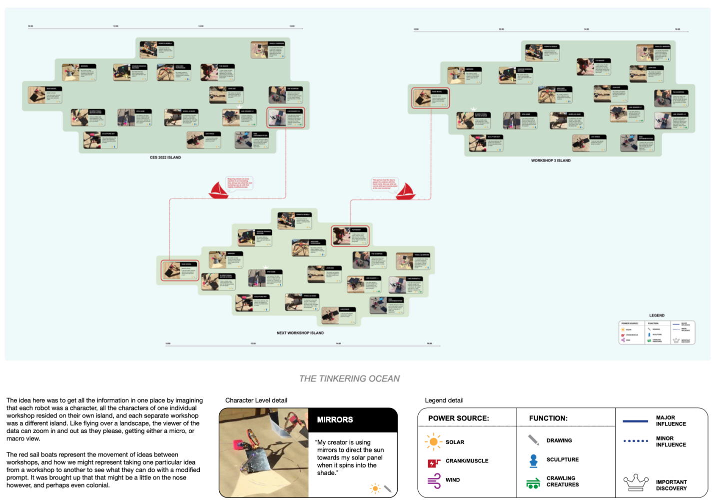


Figure 19: A strategy developed with Nick Bromann for representing the exploration of a design space at 3 levels: The individual participant's project, the workshop in which the project was made, and the overall space of possibilities around the activity.

11.2 Published Elements of Playing with the Sun

Playing with the Sun is open source. All information, including activity descriptions and instructions for building the construction kit, is shared under a Creative Commons Attribution-Non Commercial 4.0 International (CC BY-NC 4.0) license (https://creativecommons.org/licenses/by-nc/4.0/) . It is documented and shared publicly in three places:

11.2.1 The Playing with the Sun Website

Visible at: https://www.playingwiththesun.org, the playing with the sun website introduces the project and briefly explains the goals. It is available in both English and Danish.

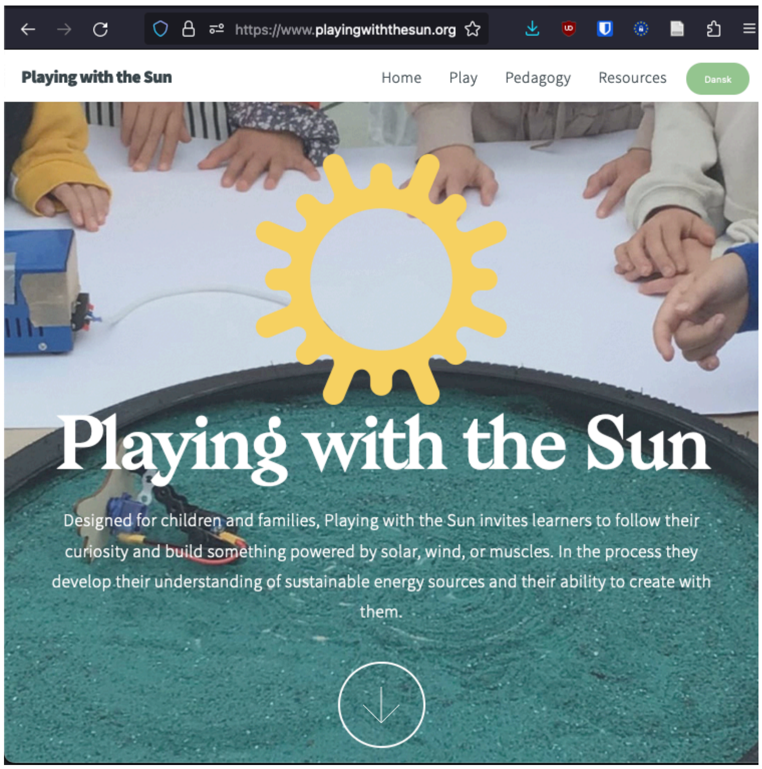


Figure 20: The Playing with the Sun website.

11.2.2 The Playing with the Sun Resources Website

Visible at https://resources.playingwiththesun.org/, the resources site contains in depth descriptions of the construction kit, activities, design considerations for contributors, and other information. The page for each element of the construction kit contains information about sourcing parts, assembly, desired improvements, and past design revisions. These last two sections are present so that anyone interested in working on another revision of the element can understand how it has developed so far (and any key design considerations that emerged), as well as areas in need of improvement. The resources website is designed to be easily updatable.

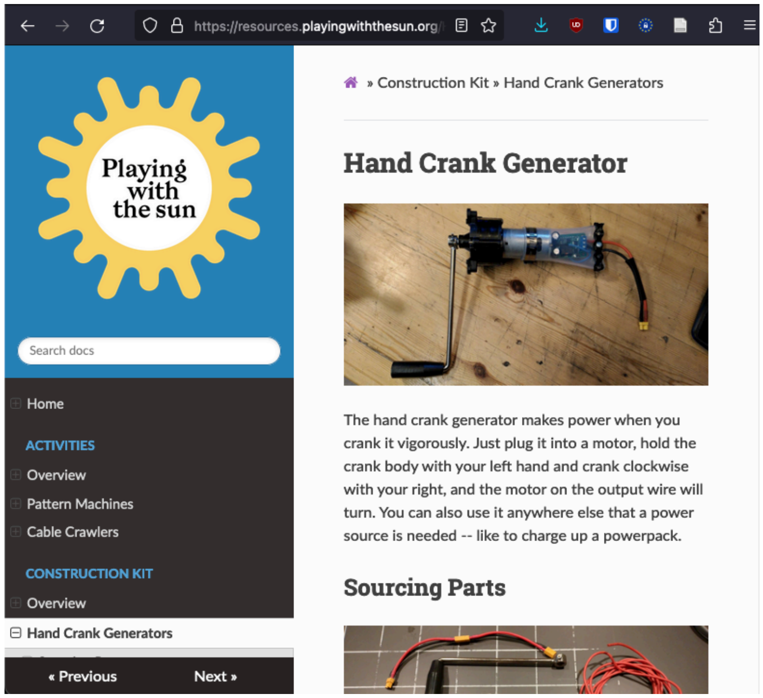


Figure 21: The hand crank generator page on the Playing with the Sun Resources site.

11.2.3 Publicly Shared Source Code

The source code for all aspects of the project is hosted on gitlab at the following URL: https://gitlab.com/playing-with-the-sun. All code is shared with a CC-BY-SA 4.0 international license (https://creativecommons.org/licenses/by-nc/4.0/). This allows anyone to fork or copy any parts of the source code for their own projects, as long as they give credit back to the project, share any changes or derivative works under the same license, and do not use it for commercial purposes. Creative commons licenses are important for practitioners around the world, as they make it possible to use ideas without having to first secure permissions or involve institutional lawyers.

Revisions are tracked via the open source Git revision control system. This makes it possible for anyone to make a copy of or "fork" the code, modify or improve it, and optionally submit it back to the project's maintainers (currently Amos Blanton and Mark Moore) as a "pull request." The maintainers can then consider integrating the proposed changes into the main code repository, so that subsequent versions of that resource will make use of them.

There are four source code repositories belonging to the Playing with the Sun project.

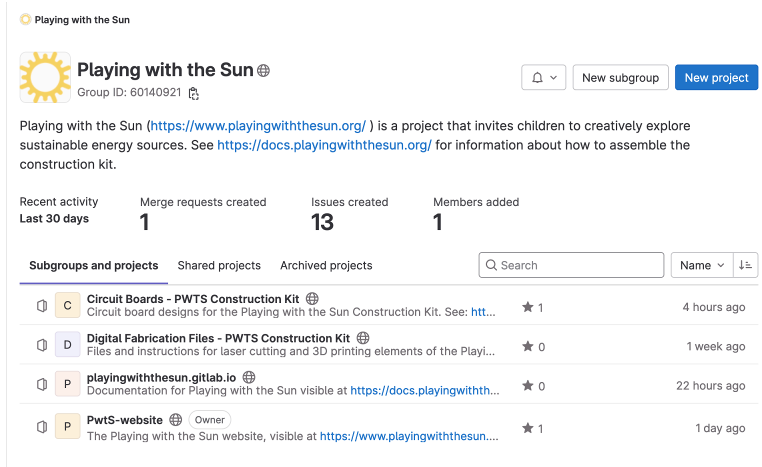


Figure 22: Screenshot of the public source code repository for Playing with the Sun at Gitlab.

- The circuit boards repository contains source files needed to fabricate the electronic circuit boards, and contains code / technical work done by Mark Moore in design collaboration with Amos Blanton.
- Digital Fabrication Files contains the files used to 3D print the wheel hubs, made by Jane Kunze, the motor board mounting plate by Henrik Viking Hansen, and the wooden or acrylic wheel-like shapes (by both Jane Kunze and Henrik Viking Hansen).
- Playingwiththesun.gitlab.io contains the source files and content displayed in the Playing with the Sun Resources website, which is a static site generated with MkDocs. The resources website was made by and is maintained by Amos Blanton, but can be contributed to / edited by anyone via git pull request.
- PwtS-website has the source code for the Playing with the Sun website, made by Amos Blanton built on a template published and freely licensed by HTML5up.

11.3 The Process of Designing the Construction Kit and Activities

This section describes how the Playing with the Sun construction kit and activities were created in collaboration with the Technological Literacy team at Aarhus Public Libraries, Mark Moore, and many others.

###Initial Inspiration and Exploration

In the Summer of 2021 I began exploring strategies for designing Tinkering activities that engage children around playful learning experiences that involve sustainable energy generation. This resulted in some early prototypes, including the solar bug, a small and very simple arrangement of two solar panels and two gear motors.

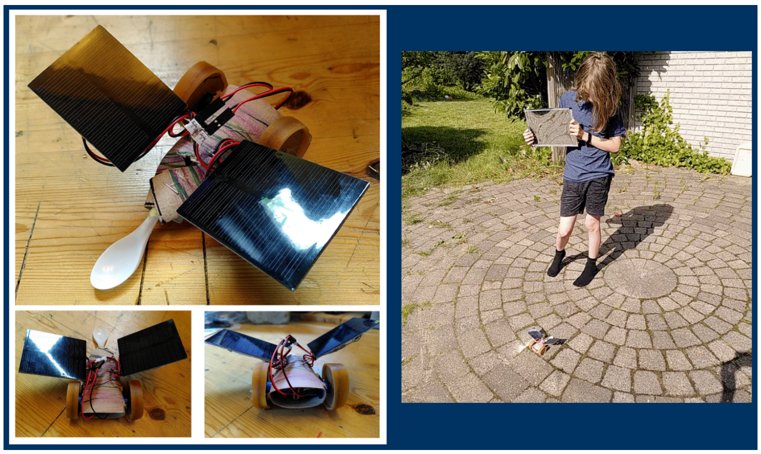


Figure 23: The first solar bug consisting of a cardboard tube and two .5 watt solar panels attached to gear motors on opposite sides. It can be steered by reflecting light onto one or the other solar panels using a mirror.

I wrote a brief essay describing the thinking behind this called *Playing with the Sun*, and shared it with a few friends, including Ben Mardell. This essay argued for the need to develop more and better toys to enable children to understand sustainable energy generation through play.

Prior to this I had been running workshops with a Tinkering Studio activity called *Cranky Contraptions* (*Cranky Contraptions | Exploratorium*, 2023) as part of a course I co-taught about Play and Playful learning. The activity invites participants to build simple hand-cranked automata out of steel wire, foam, and wooden blocks. I decided to build a solar powered base that would make them crank by themselves whenever they stored up enough solar energy to do so. This utilized simple circuits called "solarengines" that emerged out of the BEAM Robotics "Scene" or community in the 1980s (Hrynkiw & Tilden, 2002). Solarengines were often used to make machines that mimic animal-like behaviors, such as seeking light to collect more solar energy the way an insect might seek food.

BEAM robotics made an impression on me because it represented a different relationship to energy than that of most modern technologies. As I described in the first *Playing with the Sun* Essay, plugging an electrical appliance into a wall socket gives a child access to an essentially infinite river of power regardless of whether it's sunny or cloudy, windy or calm. The power arrives the same way all the time like magic, with no accompanying information about where it came from or how it was made. Feedback to the user consists of a difficult to decipher monthly bill that many people rarely look at and most children probably never see. Batteries work in more or less the same way: Someone does something magical far away that puts power into a small cylinder or box. We use it until it runs out, and then we buy a new one. There is usually no information given about where the power came from, or how it got put it into the box.

Many BEAM robots use solar panels instead of batteries as a power source. A *Photovore* (Hrynkiw & Tilden, 2002) mimics the behavior of an insect seeking food. If there is more light, the robot bug will move towards it. If there is plenty of light energy to be had it will move about faster than it otherwise would. If there is less light, it will move more slowly. Moving fast when there is more energy and slow when there is less is a basic strategy of energy conservation that we can recognize from our own embodied experience. When we are tired, we move more slowly than when we are rested or energized. Nearly every living organism on earth uses this strategy to help balance their own equation of energy intake and energy usage.

The move towards sustainability will likely involve learning to use more sustainable energy when it is abundant, and less when it isn't. Many BEAM robots do this already, but they stand out as a rare exception in the world of modern technology. Most privileged people use as much energy as they want whenever they want it, without thinking about how it was generated. This is a relationship to energy born out of the use of fossil fuels. With fossil fuels, the energy generation side of the equation was satisfied some 300 million years past. But this is a relationship to energy that we can no longer afford to continue due to the climate crisis.

From this stage of my PhD forward, I used my self-hosted Raspberry Pi based Pleroma server (a free and open-source alternative to Twitter that is part of the same Fediverse that Mastodon is part of) as an open design notebook. I documented most design experiments and relevant thoughts through photos and video uploaded with posts to my server, which mirrors a practice I formerly did on Twitter with the

#LEGOtinkering hashtag. You can view an HTML archive of these posts at this URL: https://www.playingwiththesun.org/timeline/. Many of the photos you'll see below are taken from that timeline, which consists of about 320 posts containing text, video, and photographs, recorded between March 20, 2021 and May of 2023. Many of the still images included below are from videos ranging from 5 to 20 seconds long that can be viewed via the timeline included above.

In each Solar-powered Cranky Contraptions workshop I ran, I prompted the participants to build a creature that was inspired by one from the existing taxonomy, which were created by previous participants. When completed, I added their creature to the collection and place a line of red-tape between it and the "ancestor" that inspired it. After each workshop, the taxonomy grew larger.

When new ideas and strategies emerged, myself or my colleagues would create a small placard to describe the new idea in such a way that future participants could understand and build on it. For example, after a tinkerer made a contraption that used double cranks on either side of the wooden base, my colleague in Dokk1 Library made a small placard explaining how this is done, and placed it in the taxonomy next to the creature where the idea first emerged. Therefore the taxonomy (consisting of the various cranky contraptions and their relationships of "descent") became both a record of the past and a reference or resource for people building the next generation of creatures.

This activity and early experiments with an "evolutionary" prompt led to interesting examples of additive designs made by people who never met one another.

11.3.1 Early Drawing Machines Activities

Around this time I began exploring solar powered drawing machines using solar panels, solarengines, and various different means of mounting motors to the panels. Using mostly binder clips I was able to arrive at several "base model" designs. A base model is a concept that emerged from work I did in 2016 developing the Lego Art Machines activity with Ryan Jenkins and Nicole Catrett of the Tinkering Studio at the Exploratorium. It describes a design for a pre-built entry point for an activity that invites the learner to modify or build onto it. A base model "lowers the floor" for new users by providing a ready-made platform as a starting point. It's usually built

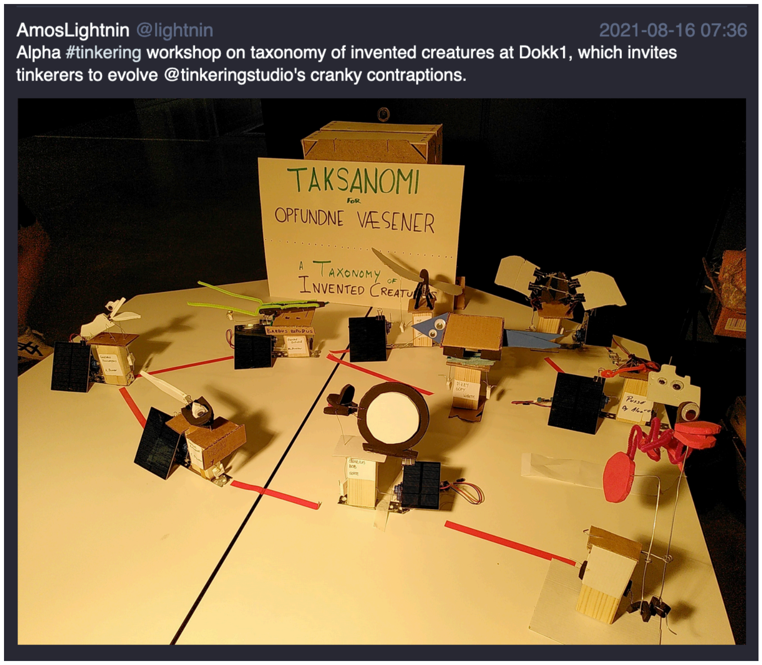


Figure 24: An overhead view of the early Taxonomy of Invented Creatures.

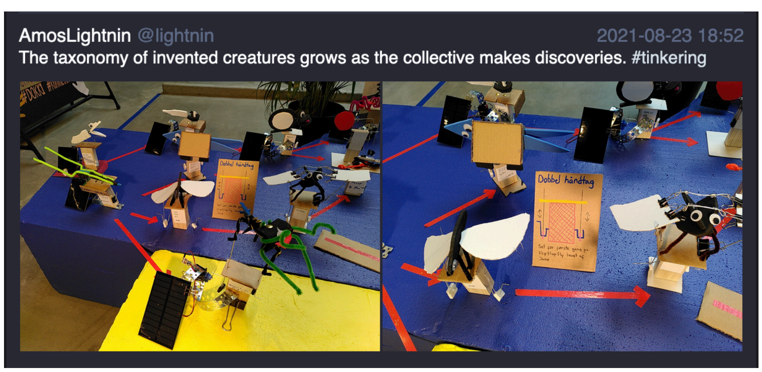


Figure 25: A later view, with close up of the placcard describing how to make double-handcranks.

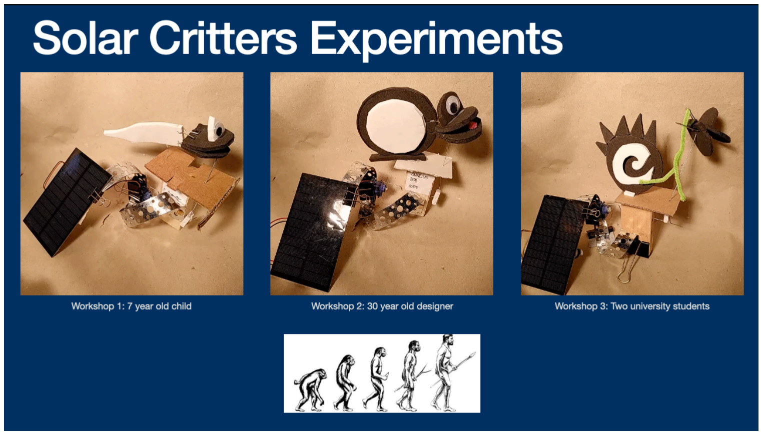


Figure 26: Slide showing progressive growth in complexity in early invented creature experiments across multiple workshops. Note the preservation of the single eye / binder clip mouth design across all three generations, and the overall increase in complexity.

to mitigate some sort of technical or engineering problem which would otherwise distract the learner from the initial area of creative exploration that the activity designer wants them to encounter. In this case, the base models provide a working configuration of panel, solarengine, and motor that immediately moves and draws something. It allows for plenty of further experimentation in the form of changing the position of the pens and motors, and stimulating the machines with mirrors.

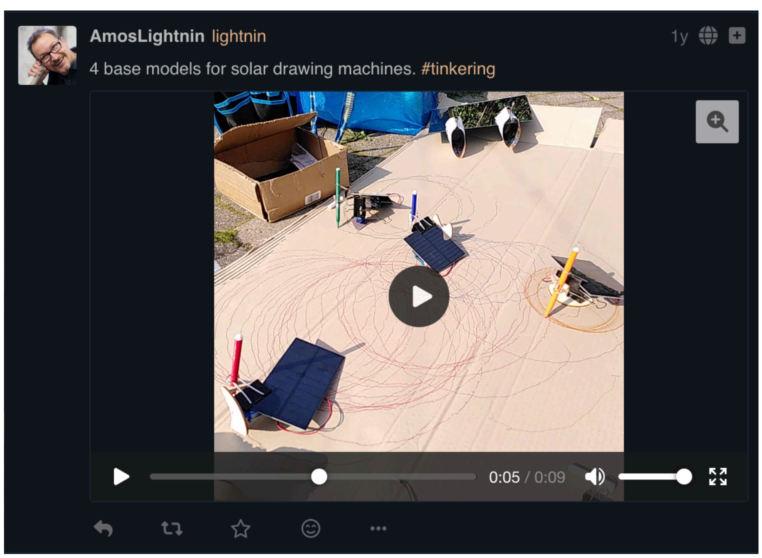


Figure 27: Four different drawing machine base models developed for the workshop described in the article titled A short-term ecology for the having of wonderful ideas.

I began to recognize that the solar drawing machines have a relationship with their environment that their battery powered equivalents do not. When rotating around in a circle, the angle of incidence between the solar panel and the sunlight changes, which in turn changes how much energy is fed to the solarengine. As a result, the machine rotates more slowly when the panel is oriented away from the oncoming sunlight, and more quickly when oriented perpendicular to it. One can also shade the panel which causes it to dramatically slow down or stop. And one can also reflect additional light onto it using a mirror, which causes the panel to generate more energy, which causes the motor to move faster. Something similar to these effects happens naturally when clouds pass by and change the level of light reaching the solar panel without any intervention on the part of the learner.

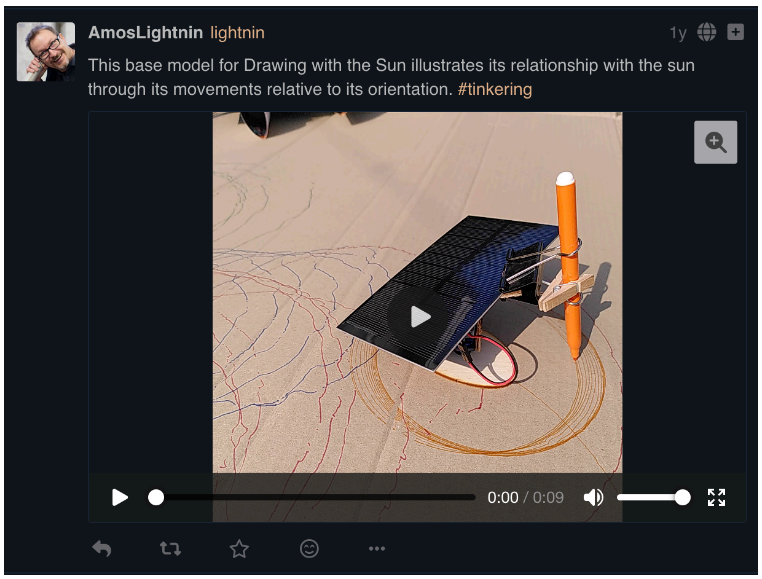


Figure 28: This video of a drawing machine shows how its movement is contingent on the relationship to the sun.

In September of 2021 I ran solar drawing machines at Olafur Eliasson's Copenhagen Studio as part of an EER workshop called *More than Human*. I had assistance from my long time friend and Tinkering collaborator Liam Nilsen. The goal was to experiment with cross-pollination as a means of stimulating collective creativity. The workshop is described in detail in the article titled *A short-term ecology for the having of wonderful ideas: Catalyzing collective creativity through cross-pollination.* Subsequent analysis of the data led to the idea of mapping the movement of ideas through collectively creative activities.

In October of 2021 the CLRG team visited Reggio Emilia for a small conference I

Figure 29: "More than Human" EER solar drawing machines workshop, 30 Sept. 2021. Photo by Runa Huber.

helped organize on Practitioner Research. Ben Mardell of Project Zero joined the trip as well as several researchers from the Interacting Minds Centre. During our visits to the various Ateliers of Reggio Emilia, Ben and I conceived the idea of Playing with the Sun as a space filled with activities children could use to explore how sustainable energy works. Ben and I began having recurring meetings to work on Playing with the Sun, a collaboration which continues to this day.

As the pandemic restrictions eased in further in the Winter / Spring of 2022, all but one of the original CLRG members were unavailable to continue. I wanted to shift the design focus from general tinkering activities towards tinkering activities in the realm of sustainable energy. My supervisor Sidsel Bech Peterson and the Makerspace coordinator Jane Kunze proposed that we form a new design group around Playing with the Sun in Aarhus Public Libraries. The goals were well aligned with a project on Teknologiforståelse (Technological Literacy) funded by the Danish ministry of culture and palaces. Jane and four new library educators joined our team, and in March we began meeting and working together every Tuesday.

In the early stages we spent time discussing basic tinkering principles and ideas. Soon after we began exploring the characteristics and qualities of the different materials used with solar drawing machines. Our goal was to increase the potential for more creative exploration and more diverse outcomes in the drawing machine activities while maintaining (or if possible lowering) the floor.

As with all design explorations, some things worked and some didn't. We stumbled upon many more interesting possibilities than we had time to follow up on. Jane made some solar drawing machines that focused on aesthetic elements, using round laser cut shapes and coloring them with markers. Mathias developed a machine that rotated around until its angle with the sun starved it of power, which we recognized made it somewhat like a motorized sundial. I connected a motorized hand drill to a large 20 watt solar panel to try and make a human-rideable solar drawing machine, but couldn't quite make it work. Meanwhile we experimented with different ways of connecting various elements together that would allow the learners to easily explore different designs.

In May of 2022 we hosted a design residency with Ryan Jenkins of Wonderful Idea Co., formerly of the Tinkering Studio at the Exploratorium. Ryan had been working on solar powered tinkering projects as part of another project. For two days we explored different prototypes involving solar energy, which led to a variety of important and interesting ideas prototyped in cardboard. I began to recognize that the need to work with small, sensitive wires and connectors was a significant barrier to entry for most people, and tried to think of different means of "lowering the floor." At the same time we all recognized that Denmark it is not always sunny outside. At some point in the prototyping process with Ryan, I began to wonder if we might use human power to temporarily charge our machines when sunlight wasn't available.

At the end of Ryan's residency we hosted a workshop on Tinkering with librarian educators from around Denmark, and demonstrated our progress. Many colleagues in the team noted Ryan's skill at leading workshops and group reflections, and the quality of the marble run tinkering experience (which has been continually refined over the course of about 15 years). We also gave a brief demonstration of our initial ideas around Playing with the Sun activities.

Mark Moore (https://moore.dk/) had already been supporting the project with advice and expertise in various ways, and became even more active around this time. Mark is an educator and technologist who teaches at Aarhus Gymnasium (what in the United States would be called a high school). He has the rare gift of being able to understand complex technologies and explain them in terms most people can understand. He is *exceptionally* talented at collaborating, ideating, and rapid prototyping in a way that reminds me of what it was like collaborating with friends

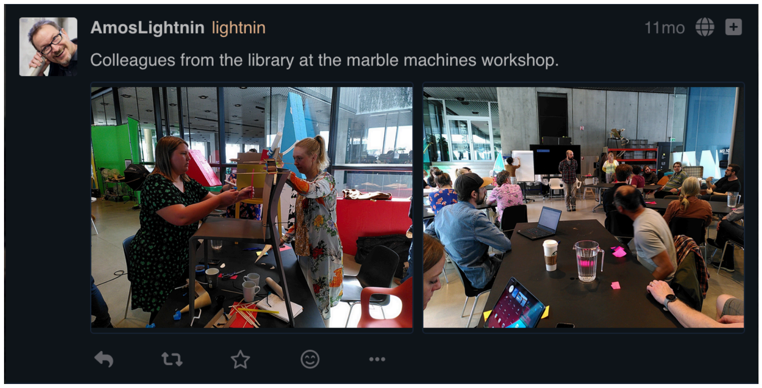


Figure 30: Ryan Jenkins leading a marble machines workshop for librarians from around Denmark at the end of his residency.

and colleagues from the Lifelong Kindergarten group at MIT Media Lab. While he has been paid for some of his work on Playing with the Sun, he has volunteered a great deal of time and energy out of his enthusiasm for the project and its goal to enable children to explore sustainable energy through play.

11.3.2 Human Power as an Alternative to Solar Energy

With Mark's help I began prototyping some of the ideas that came out of the residency with Ryan. I integrated a large 5 Farad capacitor into a solar drawing machine so that it could be driven by the sun or hand crank-charged. The idea was that by having two ways to generate sustainable energy, we would have some flexibility to run workshops on days when the sun could not break through the clouds. We recognized that this in itself is an important lesson about sustainable energy sources: When they are intermittent, as both solar and wind power are, it's best to have a range of different options to rely on.

This required research into sourcing supercapacitors, circuit design and prototyping, and related areas - and a number of different prototypes. All of this happened in conversation with Mark and with his ongoing support, and while he was working circuit design for different elements as well. The resulting prototype showed utility in that we could now demonstrate activities like solar drawing machines without sunlight or expensive, energy hungry halogen lights. But the fact that the machine had multiple complex components packed together in a large circuit made the inner workings difficult to explain.

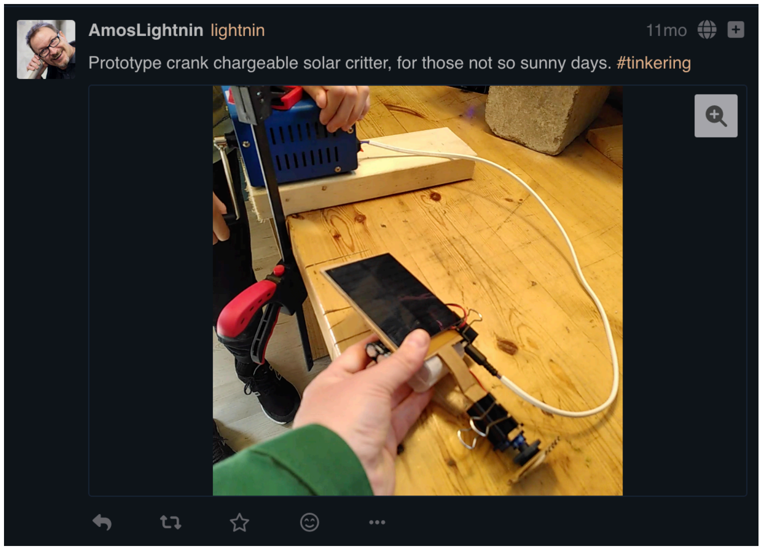


Figure 31: Still frame from a demonstration video showing how to crank charge the prototype.

Around this time my colleague Mathias Kær Helge and I ran a workshop on solar drawing machines at a small climate festival at Gellerup Library. We noticed that even very young children seemed to get engaged with shading or reflecting additional light onto the panels, and playing with the relationship between light and the behavior of the machine. How to best support families working together to explore what could be made also seemed worthy of further consideration. Subsequent reflections on the workshop at Gellerup led to the emergence of two design principles which remain important to this day.

The first is that the behavior of the output, a motor, should closely track the behavior of the power source - usually light from the sun. When the child puts their hand over the panel, the machine should slow or stop. This allows the child to explore the relationship between power generation and power usage at a timescale that they can experiment in.

It has long been possible for children to leave solar flashlights charging in the sun all day, and then see them power an LED light in the night. But this puts the time between energy generation and energy use at several hours or more, a very large feedback loop. If the child is inspired to experiment, it's difficult for them to get feedback when operating at this timescale. For example, they are unlikely to notice the relationship between the sunlight's angle of incidence to the solar panel and how long the LED subsequently stays lit through the night. They'll probably be asleep when the LED goes out. So one reason the elements use capacitors and not rechargeable batteries is that the capacitor's charge / discharge cycle length is measured in seconds and minutes, instead of the battery's hours and days. This makes it possible for a child to experience and experiment with both sides of the charge / discharge cycle dozens of times an hour.

A second design principle emerged out of the experiments with the hand-crank powered machines. Part of understanding of how sustainable energy works is getting to know the qualities and proportions of different energy sources. Once a child sees that a solar panel approximately 14 x 18 cm can make a small motor move in full sun, they begin to get a sense of how much energy there is in the sunlight falling from the sky. When they make the motor move the same way by hand cranking a generator, they can then start to form a physical, embodied sense - a "feel" for just how much power it takes to make the motor turn. This makes it possible for the learner to develop a sense of proportionality between different energy sources. Sustainable sources of energy like wind and solar are intermittent, so getting a sense for their different qualities, proportions, and characteristics will be important as we collectively figure out how to combine them to live sustainably.

11.3.3 A Construction Kit with the Potential to Support Different Activities

Soon after the workshop at Gellerup it became clear that working with solar panels and motors required a level of technical sophistication that was a significant barrier for the librarian educators on the design team, not to mention other librarians with less access to technical expertise than we had. As Mark and I discussed this, the idea of making each element into a component of a larger construction kit emerged. We realized that the various activities we'd been prototyping and imagining could all be done with a set of components that could be joined together with a common connector and power specification (5V). I began prototyping construction kit elements during my Summer vacation and subsequent residency during August of 2022 at the University of Colorodo at Boulder.

In Boulder I was able to get feedback, advice, and help with design prototypes from Celeste Moreno and Ronnie Hayden, PhD students working with my friend and colleague from MIT Media Lab Professor Ricarose Roque. Celeste put me in

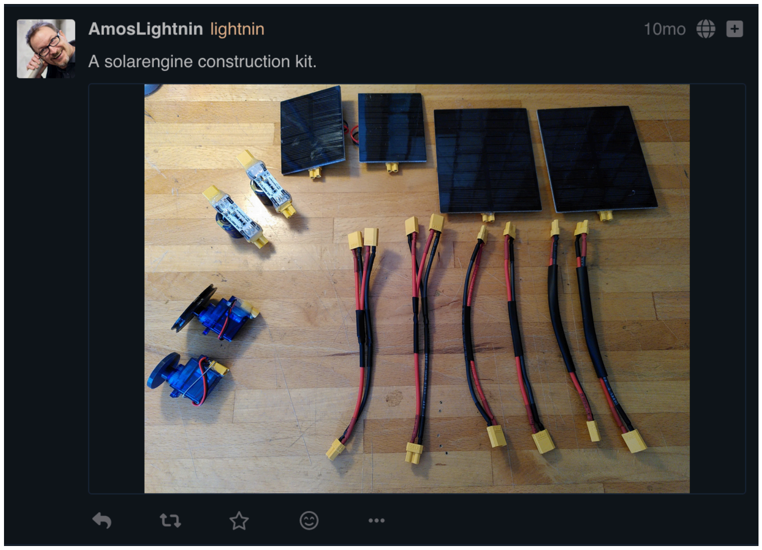


Figure 32: First prototype of the Playing with the Sun construction kit.

touch with the founders of the Junkyard Social Club, an unschooler cooperative / Makerspace / Adventure playground in Boulder, where I was given the opportunity to run several workshops with local kids. In addition to these I ran two small workshops at local libraries. All of these were focused on the design of the construction kit and the framing of the activities. The last one was my first experiment with documenting recursive prompting using iPads to capture and display video of children's different drawing machines. Later iterations can be seen in the "Recursive Prompting" article.

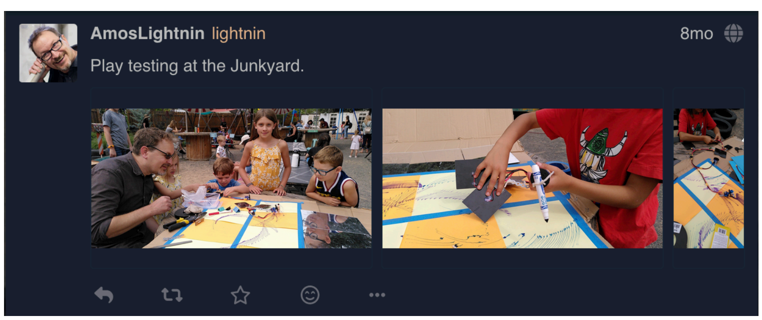


Figure 33: Playtesting with kids at the Junkyard Social Club in Boulder, Colorodo.

To provide a common frame for attaching components and building structures, I'd been experimenting for some time with Plumber's strap (Danish: Patentbånd), a flat steel band with holes every 15mm. It allows different parts to be joined together by placing pipe cleaners or brass paper fasteners through overlapping holes. These were also removable, but not always easily and quickly. The higher the time cost for each iteration, the fewer iterations the learner can make during a given period of time, which decrease the range of creative possibilities that can be explored. Because ease of use and speed of iteration are fundamental to the design of constructionist toolkits (Resnick & Silverman, 2005), I began to search for and experiment with various connectors to evaluate them based on feel and ease of use. After testing samples of about 30 different varieties, I eventually discovered the T-TYPE .161" DIA .24" push rivets used in the kit today.

The strap and snap rivet system has strengths and weaknesses. The coated strap can easily be bent into a variety of angles and so far remains quite durable. The rivets hold tightly enough that structures hold well enough, and allow for a variety of angled configurations. They do sometimes come apart into two pieces, or fail to reset themselves to the correct state when pulled out. Another weakness is that the system is not particularly aesthetically pleasing, which may discourage learners for whom aesthetics is a more interesting realm to explore than engineering.

Upon returning home to Denmark after the residency in Colorodo, I proposed that we reallocate the roles in the Playing with the Sun design team. The librarian educator members from Aarhus Public Libraries agreed to focus on creating different activities using the construction kit as a base. Mark and I continued to iterate on the design of the construction kit itself, including the design of the electronic circuit boards for solarengines, powerpacks, motors, and handcrank generators - now reaching their second and third revisions. Construction kit design vs. activity design served as a useful distinction that clarified our different roles and responsibilities, but it must be understood to be a porous boundary. The design of each informs the other in a variety of ways.

Around this time Matilda Kristina Ejgreen Tjellden, a science educator who had joined the team not long after encountering the project during Ryan Jenkin's residency, had the idea to explore solar powered machines that make marks in colored sand. Collectively we experimented with this activity and found it to be aesthetically engaging. Sand became a core part of the drawing machines activity thereafter, and shaped many of the subsequent workshops and activities.

Not long after, we ran a drop-in workshop outside of Dokk1 library for children attending a playful climate conference. We setup four tables with various forms of

Figure 34: Photo by Matilda Kristina Ejgreen Tjellden showing her early experiments with drawing machines that make patterns in colored sand.

drawing machines and sand drawing machines, and got very enthusiastic and positive responses from the children. There was evidence of the kind of experimentation with sustainable energy that we were hoping to see. One child prototyped a way of using a mirrors to maintain constant light levels on the panel regardless of its orientation. Others joined together to try and build a car with multiple motors and powerpacks. Still others created large rotating sculptures with many solar panels. The fact that the children were able to use the elements of the kit to take the initiative to make their own experiments was very promising. This workshop was energizing for the whole project team.

Figure 35: Images from drop-in drawing machines activity at Klimafest at Dokk1 Library

In September of 2022 I ran a recursive prompting workshop at the Cultural Evolution Society Conference in Aarhus, which is described in detail in the article entitled *Recursive Prompting: A Strong Concept for Collectively Exploring a Design Space*. While less successful at stimulating clear signs of collective creativity than the workshop described in "*A Short Term Ecology...*", it did demonstrate a foundation for further design iteration on the method.

11.3.4 A key pedagogical distinction: Goal vs. Prompt driven Learning activities

In October of 2022 Dokk1 hosted a 4 day residency with Sebastian Martin of the Tinkering studio focusing on activity design and facilitation. This was both interesting and enlightening for the team, and led to many thoughtful discussions about the nature of play and learning. Of particular value was a distinction Sebastian made about Prompts vs. Goals, which he said was shared with him on the back of a napkin by a tinkering educator in Spain.

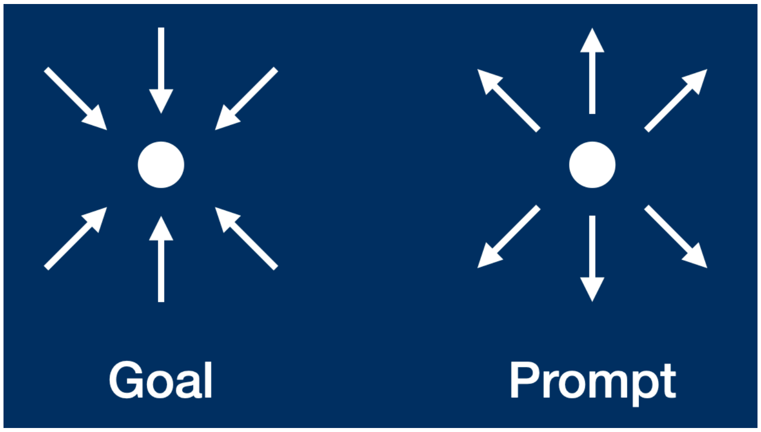


Figure 36: Image illustrating goal oriented vs. prompt oriented learning experiences.

Learning goal driven activities structure most of what happens in schools. An example learning goal might be to teach the children how to calculate the area of a circle, or to memorize a set of facts. The teacher tries to get all the students to achieve the same goal. At the end of the class, some will reach the goal, some will be bored because they reached the goal in the first 15 minutes, and others won't quite have reached the goal yet.

In a prompt driven learning activity, the prompt serves as a starting point for learner-driven exploration. Everyone begins from the same prompt - for example, make this machine make drawings you think are interesting. But each learner ends up exploring someplace different, depending on where their curiosity takes them. Some may use vibration to move their machine, others wheels, and still others linkages. Some will be interested in exploring the aesthetic possibilities, while others will be more interested in engineering. The educator's role in prompt-driven activities is also different. Instead of trying to get them all to achieve the same goal, the facilitator of a prompt-driven activity tries to make sure everyone has a good start, finds something interesting to pursue, and doesn't get stuck for too long.

Of course, things are never as simple or clean cut as a model like this suggests. Even so, it was clear from the design team's reaction that it was an important distinction for them in that moment. It was also an important moment for me as an English speaking educator working in Denmark, because I learned that there is no direct Danish translation for the word "prompt." This is a fundamental idea in Tinkering pedagogy, so from this day forward I have been careful to take the time to carefully explain it when speaking to Danish educators about Tinkering and playful learning.

11.3.5 Formulating the Activities and Maker Faire

The rest of the Winter consisted of working with the team on activity design and production, and iterating on the design of construction kit elements. We went through several iterations of handcrank charger designs, each of which are documented on the resources website. In late January of 2023 I ran a workshop for middle school students in Berlin as part of an EER project event. This was another variation on the theme of recursive prompting designed for formal, school workshops (where all learners start and end at the same time). This showed some signs of collective creativity and suggested still more changes to the method design.

In late February revision 3 of the playing with the sun construction kit electronic circuit boards arrived, giving us enough working prototypes to run workshops with school classes of up to 24 children. The Playing with the Sun activity design team began running workshops for school classes and working on resources for educators, including documentation and activity descriptions. This approach of integrating documentation of children's playful inquiry with "How-To" instructions for educators was inspired by ebooks made by and for educators by Professor Ole Caprani and our Playing with the Sun team member Sarah Petrat-Melin, formerly a teacher in Aarhus public schools.

Around this time we did yet another round of iteration on the design of the wheels and wheels hubs. Previous versions had the hub press-fit onto the spline of the motor, but this was difficult to make reliable given the rather coarse tolerances of 3D printers. Based on some great suggestions from collaborators at Ballerup library, where PwtS team members ran an introductory Playing with the Sun workshop, we eventually arrived at a hexagonal hub that various interchangeable laser cut wheels can fit onto. The hub accepts the same push rivets that work with the plumber's strap, resulting in a very flexible platform with a consistent design language. All of the hub prototyping was done by the Playing with the Sun project coordinator Jane Kunze, who undoubtedly reached the limit of her patience more than once, and kept on going. The result is a robust design that's held up admirably.

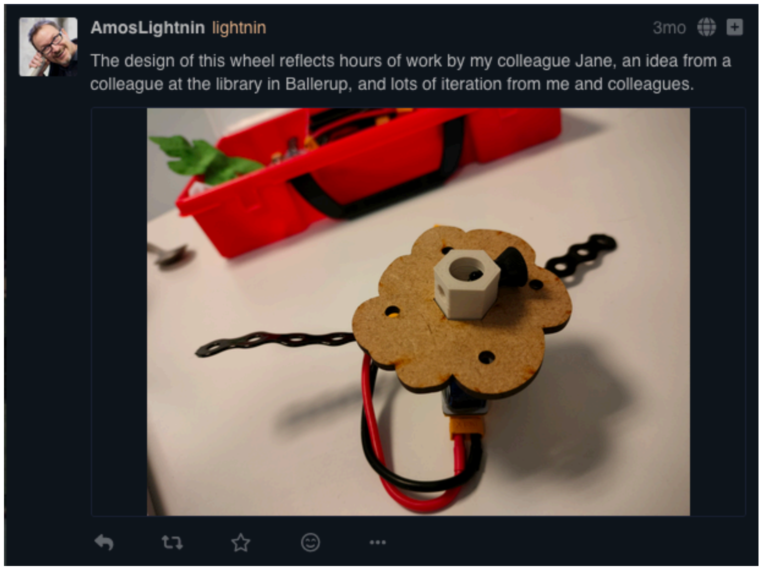


Figure 37: The process of wheel design was, like many design processes, a series of failures that ended in success.

In the Spring of 2023 we ran workshops for children whenever we could organize school visits. Drop-in workshops would have been better for our design process. But drop-in workshops with kids in our target age range of 8 and up are difficult to do in Dokk1 Library during weekdays due to a lack of visitors in that age range. We did run a few drop-in workshops with very young children between the ages of 2 and 6. While they showed some engagement with pre-assembled crank driven automata, building with the kit requires more manual dexterity than children in this age range generally have. In constructionist design terms, the floor is too high for them. Our design iteration speed was limited by the challenges of finding the right kids to work with and get design feedback from. We never managed to find a good solution to this challenge.

The last drop-in workshop we ran was at Maker Faire 2023, hosted by Dokk1. Henrik Viking Hansen, who designed the Playing with the Sun logo and signage and did many promising experiments with element and activity design, proposed and built a large table for documenting drawing machines with video. While still in the early stages of design, it shows promise as a means of recording documentation of learner-driven creativity.

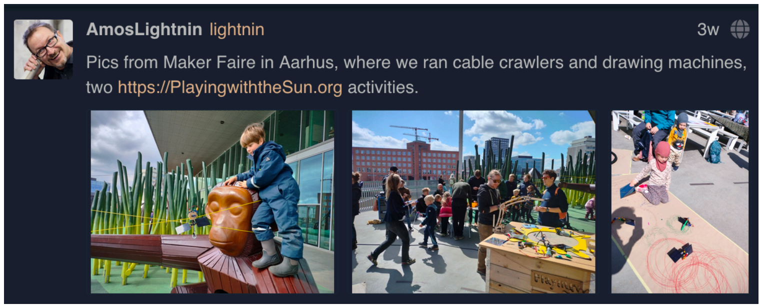


Figure 38: Still images from Maker Faire 2023 at Dokk1 Library.

11.3.6 Residency on Documentation and NEXT Library 2023

Ben Mardell was the last of the project's residents. In May of 2023 he ran a three day workshop on Documentation for the Playing with the Sun team. This began with an introductory workshop and discussion about Documentation in which we prepared to run and document a cable crawlers workshop with students from a local school. We then reflected on the documentation collected from that workshop before running and documenting a final workshop for a different class. The resulting Documentation was used in Ben's keynote at the NEXT Library conference.

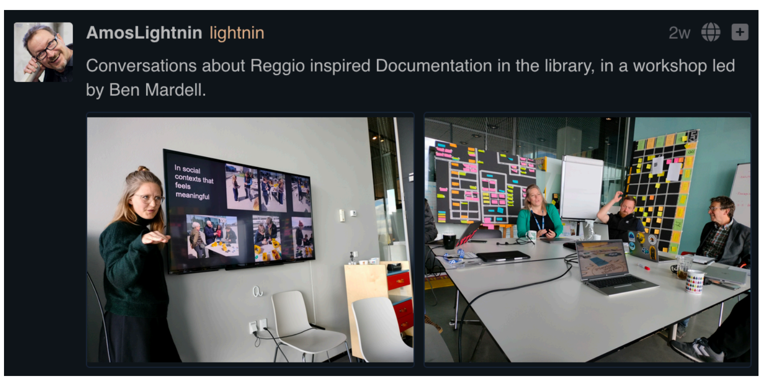


Figure 39: Documentation workshop during the residency with Ben Mardell of Harvard Project Zero.

In the process the design team invented a two stage variation on the cable crawler activity which we subsequently ran for visiting library professionals at NEXT. It invites learners to begin by making a caterpillar powered by hand crank energy. Once finished, the participants transform their caterpillar into a butterfly that uses solar power to climb a string. The activity does an excellent job of inviting the learner to experience two different forms of sustainable energy while exploring the various aesthetic and engineering design possibilities.

Figure 40: Ben Mardell presenting his keynote on Playful Learning in the Library at NEXT 2023

11.3.7 Conclusion and Ways Forward

In our final meeting the *Playing with the Sun* team discussed future directions to take the project specifically as well as the idea of Tinkering in the Library generally. With the remaining budget we agreed to produce more of the *Playing with the Sun* elements so it will be possible to loan them to other libraries, several of which have expressed interest. There may be ongoing collaboration with the library makerspace in the city of Aabenraa, Denmark, which took inspiration from our early design work and built their own version of a kit designed to support playful exploration with solar energy.

There are ongoing discussions on how best to support Tinkering and playful learning in general within the library system. Several ideas about this emerged out of our conversations, including developing and distributing a monthly or quarterly "tinkering activity in a box," which could be sent to interested libraries with educators who have already attended introductory workshops on Tinkering pedagogy. These would be designed to enable them to run their own activities with citizens in their library. We have also discussed doing residencies at interested libraries in which team members help librarian educators launch, facilitate, and observe hands-on creative learning activities. Because so much of the character and quality of Tinkering activities is transmitted through a kind of oral culture, in my view this idea has good potential to be a powerful intervention.

Figure 41: The Playing with the Sun / Teknologiforståelse project Team.

12 Appendix 1: Berlin Playing with the Sun EER Workshop

This documentation appears on the EER project Website along with a brief video documentation of the activity at this URL: https://www.eer.info/activities/playing-with-the-sun. It was written for a public audience as a brief informative piece about EER research. The essay and link to this seven minute video https://player.vimeo.com/video/799029719 are included here as part of the materials submitted for consideration by the PhD committee.

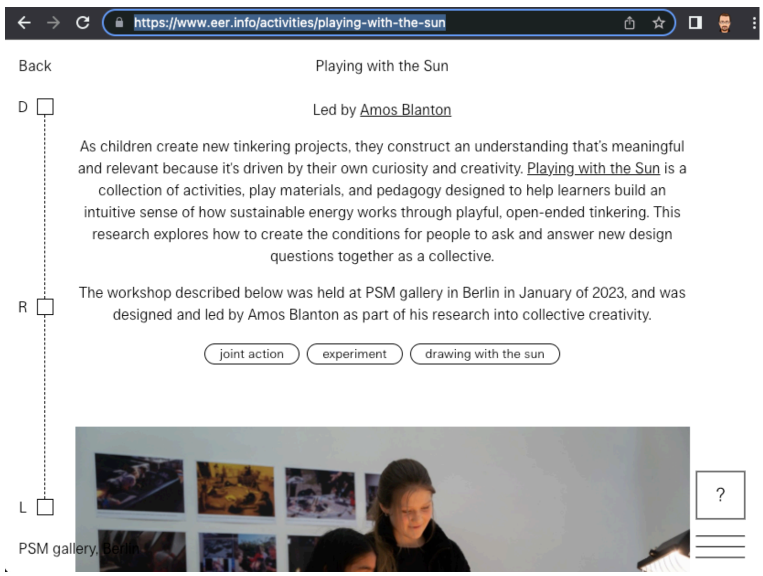


Figure 42: Screen capture of EER Playing with the Sun page, containing documentation of the Berlin workshop at PSM art gallery, January 2023.

12.1 Playing with the Sun, EER.info website

As children create new tinkering projects, they construct an understanding that's meaningful and relevant because it's driven by their own curiosity and creativity. Playing with the Sun is a collection of activities, play materials, and pedagogy designed to help learners build an intuitive sense of how sustainable energy works through playful, open-ended tinkering. This research explores how to create the conditions for people to ask and answer new design questions together as a collective.

The workshop described below was held at PSM gallery in Berlin in January of 2023, and was designed and led by Amos Blanton as part of his research into collective creativity.

Figure 43: Two workshop participants at the EER PSM Gallery.

12.1.1 Design

How can we create the conditions for children to not only solve problems, but to invent new problems to solve? After their individual explorations into an open-ended design space, how can we help the group reflect on and choose which ideas to explore further? These skills are at the foundations of collective creativity, what Brian Eno referred to as "Scenius" or the collective form of genius. This work builds on the pedagogy of tinkering and constructionism to create conditions conducive to a short-term form of scenius. The goal is for children to build their knowledge of how sustainable energy works while working towards shared goals they themselves define.

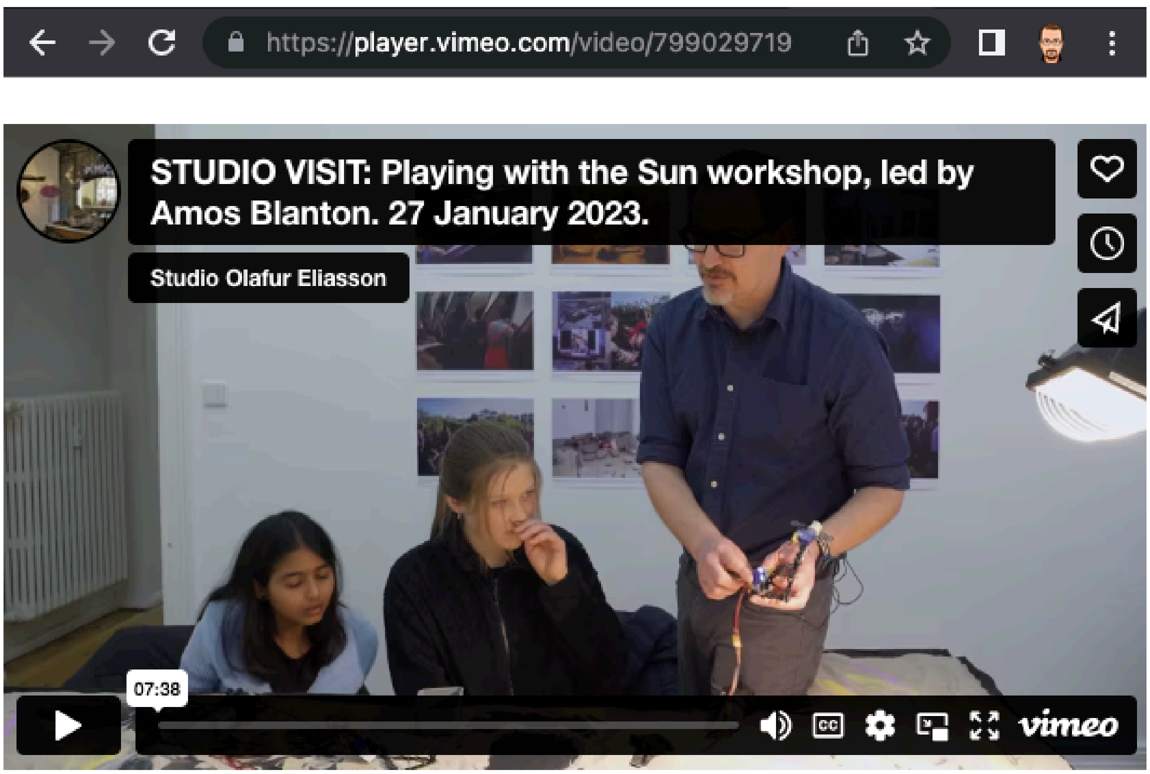


Figure 44: Video documentation of Playing with the Sun EER workshop, Berlin January 2023

12.1.2 Run

In January of 2023, students from the International Kant School, Berlin, visited PSM Gallery to participate in this EER experiment. Earlier that morning, artificial for playful experimentation using sand and cinefoil. There was no sunshine in Berlin that day, so Amos setup a halogen worklight over one area of the table and provided hand-crank generators and chargeable powerpacks as an alternative, human-powered power source. These are a few of the elements in the Playing with the Sun Construction Kit, an open source project to develop play materials for children to build with and learn about sustainable energy.

Figure 45: Participants building at the start of the workshop.

After demonstrating how the different elements in the construction kit work, Amos invited the children to build a creature powered by sustainable energy that interacts with the sand-filled environment on the table. As they tried out different ideas, Ida [Last name?] documented them by recording videos with an iPad, printing out still images and placing them on the gallery wall. Using AR software called Artivive, the learners could see the videos of their projects in action at different stages by

Figure 46: Experimenting with the crank charger.

pointing the iPad's camera at the still image. The documentation wall served as a live-updating repository of the children's emergent ideas, which they could then reflect on as they explored. It was also a means of collecting data to create a map of their creative process.

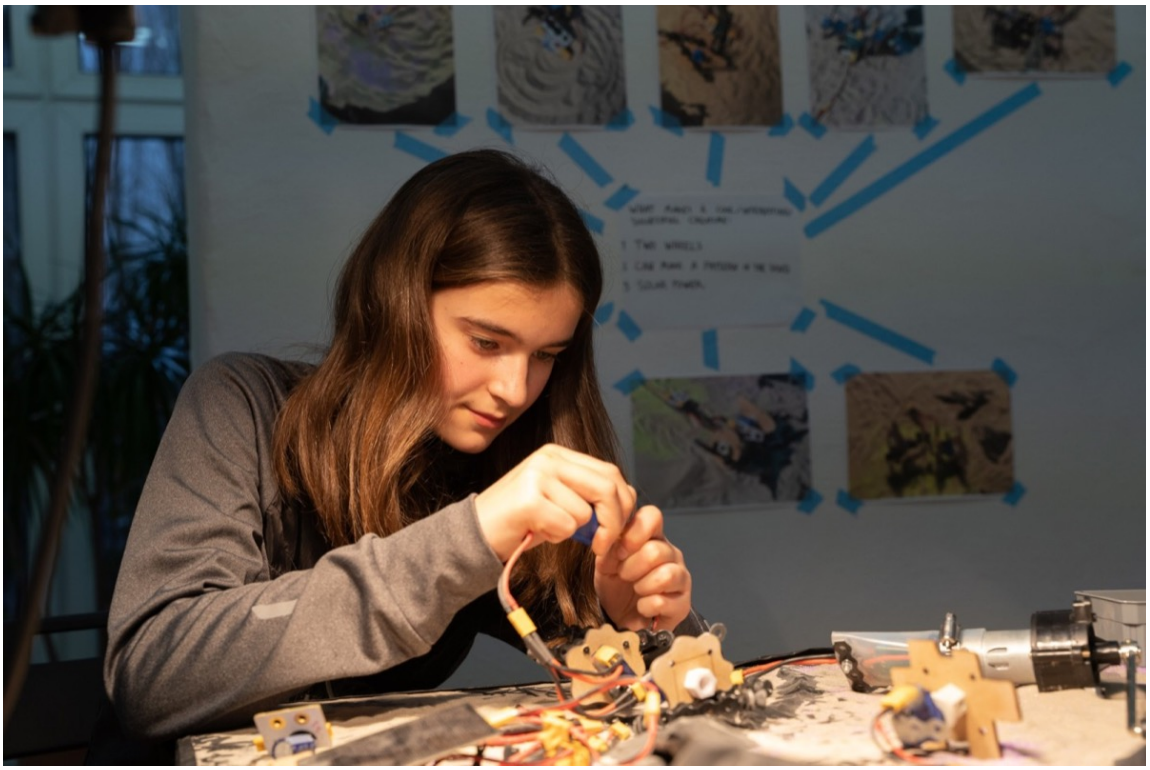


Figure 47: Assembling a solar creature with images of recent builds in the background.

Under the relatively weak artificial lighting, it was difficult to build a creature strong enough to pull the weight of its own solar panel unless it was directly under the lamps. One participant recognized this challenge and invented a solution. She placed the solar panel in the ideal location under the lamp and joined six wire segments together to make a long cable. Like a cable running between a solar farm and a city, she used it to transmit solar energy from where it was generated to her creature.

After the first 45 minutes of experimentation, Amos asked the participants to stop and discuss what emerged from their process that they felt was interesting and worth exploring further. The stationary solar panel with tether idea featured prominently. Two other ideas emerged: two-wheeled creatures, and drawing interesting patterns in the sand. After the discussion they spent another 40 minutes tinkering with these

Figure 48: Positioning the solar panel for optimum light.

Figure 49: The tethered creature powered by the solar panel on the mountain.

ideas as self-imposed design constraints intended to give focus to their collective inquiry.

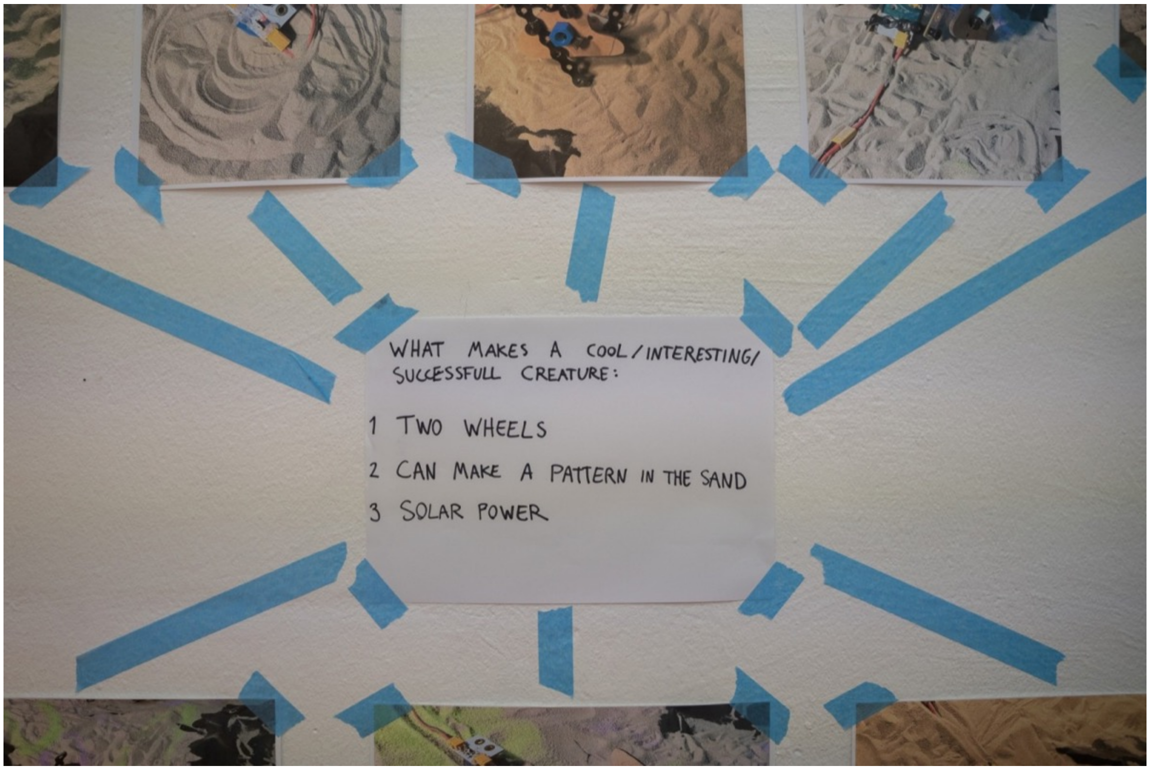


Figure 50: The participant's definition of quality.

At the end of the workshop the participants had created a sub-genre of two-wheeled sand creatures. The students expressed appreciation and seemed to enjoy the workshop. When asked what they would tell a future group of participants exploring a similar activity, they said that they'd had fun exploring two-wheeled solar power tethered creatures, but felt they'd explored most of what was possible in that particular corner of the design space.

12.1.3 Learn

How can we create the conditions for children to not only solve problems, but to invent new problems to solve?

In the classroom, a successful student gives the correct answers to questions asked by their teachers (who already know the correct answers). In art and design, the question is often invented at the same time that it's being answered. Out of this messy, iterative dialog, both new framings of problems and new creative solutions can emerge.

Figure 51: Describing exciting possibilities.

In the coming decades of the climate crisis, this kind of creativity will be more important to our survival than recalling the right answers to questions that are already defined, which computers can already do far better than we can. Therefore the only correct answer in this activity is the answer to a question or problem that the children themselves have posed. One example from this workshop is the invention of the long cable that allows the creatures to be powered by a stationary solar panel. This is not an idea that was present in anything that was demonstrated to the children at the beginning. Nor was the problem that led to this particular solution framed for them in advance. This suggests that the structure built into the design of the environment, materials, and facilitation in this workshop was simultaneously *enough* and *not too much* to create space for their curiosity to lead.

After their initial individual explorations into an open-ended design space, how can we help the group reflect and choose which ideas to explore further?

During the workshop, one participant noted that the staccato movement of his creature, caused by an energy storage component called a solarengine, makes it appear as though it was a stop motion animation. Children tend to use descriptive metaphors like this as they reflect on their experience, both as a means of synthesizing knowledge and to communicate subtle ideas. Sometimes they lead to new question and problems to pose.

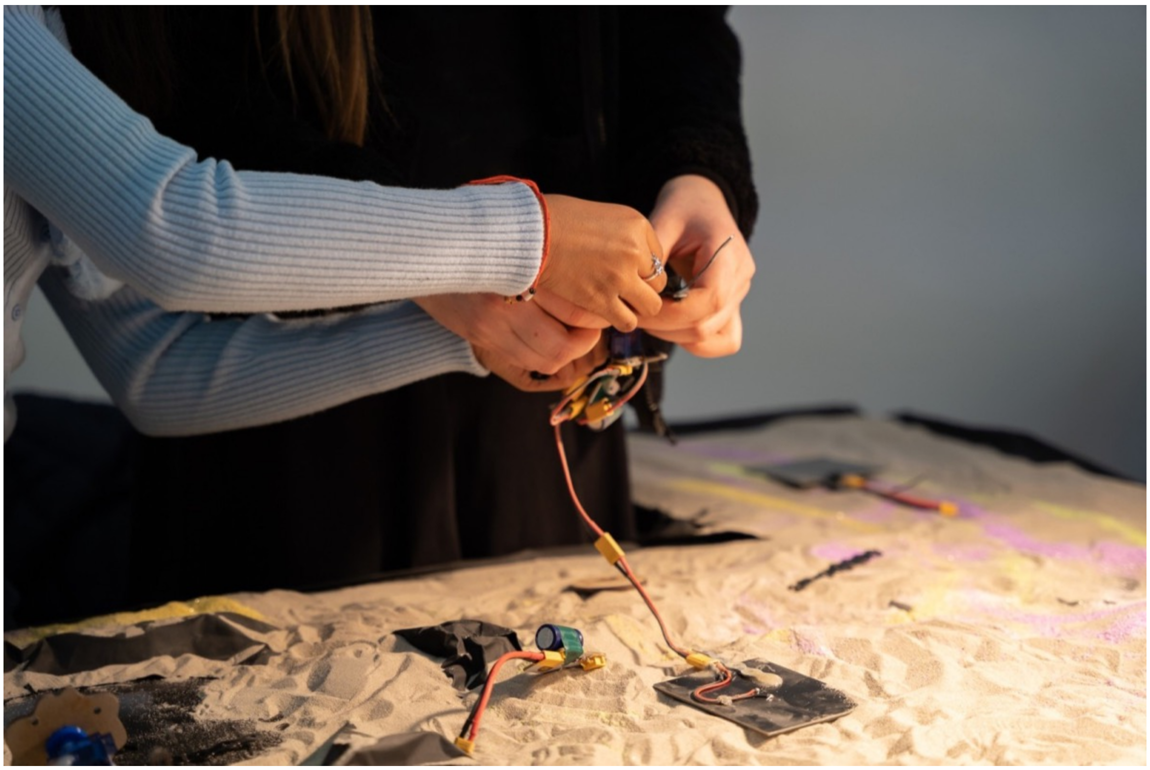


Figure 52: Building together.

The strategies used to create the conditions for problem posing have been established for decades in progressive education (even if they are used too rarely in many schools). But how to create the conditions for collectively creative inquiry is less clear. There were two interventions designed to support collective creativity in this workshop.

The first was the collection and posting of images and augmented reality video recordings of their past builds to be used as shared notes to facilitate group reflection. This is intended to function as a kind of designer's notebook for the collective that participants can refer to as they choose which new directions to explore. The second intervention was structuring the workshop with a beginning tinkering session, followed by a reflection session in which the children discuss and select future directions to explore, followed by a second round of building based on the constraints they agreed upon.

While the pre-lunch break discussion about what they'd found interesting so far seemed natural, the post-lunch conversation felt a bit forced. And while they were impressed by the video collection, it didn't clearly lead to the building of insights or stronger reflection. Both ideas show some promise, but need further iteration and development by research practitioners and design researchers.

One of the aspirations of Playing with the Sun is to create the conditions for collective exploration at two scales: The workshop scale (described here) and the broader scale of the area of inquiry itself. Rather than seeing a workshop as a one-off educational intervention, we document it as participation in a collective design experiment spanning both time and participants. The next group that does this workshop should be able to use the map of its prototypes as the starting point for their exploration.

Design processes like these can and should be a means of democratic inquiry - an approach that could come in handy whenever local communities need to think together about how to respond to wicked problems like climate change.

12.1.4 Acknowledgements

We would like to thank the students who participated from the International Kant School and their teachers, PSM Gallery, as well as Ida Thomsen for her work helping to document. Thanks to Yanina Isla for the photographs and videography.

This workshop evolved from earlier work in EER by Amos Blanton on Drawing with the Sun. The activity itself was developed in collaboration with the technological literacy group at Aarhus Public Libraries.

The pedagogy of Playing with the Sun is based on a learning theory called Tinkering (Wilkinson & Petrich, 2013) which is inspired by artistic processes and employed in science centers around the world. Amos' research into collective creativity is informed and inspired by the work of the children and educators of Reggio Emilia, Italy (Vecchi, 2010). All of these theories aim to create the conditions for what Eleanor Duckworth (1972) called "the having of wonderful ideas," and form the foundation for this research.

Figure 53: The recursive prompting board on display in the gallery.

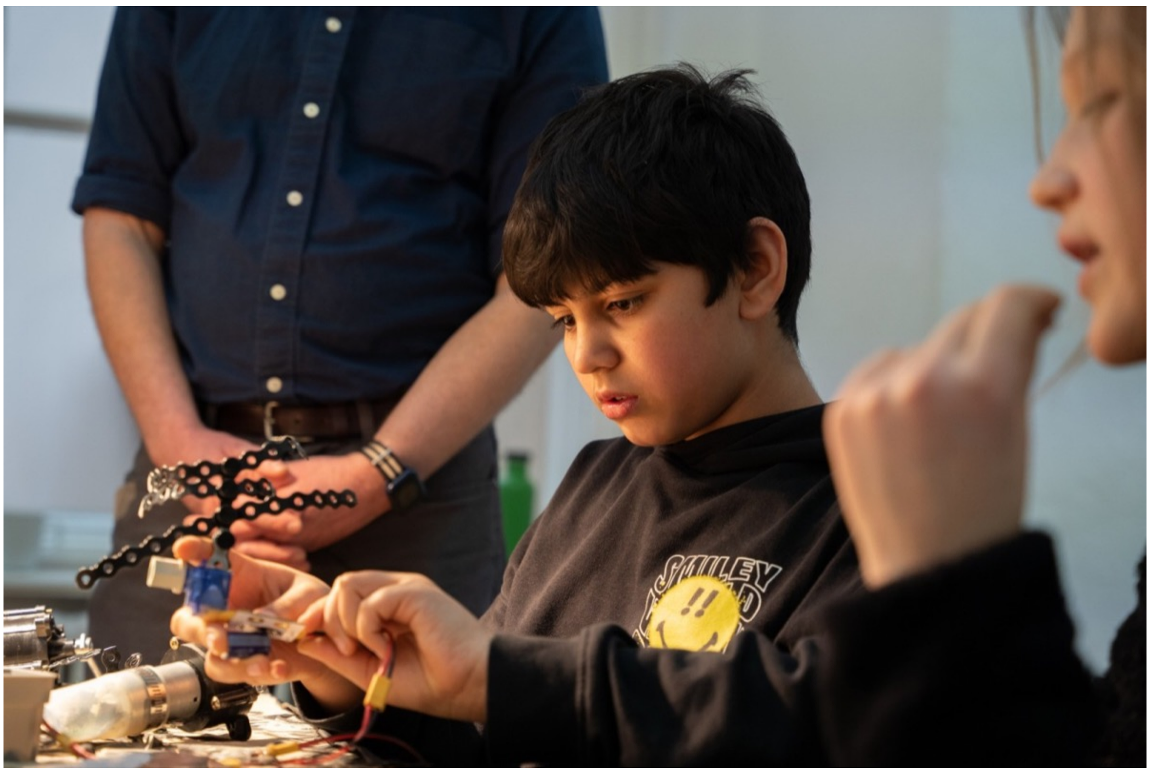


Figure 54: Creative engagement.

12.1.5 References

Duckworth, E. (1972). The Having of Wonderful Ideas. Harvard Educational Review, 42(2), 217–231. https://doi.org/10.17763/haer.42.2.g71724846u525up3

Vecchi, V. (2010). Art and Creativity in Reggio Emilia. Routledge. https://doi.org/10.4324/9780203854679

Wilkinson, K., & Petrich, M. (2013). The art of tinkering: Meet 150+ makers working at the intersection of art, science & technology. Weldon Owen.

13 Appendix 2: Copenhagen Drawing with the Sun EER Workshop

This documentation of an early Playing with the Sun workshop appears on the EER project Website at this URL: https://www.eer.info/activities/drawing-with-the-sun. It was written for a public audience as a brief informative piece about EER research that took place in September of 2021. It is included here as part of the materials submitted for consideration by the PhD committee.

13.1 Drawing with the Sun, EER.info website

How do ideas move through a group of people exploring an open-ended activity, and do they inspire new ideas in the process?

Drawing with the Sun is a 90 minute workshop designed to explore how groups engage in collective creativity in tinkering activities. Tinkering is an open-ended, exploratory approach to learning inspired by the work of Seymour Papert. In this workshop we invited participants to modify solar powered drawing machines to make marks they felt were aesthetically interesting. A smaller portion of the participants were asked to document and spread new ideas as they emerged.

13.1.1 Design

Solar drawing machines was developed as part of a larger initiative called "Playing with the Sun" - a practitioner-researcher collective that creates activities that invite people to play with the elements of sustainable energy - envisioned by Amos Blanton, Ben Mardell and Dokk1 Library in Aarhus, Denmark.

Playing with the Sun invites educators to take on the role of facilitators of design explorations led by the participants. Using provocations like solar drawing machines, we invite the learners to playfully imagine and create whatever they like. As they explore, we document the process so their insights accrete and can form a new starting point for future participants. Our goal as designers is to create play materials that invite children and adults to develop an intuitive understanding of the elements of sustainable energy. And as researchers, we try to document and understand how this shared learning process works, and how we can design environments and prompts to

Figure 55: Workshop participants shining additional light onto solar drawing machines.

support it. As Seymour Papert put it, a toy can be “an object to think with” which reveals new possibilities for understanding and interacting with the world.

Figure 56: Hands holding a drawing machine.

13.1.2 Run

How do ideas move through a group of people exploring an open-ended activity, and do they inspire new ideas in the process?

In this workshop we invited 14 participants to tinker with solar powered drawing machines while 6 “Catalysts” documented the emergence and movement of new ideas

Figure 57: Participants around the shared drawing table.

Figure 58: Video of the interaction around the shared drawing table, visible at: https://www.eer.info/activities/drawing-with-the-sun

through the collective. The goal was to understand and begin to map the process of collective creativity - or how a group playfully imagines and explores a space of possibilities.

Each pair of tinkerers was provided with a working drawing machine, consisting of a solar panel, a motor, and a simple solar engine (a circuit designed to store solar energy in a capacitor until just enough is present to pulse the motor for 1/4 second. The machines do not have batteries.) We setup worktables covered with drawing paper outside, and made available a variety of pens, paints, and markers, along with clamps and other materials to enable participants to make a wide variety of creative modifications to their machines. Each worktable also held several A4 sized mirrors and stands, which the tinkerers soon realized could be use to reflect additional sunlight onto their drawing machines, which increased their speed and power.

During the workshop they were lightly facilitated by Liam Nilsen and Amos Blanton, who provided technical support, advice, and feedback when needed.

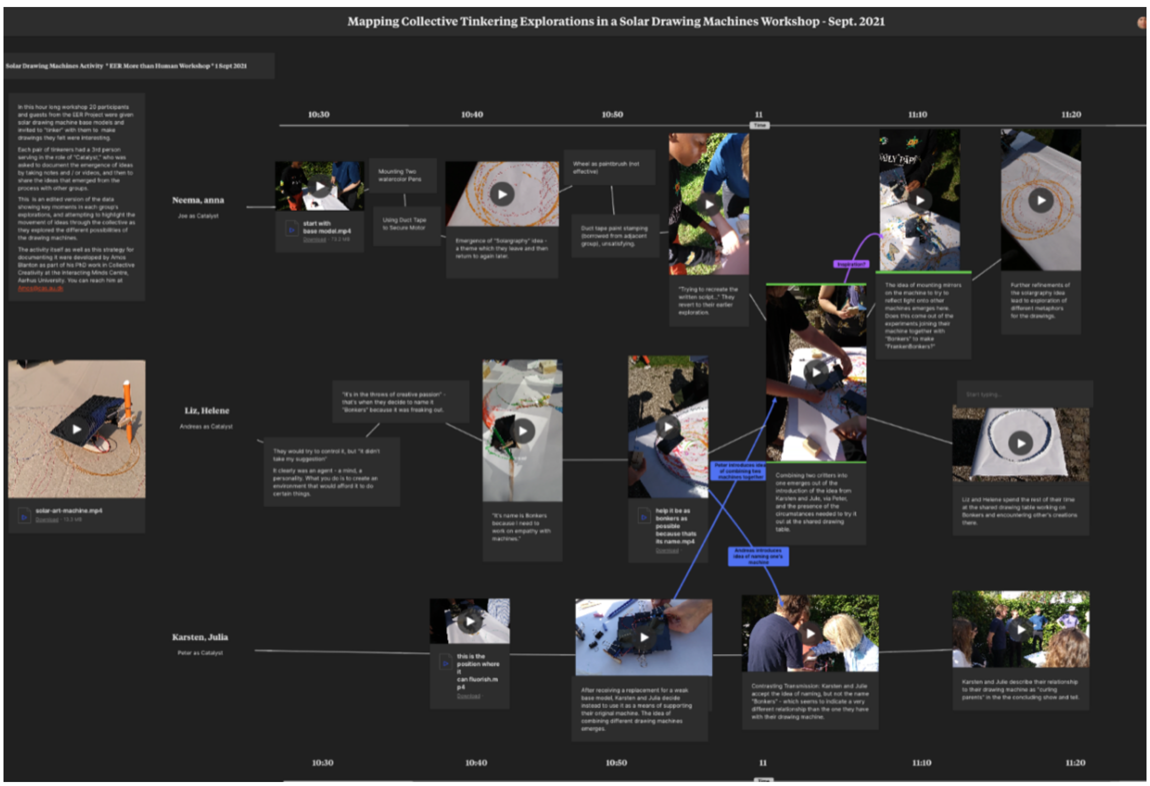


Figure 59: Milanote board of documentation of the workshop. An interactive version is visible on the Milanote website at https://app.milanote.com/1N5Oxi1L7tMr8Y?p=7qEZrvV8sun.

13.1.3 Learn

In the above Milanote board there is a map showing the design process of three pairs of participants, highlighting points where ideas moved between the groups due to the actions of catalysts. In the bottom row, Karsten and Julia discover that their drawing machine seems weaker than most, and ask for and are given a replacement. But having formed a sentimental attachment to their first machine, they decide to join the new one to the original in order to help it, thus inventing the first combined solar drawing machine. This idea of combining machines is then shared by their catalyst with two other groups present at the shared drawing table, a space which is designed to invite encounters between groups to facilitate cross-pollination of ideas and collective reflection. One of these two groups named their machine "Bonkers," inspired by its erratic movements when given extra sunlight via mirroring. The two groups decide to try combining their two drawing machines together, and create "Frankenbonkers." In the process, they have a conversation about collaboration and togetherness.

Out of this conversation (shown in the slightly larger video positioned between the first and second rows) several new ideas emerge. One worth noting is the idea of attaching mirrors to the machines themselves, so that they can shine light onto one another. This suggests a new domain of interactivity (communication?) between machines. I argue that the idea is an emergent property of the group's playful inquiry - more a product of "Scenius," (Brian Eno's term for the collective form of genius) than "Genius."

The Adjacent Possible

Proposed by the biologist Stuart Kauffman, the adjacent possible is a useful concept for understanding the exploration of a space of possibilities in a collective tinkering session like this one. Simply put, the adjacent possible is what's next door to whatever state something is in right now. Before the Post-It note existed, it was an adjacent possible of the plain paper note taped to a wall. Once invented, it became a new "actual" from which new adjacent possibles could emerge in various realms, from using them to make fish scales in craft activities to a tool for organizing collections of thoughts in design meetings. Kauffman's work suggests that even the most dramatic changes in both design processes and the evolutionary fossil record can be explained by a series of small steps between adjacent possibles.

In the documentation shown above, we can see evidence of movement between adjacent possibles that results in a new idea, an idea that no one in the group imagined prior to the collective tinkering activity. First the idea of combining two machines is born. It is then reinterpreted by a different group, which appears to lay the foundation for an innovation to emerge out of the participant's interests exploration of interdependence - the idea of drawing machines that reflect light onto (and thus interact with) one another. While this is just one of many ideas that emerged in the workshop, we emphasize it here because it opens up a new design realm that didn't exist before – that of interactivity between solar drawing machines. That realm, while admittedly complex and challenging, has interesting potential for further creative exploration.

It is always difficult to draw firm conclusions about the origin of ideas. Because tinkering is open-ended and sensitive to what the participants bring to it, any tinkering workshop is at least as complex as Heraclitus' famous river. You cannot step into the same tinkering workshop twice. But we do not need to make claims of strict repeatability to document, observe, and theorize about how best to support collective creativity.

14 Appendix 3: Learning about Facilitating Creativity from Parents and Grandmothers

This documentation appears on the Aarhus Public Libraries Website at this URL: https://www.aakb.dk/nyheder/kort-nyt/learning-about-facilitating-creativity-from-parents-and-grandmothers . It was written for a public audience as a brief informative piece about research done by the Creative Learning Research group in Aarhus Bibliotekerne. Extensive editing and input was given by the members of the Creative Learning Research Group. The piece is included here as part of the materials submitted for consideration by the PhD committee.

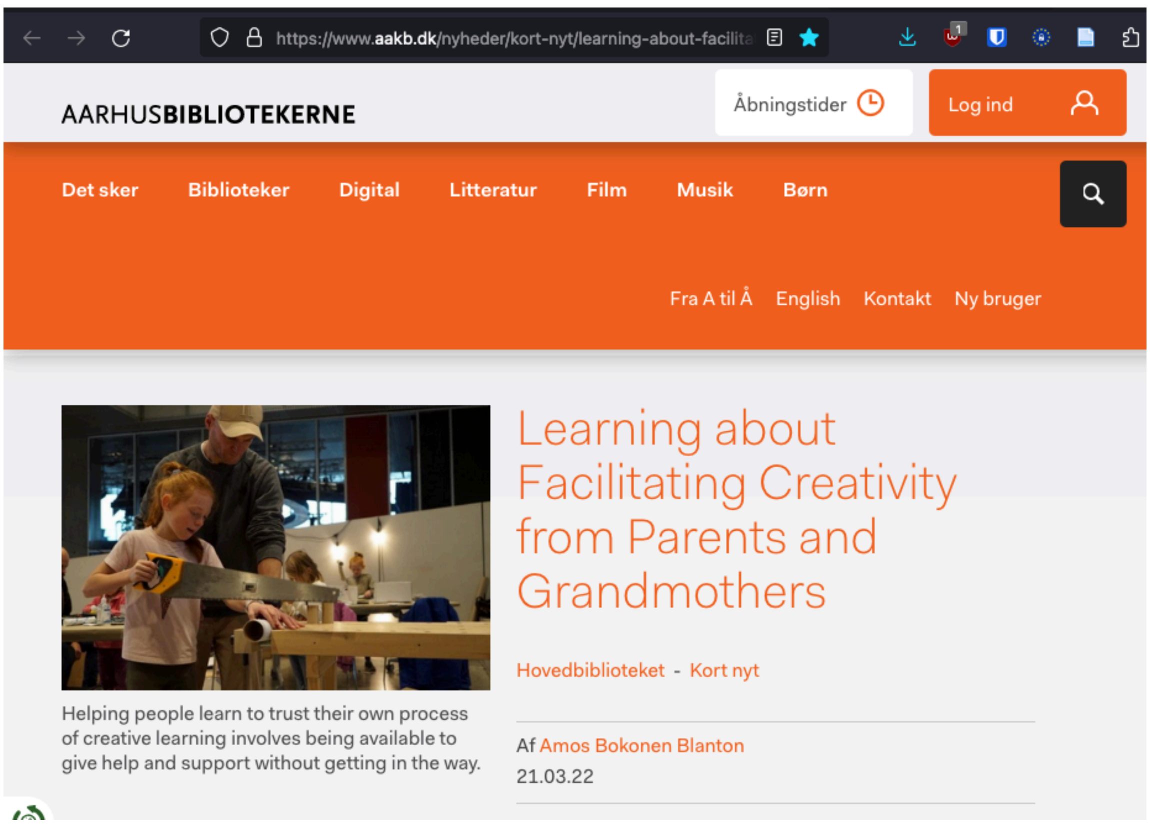


Figure 60: Screenshot of this essay on the Aarhus Public Libraries website.

Figure 61: Helping people learn to trust their own process of creative learning involves being available to give help and support without getting in the way.

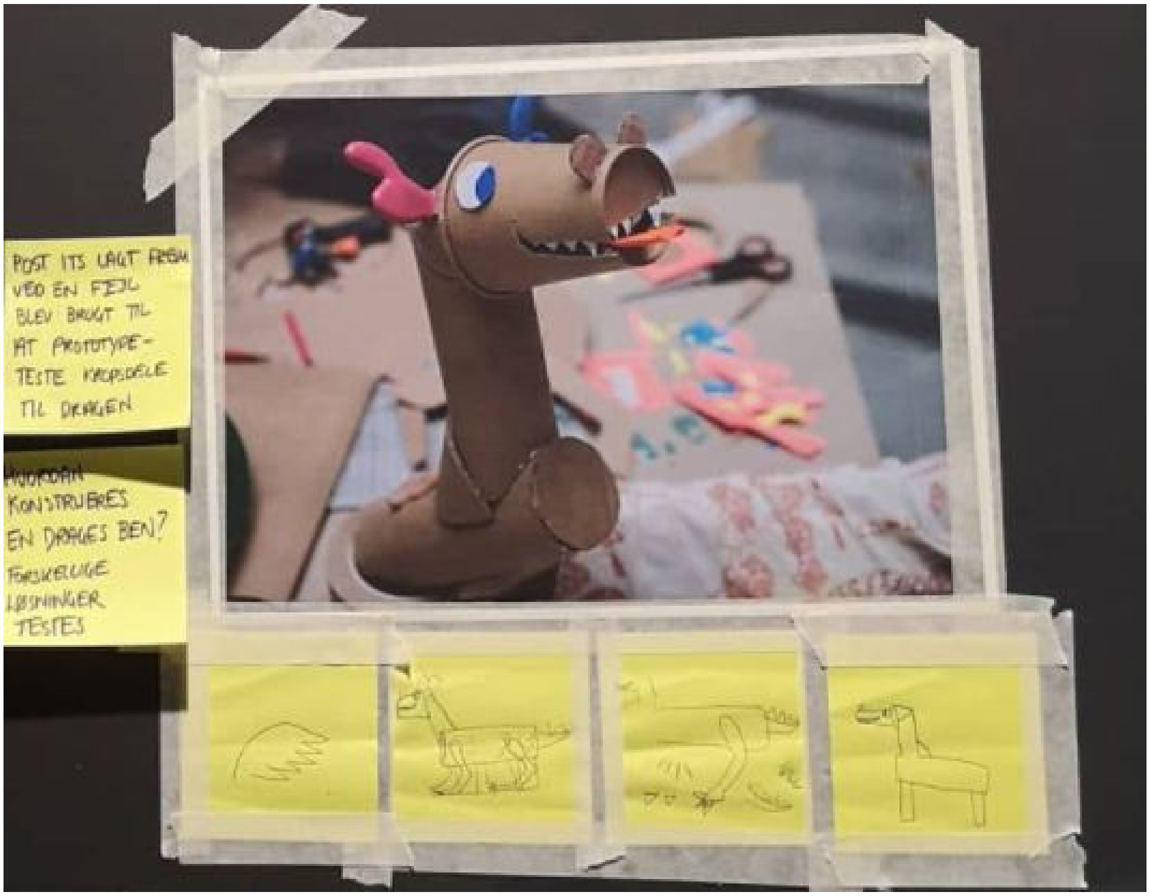
14.1 Learning about Facilitating Creativity..., Aarhus Bibliotekerne Website

Recently the Creative Learning Research Group at Dokk1 hosted a workshop developed by En Hemmelig Klub called Papalapap. In Papalapap, citizens of all ages are invited to build with cardboard. In their excellent workshop design, En Hemmelig Klub provided a thoughtful constraint in the form of starting points for people to begin their tinkering. They were invited either to build a link in a chain of cardboard marble runs that stack on top of one another, or to build a tetris piece that can interlock with other similar pieces.

Over the past year in the Creative Learning Research group at Dokk1 we have spoken often about the right amount of constraints in open-ended activity design. As long time facilitators of creative activities, each of us has experienced inviting a learner to "make whatever you want," with little to no constraints. This generally seems to work only for those who are already very confident in their creative abilities, and know what they want to do. But the rest often don't know where to begin, and get stuck at staring at a blank piece of paper. The art of facilitating a good tinkering activity is to find a constraint that is narrow enough to help the learner get started, but open enough that they can make something unique and meaningful that reflects their own interests and curiosity.

Our position is that everyone is creative, but some have more trust in the creative process than others. During this workshop we were watching for patterns in the way participants exercised their creativity and self-expression in order to help develop our understanding of how best to facilitate creative experiences. While reflecting on our observations afterwards, we noticed that the parents and grandparents demonstrated several different ways of supporting children's creativity that we felt we could learn from. These descriptions consist of our own interpretations - we make no claims to objective truth. Nonetheless, we feel that what we describe here can be useful for our ongoing conversations about how to design and facilitate creative activities.

During the workshop we observed one girl become excited about making a cardboard dragon. While technically this falls outside of the constraints we suggested at the start, it was a kind of modification or "hack" of our proposal - one which the child was clearly both capable and motivated to explore. Her parents, who seemed like they had experience with the creative process, provided support and help - but not so much support and help that they took over. At one point they suggested the child sketch out a few post-it-notes of different possible leg designs to help imagine and choose what would work best. Out of this creative process a beautiful dragon emerged.



A grandmother we observed used a different approach to helping her grandson follow through on his creative process. When the grandson lost interest in their common project, she would continue the work by herself. After a little while, she would invite him to join back in by posing interesting problems or design decisions to him. “How will we get the marble around this corner?” she might ask, or “What should this part look like?” After several prompts like this, the grandson would join back in and become engaged with their project again. Eventually, they ended up completing an addition to the marble run chain that randomized the direction the marble would go - an idea that was both challenging and innovative.

Not everyone has had the chance to develop trust in their creative process. We sometimes encounter adults who, when invited to be playful and creative, throw up their hands and say “I’m not a creative person!” When that happens we’ve learned to intervene in different ways, with the goal of helping them find a sense of “flow” so that they forget to be worried about being creative. Like helping a child learn to ride a bike, the trick is figuring out the best way of supporting them as they get the hang of it. Much as we might want to, we cannot learn to ride the bike for them.

Out of this workshop, and the discussions we had about it afterwards in the Creative Learning Research Group emerged a new question. How do we communicate the idea of trusting in the creative process so that everyone, even those who don't yet think of themselves as creative, can benefit from it? What sort of statement or set of guidelines can we highlight in our various workshops to help people feel more comfortable being playful and creative? It's difficult to sum up an approach to creativity in a few words. But there's lots we can learn from watching parents and grandparents as they work with children. So we'll be observing and thinking about this question in the months and years to come.