Praxis: Connecting knowing and doing through designing and making.

by

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Abstract

The purpose of this research project is to explore how we learn and to design an experiential, studio-based learning framework based on designing and making that incorporates these findings. Research indicates that people learn best when they follow their own interests and curiosity; through perseverance and trial and error; in a mixed-age, facilitated, exploratory environment; pursuing project-based investigations with authentic context. Creativity is fundamental to innovation and problem solving and is nurtured by interdisciplinary learning, a playful mindset, and one's intrinsic motivation. Design provides a systematic process to deeply understand, ideate about, prototype, and test a proposed solution or intervention to a problem. Making is an opportunity for learners to more deeply understand their ideas and thinking through tangible representations and to foster a sense of empowerment and agency over their world. A systems perspective allows learners to see the connections and relationships between the parts and processes they consider. By developing ecological literacy and incorporating resilience into their designs, learners create sustainable and adaptive solutions. The proposed design-make framework is an adaptive, studio-based alternative learning system. Through service-oriented, project-based investigations, learners use the multiple resources in the design-make studio to deeply understand the problem in question and their ideas around that problem through iterative prototyping and presenting their findings to their mentors and peers for reflection and feedback.

Key words: learning – creativity – design – maker – systems – studio-based – hands-on – education – experiential – play

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Introduction

There is growing concern about environmental strains our steadily increasing population is forcing on our planet's ability to maintain its natural homeostasis. Perpetual growth as a global economic goal is just not possible in a closed system like Earth. We as a society, as countries, as communities and as individuals have the opportunity to prepare for the inevitable challenges ahead. The question is: What will we do and what won't we do? What will move us to take action and what will that act be? The real challenge isn't creating a succinct and thoughtful plan – though that is daunting – but overcoming the social inertia of culture to embark on change. If we want to make change in society then we must influence the change-makers that can make the most change. I would argue that those are the young citizens of the world, those just forming their understanding of life and least affected by prior biases and a preconceived world-view. They are the new thinkers, new voters, new rulers, new designers, and new makers. It will be their values that guide our future actions.

Are we preparing our children and youth for their future? What should they be learning? How should they be learning and where will that learning take place? What skills and understanding should they be developing? What perspectives and attitudes will serve them best? How is all this best learned? These are the questions we should be asking ourselves as parents and educators. With the enormous amount of time our children spend under the influence and teaching of our educational system, we must be certain it

Figure 1. The only certainty about the future is change.

is doing its best to prepare them for this rapidly approaching future. The methods and systems employed to educate must equip learners for this future of accelerating change.

Innovation is key to understanding, managing, and mitigating the changes that are already impacting our world. Creativity is key to innovation and yet creativity is not valued in our schools. In fact, creativity is being 'taught out' of our children. Play, the ultimate freedom of expression and exploration is seen as a waste of time once children enter grade school, though research suggests that a kindergarten-style of learning is the best way for our children to learn. Even past those early years, school has become more and more focused on standardized test scores and quantifiable knowledge acquisition. Our education system needs to change, to re-evaluate its purpose and how it will provide the best learning opportunities and learning environments for our children. However, like with any large institution change is difficult and slow. As parents, however,

we cannot wait for that change to happen at such a slow pace. We need to foster learning that will take our children into the future with the skills and abilities that help them to be productive and caring stewards of our world.

We currently reside in a time dominated by consumerism. We buy for pleasure, we buy to drive our economy that strives for unwavering and perpetual growth, and we buy because it is cheaper than repairing or maintaining. We have become micro-specialists with an incredibly high level of skill and knowledge about very specific domains and huge deficits in so many others. Life is faster than ever and still accelerating and everything we want to have or know is at our fingertips. All of our daily activities and communications depend on our smart phones and other powerful technological devices. The advantages to so much tech integration are staggering. We can find answers to questions instantly that in the past would have required a trip to the library or the assistance of an expert. Planning and arranging are effortless and done virtually instead of face-to-face and across oceans and cultures. Healthcare is better, we live longer, we are more affluent and we know more.

What are the costs of these conveniences? Most of the negative impact of our consumption is externalized from our direct costs. The damaging impacts affect those far away from us that often labor under conditions that we would consider completely unacceptable. We don't see them working long hours, in unsafe conditions, for unacceptably low wages and so it is hard for us to relate to their condition. Why should

we care? They want what we have anyways and are working in those horrible conditions so they can afford a more comparable standard of living. What is it we truly value? What values will are children develop?

It is also a time of incredible and prolific inventiveness. We are ingenious and tenacious and insightful and curious. Many will continue to discover and improve as in our recent past and present, but will we have enough curious, innovative, inventive, perseverant professionals in the future? Will our children have the empathy and drive to put their efforts and professional lives in service to the greater good? Will they have the perspective and understanding to see this as their current opportunity for greatness?

Those that will inherit the future must be creative problem solvers, curious explorers, playful integrators, critical thinkers, excellent collaborators, tenacious learners, animated

Figure 2. Future Change-makers

storytellers, holistic thinkers, resilient and empathetic neighbors, and calculated risk-takers comfortable with the unknown.

I am deeply interested in knowing how learning can be offered in a more engaging, self-directed, self-motivated, experiential, and inquiry-based way than is available in a formal education setting. What are the necessary components of that program? How is it taught and by whom? How can design and making support learning? What does the design-make studio look like?

The proposed design-make framework is a very effective project-based learning process that creates an integrated experience emphasizing functionality, social impact, creative problem solving and its application in an authentic context. Making becomes the harvest of a concept. The artifacts created form the story that tells one's active, hands-on, heart-felt, and cerebral journey through the process of learning and discovery. The design-make framework developed and outlined here is for children of all ages, but really it is for anyone interested in learning. By presenting itself as a place of learning and inquiry within the local community, the design-make studio will be available to everyone. Because this holistic, experiential programming appeals to the various intelligences we all have in varying degrees – kinesthetic, visual/spatial, interpersonal, to name a few – there is appeal and opportunity for the full diversity of learners. The self-directed and topic- or problem-driven structure of designing and making belongs in a supportive studio environment, where learners are free to explore their ideas with a variety of

materials and tools. The word studio comes from Italian and Latin meaning "to study or zeal"[1]. It is a place of continued learning with an energy and commitment to experimentation and innovation. The design-make studio embraces that quality, encouraging learners to question and seek answers through quick and investigative creating, prototyping, and refinement from feedback and reflection. It is a collaborative space where learners are encouraged to work together, supporting each other as needed, no matter one's age or experience, with facilitators providing measured guidance, demonstrations and feedback. In the studio the hands are an extension of the mind, creating tangible versions of ideas so they can be thoroughly considered and better understood. Studio time allows learners to create their own learning path by following their curiosity, passions, and interests. Learners experience a refreshing freedom and playfulness as they explore and discover new knowledge, new skills, and new questions to pursue.

It is clear that the challenges of our education system cannot be changed easily or quickly. The design-make learning framework offered here is an alternative way to learn; one that focuses on engaging children and all people in learning, inviting inquiry and exploration based on one's own interests and passion, creating functional creations that deepen understanding, and positively impacting the local community. Therefore, the framework suggested is to be offered outside of the formal education system – at least at first – to avoid the challenges associated with such a large, layered, and administered entity. Beginning as a grassroots offering in a local studio space, the program will be

refined through an iterative process of prototyping and program evolution. After gaining traction, appeal, and recognition as an engaging and exciting alternative and disruptive learning model, the timing will be right to approach formal learning institutions to find ways of implementing this design-make framework into their programs.

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[1] Studio. (2015, August 26). In Wikipedia, The Free Encyclopedia. Retrieved December 12, 2015, from https://en.wikipedia.org/w/index.php?title=Studio&oldid=678021312.

Praxis explained

Figure 3. Rural Studio[1] (http://bombmagazine.org/article/2380/samuel-mockbee)

Praxis lies somewhere between the theoretical and the practical. It is not pure process because it implies that by doing – putting an idea or theory into practice – that doing informs the way something is done and what is actually accomplished.[2] There is a 'conversation' and back-and-forth nature to relating ends with means, thoughts with actions. The doing changes the original intention by providing an opportunity to understand and, therefore, alter the original objective. Praxis is creative and provides insight before final understanding is formed. Smith explains,

> *"As we think about what we want to achieve, we alter the way we might achieve that. As we think about the way we might go about something, we change what we might aim at."*[3]

Praxis forms a combined effort to interpret, understand, and apply. There is an important component of moral disposition. The doing is also informed by what is best for well-being; it must be right and truthful.

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[1] Oppenheimer Dean, A., Hursley, T. (2002). *Rural studio: Samuel Mockbee and an architecture of decency*. New York, NY: Princeton Architectural Press.
[2] Praxis (process). (2015, November 29). In Wikipedia, The Free Encyclopedia. Retrieved December 8, 2015,
from https://en.wikipedia.org/w/index.php?title=Praxis_(process)&oldid=692957216
[3] Smith, M. K. (1999). *What is praxis?* In the Encyclopaedia of informal education. Retrieved December 8, 2015 from http://www.infed.org/biblio/b-praxis.htm

Figure 4. How do we learn?

How do we learn?

We learn in many ways, but what are the best ways to learn? What leads to the most robust learning? By looking at the evolution of Learning Theory, we see that hands-on, real-world, experiential learning is consistently regarded as superior to other forms of learning.[12] Even as early as the mid 1700's Jean-Jacques Rousseau suggested that education should be shaped to the child. Edward Thorndike believed that learning was incremental and that people learned through a trial-and-error approach. While around the same time, Jean Piaget was the first to state that students create knowledge rather than receive knowledge from the teacher. Vygotsky added the idea that all learning occurs in a cultural context and involves social interactions. John Dewey, the father of experiential learning, believed experience and inquiry lead to the development of the mind. Maria Montessori, saw the teacher as a "leader of group activities" – it's designer – responsible for creating a specially prepared environment in which learning could

occur. People learn in different ways or have "multiple intelligences"[3] as suggested by Howard Gardner (Fig. 5). So, ideally, they should be introduced to new information in a way that best suits their learning style. However, it is important that learners be challenged to take on styles and perspectives with which they are less comfortable. Free

Fig. 5: Howard Gardner's Multiple Intelligences
(http://www.jenx67.com/2014/05/stem-steam-theres-one-kind-smart.html)

choice is an opportunity to experiment, push the boundaries of typical routines, and tread outside of expectation.

We can understand our basic drivers by considering the three core aspects of human nature: curiosity, playfulness, and sociability.[4] Curiosity is the drive to explore and

understand. By following our curiosity we develop new knowledge; are exceedingly good at recognizing change and novelty and, in fact, show a preference to novelty over that which is familiar; attend to what holds our interests; and experience the joy of discovery. Our curiosity manifests in playfulness, the drive to practice and create.

For true playfulness, unencumbered by adult supervision and input, creating and practice must be self-directed and self-chosen, about means not ends, imaginative and involve an active, alert mind, and be repetitive. Playfulness can but rarely happens in isolation. There is a social aspect, a drive to share and collaborate. As we explore, creating new understanding, practicing and creating interpretations of that learning, we cement that knowledge by passing it on to others. As sharing spreads, there forms a network of minds that can eventually lead to the formation of culture through the greater insights provided. This network of shared knowledge also supports collaborative problem solving.

Currently, the brain is seen as a complex, highly adaptive, self-organizing system. Our understanding of the process of learning "recognizes the active construction of knowledge, in which all new information is related to past experience in a constant search for patterns and meaning; the importance of experiential learning; of diverse learning styles involving multiple intelligences; and of the emotional and social context in which learning takes place."[5] Project-based learning is a very effective way to create an integrated curriculum that emphasizes knowledge within a context. The different

subjects support the learning of a central focus. This is the multidisciplinary quality of project-based learning that is a key to creating innovative thinkers and doers. Ken Robinson says it plainly, "real innovation and creativity come at the intersection of disciplines" because of "the way they merge and blend".[6]

Figure 6. What values should our children develop?

What values should our children develop?

As our children grow and mature they become the change-makers of tomorrow. The values that are the foundation of their actions and beliefs come from their learning, experiences, role models, and their developmental context in general.

To ensure that our children are intrinsically motivated in their learning and future contribution to society, we as parents and educators must encourage them to pursue their passions and interests. Allowing their internal drivers to dictate what they explore and ultimately pursue, ensures that our children's efforts are rewarding because they

have personal meaning and not because of some external reward. These passions, developed through playful exploration and inquiry, inform one's eventual purpose.

It is interesting to delineate the cultural values of our ancestors and compare them to the values we foster in our society. How does our method of parenting compare or the culture we foster in our schools and other paces of learning? We have been an agrarian society for only ten thousand years of our long existence as humans. We evolved with a much closer and more immediate relationship with nature and all that surrounds us and our learning was influenced by that closeness. We considered ourselves an integral part of the planetary ecosystem and not its master, trying to exert control over that delicate balance. Finding our way back into that precarious dance of mutualistic balance might be the greatest challenge we face. The following table (Table 1) outlines the cultural values seen in current and ancient hunter-gatherer societies.[7]

Table 1: Hunter-gatherer Cultural Values

Autonomy, Sharing, & Equality – Everyone's needs are equally important – No one has more material goods than anyone else – Everything is noticed, considered and discussed (collaboration)
Trustful Parenting – Children's strong drives to play and explore serve as education – Adults help, demonstrate when asked; children mimic
Technical Skill & Knowledge – Great skill at tracking, hunting, making tools, foraging safe foods and processing them safely, keeping fit and agile (dance, play,…) – Mixed-age – younger learn from older, older practice leadership and nurturing instincts
Social Skills & Values – Play – cooperation, knowing other's needs, consensual decision-making – Learn negotiation, compromise to keep games going – Respect, equality even with different size, strength, ability (egalitarian) – Noncompetitive – no comparisons between players

A deep understanding of the systems in which we operate and exist help us to value and understand our place within the larger context. Though we often ignore the fact, we are part of the Earth system and are subject to and influence the rest of that system. We are connected in a web of networks that make anything that acts on or disturbs that system effect every other part. We cannot consider parts in isolation; that type of additive thinking has lead to many of the complex problems we must manage today and will continue to struggle with in the future. By seeing the complexity and interconnectivity in which we operate, enhances our ability to represent and understand those systems accurately. We cannot flourish on our home, this closed system we call Earth, without basic ecological literacy that includes systems literacy. To see the multiple relationships takes multiple perspectives and supports the development of empathy. We need empathy, understanding the perspectives and point of view of others, to interact successfully and work together in a collaborative manner. It is these values that will drive the varied understanding and complex problem solving skills we need for the uncertain and accelerated change that lies ahead.

Tony Wagner, in his book *Creating Innovators*, offers a set of values (Table 2) around which the most innovative and effective learning institutions structure their programs.[8]

Table 2. Values around which schools should organize:

- Collaboration
- Multidisciplinary learning
- Thoughtful risk-taking, trial and error
- Creating
- Intrinsic motivation: play, passion, and purpose

Figure 7. How do we foster community?

How do we foster community?

With the explosion of virtual interactions, relationships, and online communities like Facebook, Linkdin, Instagram, and Twitter to name a few, we are spending less time connecting face-to-face in our neighborhoods.[9] Though we are part of these communities, we give up the real benefits of traditional community like sharing meals, having parties, providing help and support when needed, and playing together in our parks and community centres. If community and social responsibility are truly important values to teach out children then we must be sure to model that behavior. That means acting locally, supporting local businesses and organizations, investing in land maintaining local parks and green spaces, and providing needed to services to those in need. As role models we must be inclusive in our thinking and actions, show respect for people's differences and celebrate what makes us all unique, allow time and opportunity for our children to connect with others, and welcome new people into our lives.

Community must be a focus not an after thought. By recognizing contributions within our communities – exceptionality, loyalty, giving, supporting – we show with our actions what is of value.

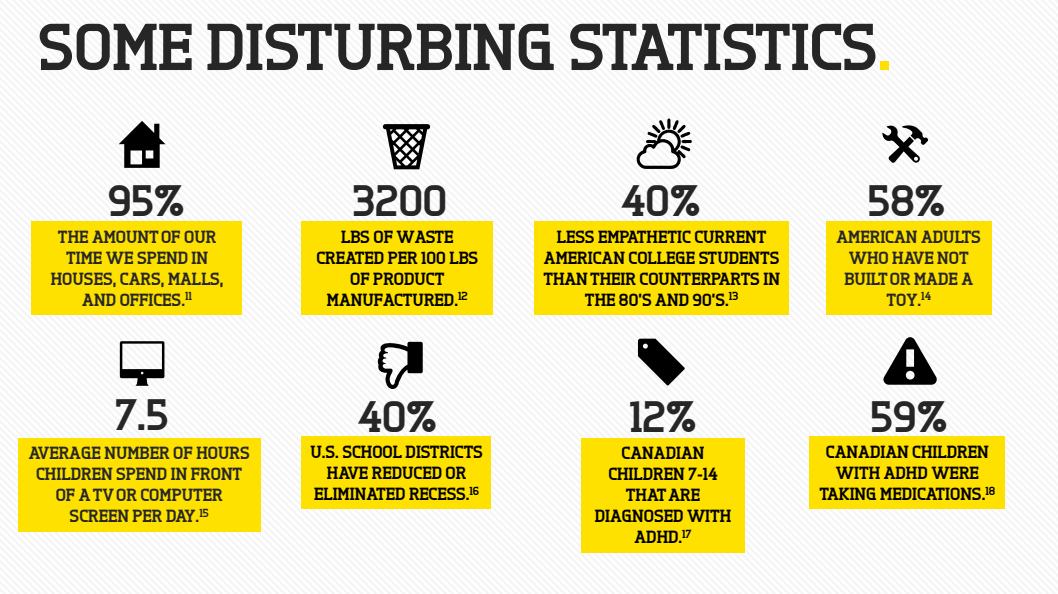

Figure 8. Some Disturbing Statistics[10,11,12,13,14,15,16,17]

Challenges with our current formal education model.

Our children spend an enormous amount of time in school and that amount has been steadily increasing since schooling began. At least some amount of schooling was mandated in Massachusetts in 1642.[18] Canadians, seeing the increasing economic power and prosperity of the United States, thought it was due at least in part to the development of its public education system and sought to create its own system. By 1873 most provinces in Canada funded their schools through taxation.[19] Compulsory school laws were introduced in Ontario in 1871. Even in those very early days of formal education children chose leisure time over sitting in packed, uncomfortable

schoolhouses and in 1900 attendance was only at 61%. Noam Chomsky says it without apology.

> *"Mass education was designed to turn independent farmers into docile, passive tools of production. That was its primary purpose. And don't think people didn't know it. They knew it and they fought against it."*[20]

Children are naturally playful. They are born curious and, through trying to satisfy that curiosity, are able to teach themselves. Yet, our education system doesn't honor that drive, that need to build understanding through exploration, inquiry and investigation. Instead schools are set up hierarchically in a top-down, authoritarian model, where teachers disseminate knowledge and provide learning that is one-size-fits-all. There is a focus on rules and standardized testing where questioning is not encouraged – if not discouraged – and typically there is one correct answer with little room for interpretation and originality. Students have little to no choice about what and how they learn. Curiosity is extinguished. Those who can't sit still, listen attentively, follow rules and inflexible schedules, or struggle to absorb and apply learning that is fed to them are often labeled as ADHD. It is the students that must adapt their natural inclination – their joyous playfulness, their inquisitive and curious minds – to fit this rigid, often boring environment rather than the learning environment being designed to optimize learning for every student. Furthermore, students are generally passive recipients of teachings – there is no physical interaction or manipulation of concepts. David W. Orr pleads with us.

> *It is time [for] a general rethinking of the process and substance of education at all levels, beginning with the admission that much of what has*

> *gone wrong with the world is the result of education that alienates us from life in the name of human domination, fragments instead of unifies, over emphasizes success and careers, separates feeling from intellect and the practical from the theoretical, and unleashes on the world minds ignorant of their own ignorance.*[21]

In schools there is often little context given to learning, no reference to where it applies in the 'real world'. There is no value given to the work as it would have if created by a professional – monetarily or otherwise. We miss a glaring opportunity to connect and compare student's efforts with professional standards and expectations, for this is inevitably where their learning will be tested. In this age of information, anything that anyone wants to know or explore is available through the Internet. With access, virtually any question can be answered. Schools and formal education are no longer the source for knowledge and understanding, but do provide the opportunity for collaboration, guidance, and 'live', in-person exploration that the virtual world can never offer.

How can we leverage these opportunities for interactive discovery in the classroom? One example of a methodology that takes advantage of this opportunity is 'flipped learning'. At Stanford a study showed that students grasp theory better after independent, tangible exploration rather than having the theory explained before.[22] This outcome is the complete opposite of typical teaching. The initial interaction provides context and associations that would otherwise be absent and is referred to as flipped learning. This style of learning is also similar to that used by The Khan Academy, in which students do their exercises and reading at home and explore their questions and uncertainties in the classroom with the teacher.[23]

Peter Gray, as described in his book *Free to Learn*, turned his research to studying education from a biological perspective when his own son became unbearably frustrated with school at the age of 9. Schools force students to learn through repetition and memorization. These are tedious activities for active, inquisitive, playful young people whose instinct are to think freely, ask lots of questions, and explore the world in their own ways. In *Free to Learn* Gray outlines seven sins of forced education.[24]

1. Denial of liberty on the basis of age without just cause or due process
2. Interference with the development of personal responsibility and self-direction
   - Children stop taking responsibility for their own education
3. Undermining intrinsic motivation to learn – learning into work, drudgery
   - Anxiety inhibits learning; best in playful state of mind
4. Judging students in ways that foster shame, hubris, cynicism, cheating
   - Testing, ranking, grading for motivation
   - Life is a series of hoops one must jump through, not self-satisfying accomplishments
5. Interference with the development of cooperation and nurturance.
   - Promotes bullying, forced competitiveness, look out for self, narcissism
6. Inhibition of critical thinking – questioning not supported, one answer
   - Needs playfulness of mind, freedom to experiment, explore consequences
7. Reduction in diversity of skills, knowledge, and ways of thinking.
   - Learn same material; can't follow passion; set schedule
   - Disallows learners from becoming experts on what fascinates them; no time to pursue own interests

As an educator one does not have to sit back and accept these failings of our current educational programs. Alternative, experiential learning methods are available to all teachers and educators. As great influencers and captivators, it is a teacher's unique opportunity to make themselves agents of change, to embrace a more learner-centric approach, and break the confines of education's current limiting system. Gray suggests that, "…the only meaningful reform is one that puts the kids in charge of their own

learning."[25] Effective, stimulating, and engaging learning methods and learning environments exist and immense amounts of research and investigation points towards a better way to learn. What follows is an exploration of what that system could look like.

Figure 9. What do our children need to learn?

What do our children need to learn?

The only certainty about the future is change. How do we best prepare our children for this uncertain and ever-changing future? Piaget put it best:

> *"The principal goal of education is to create men who are capable of doing new things, not simply repeating what other generations have done – men who are creative, inventive, and discoverers."*[26]

Education is for cultural transmission, learning, and being prepared for the future. Through education we need to create people who 'know why' not just 'know how'.[27] We are no longer concerned with taking agrarian people and preparing them to work in

industrialized urban centers, as we were when education was in its infancy. Today and in the future our children need to think differently, have specific mindsets, and grow a breadth of knowledge. Critical thinking is needed for appropriate and effective analysis and reasoning. One's evaluation of ideas or situations must be driven by insightful problem solving and result in considered decision making. An active and nurtured imagination supports creative thinking, but so does flexibility in one's thinking, adjusting to change in a nimble and anticipatory fashion. Creative thinking means challenging the status quo and often throwing off established conventions. True creativity is not just trendy, but rather something persistent, that is resistant to trends and often sets new standards and expectations. Thinking holistically, seeing the big picture is crucial to understanding and acting on not just our complex problems, but also how we fit in with the rest of the world. Systems thinking allows us to see the relationships and complex networks that are within us and that we exist within. The ability to recognize patterns and the interconnectivity between system components reminds us that they are part of a network of webs and acting on one-part effects all parts. Ecological literacy is based on the same understanding and is needed if our children are to be effective stewards of our future world. Understanding cause and effect is much more complicated seen in this light then, say, a linear domino run. One action leads to multiple reactions that make modeling processes and systems challenging. By embracing trial and error investigations and the immediate feedback they provide – failing fast, failing early and failing often – learners gain deep and first-hand understanding through prototyping.

Fundamental to learning is a mindset of curiosity – a drive to question, to seek answers, to explore and eventually make discoveries. This drive comes from within. Intrinsic motivation shows itself in the perseverance needed to continue one's search even when answers are elusive, in the grit and tenacity that comes from following one's passions and interests, and in the personal satisfaction experienced when goals are achieved, even small ones. To build confidence and comfort with uncertainty we must promote reasonable risk-taking in our children and expose them to novel situations and things. They must be bold, adaptable, and resilient. Though all of these mindsets are necessary, the most important to nurture is empathy in our children. How will they be good designers and stewards if they cannot see from multiple perspectives and connect emotionally with those with whom they play and create?

Because what we know is changing all the time, command of knowledge is important, but the ability to gain new knowledge and understanding as needed is more important. Our children need technical knowledge, including a range of skills and complex tasks, and to become expert from the drive and opportunity to practice these skills. Procedural knowledge supports us in our accomplishments. We must understand effective sequencing, how to best execute to achieve our goals, and gain materials literacy from our endeavors. Children gain intellectual knowledge like making good choices, recognizing opportunities and potential risks, and developing self-control from role models, personal experience, and objective feedback from those who care. So little is accomplished in isolation. Social intelligence is key to positive collaboration,

cooperation, and sharing. By playing and learning with peers and facilitators of all ages, children have an opportunity to nurture and be nurtured, to develop leadership skills and be lead, and the art of negotiation and compromise.

Job security is fast becoming an anachronism so we need our children to develop an entrepreneurial mindset, but with a conscience, so they can flourish without compromising the natural systems to which we are related and bound. Our goal must be deep understanding that doe not leave out imperative factors for the sake of convenience or simplicity. It is a complex world that we have created and we must cultivate young learners with the capacity to listen with all their senses and act with all their faculties. One of the basic principles of ecological design is that everyone is a designer. Every person has the opportunity to consider, create and share with the world their ideas and inspirations. Design does reside solely in the realm of the professional, but is there for all people who think crucially about what they do, the things they use, and the impact they have on themselves and the rest of the world. The significance of that responsibility rests in the shared global need to filter ideas and their subsequent expressions so that they are informed, consensual, and life-supporting. Our ability to make tools is possibly our most human quality. However, with global population swelling to almost 10 billion by the middle of the century, there isn't enough raw materials, energy, or space for us all to have our own extensive set of 'tools'. We must be smarter about how and why we make things, make smarter tools, and access and use resources in more efficient and wiser ways.

Learning happens everywhere, all the time.

Learning occurs through the development of knowledge. Formal education takes place for the most part in school classrooms, where teachers provide knowledge and students sit quietly trying to absorb what they can. Is this the best place or method for our children to learn? Where else and how else can they learn? The learning environment is an extremely important factor for learning. Studies have shown that students who have had opportunities to engage in outdoor learning have demonstrated an increased ability to think creatively and critically, improved performance on standardized tests, and renewed enthusiasm for learning.[28] Being outdoors, like spending time in the design-make studio, stimulates all the senses. Learners are provided with needed feedback as they act in and on that environment, encouraging greater perceptual development and learning.[29] Furthermore, the learner's effort is stimulated by the nature of that feedback and reinforcement. As active rather than passive recipients of information, learners physically engage with the information, the facilitator, and other participants and themselves making discoveries meaningful. Learning is based on associations – connecting new information with old. Facts, concepts and ideas are built upon by new learning that must be stored according to associated memories, processes and categories. By working on a project with a detailed plan of the design and execution, learners understand the 'big picture', helping them to remember, use, and make sense of new information with more flexibility.

Engineering and architecture programs are adopting studio practice into their programs more than has been typical in the past. These practical, hands-on environments provide a space where students can discover, design, create and build. Universities see value in the opportunity for students to collaborate, have discussions, share insights and receive feedback from other students. Freedom to challenge conventional thinking, physically handle materials and tools, and compliment thinking with manipulative exploration all support students in their learning and deeper understanding. As in the experiential model of learning, children designing and making increase their knowledge, develop skills, explore and clarify their values, and cultivate a sense of agency because of their first-hand experiences and accompanying reflection. The typical passive, sedentary classroom learner is actually at a great disadvantage. Dr. Dieter Breithecker, sports and physical scientist, has been studying movement and one's ability to concentrate. His findings indicate that if the body is inactive for too long, brain activity is reduced.[30] A small stimulation of or challenge to the vestibular system – our body's balance system – like standing on one foot or even rocking in one's chair causes the release of special hormones like neurtrophin that, when activated, have a huge effect on brain activity. School children typically lose concentration after 5-10 minutes, adolescents after 15-20 minutes. The antidote to boredom and an inability to focus is movement. From Breithecker's findings we see it need not involve long duration or complex movements, but something other than just sitting.

Learning is best facilitated rather than taught. Children are natural learners and, as Peter Gray has shown, when we were hunter-gatherers not so long ago children had command of an extensive range of skills and abilities that were learned through play, modeling, and exploration alone.[31] Through the use of play and humor, our hunter-gatherer ancestors thrived in a social and economic system based in sharing, cooperation, individual autonomy, and equality. The shear quantity of free play, without the adult supervision and competitive nature of so much of our children's play today, fostered an all-encompassing playfulness that extended to hardship that was accepted with laughter and self-control rather than frustration and complaining. The table below (Table 3) compares traditional hunter-gatherers with more recent stationary, agrarian people.

Table 3: Characteristics and Mindset of Hunter Gatherers (HG) vs. Agrarian people[32]

HG	Agrarian
Continuously adapt to ever-changing, unpredictable conditions of nature	Adhere to tried and true methods Creativity is risky
Ability to assert oneself	Structural hierarchy, obedience
Negotiation, compromise	Threat, submission
Takes risks	Conservative
Share, egalitarian	Don't share; what's mine is mine
Permissive parenting	Authoritarian, punitive parenting Corporal punishment to teach respect of power hierarchy
Children have lots of freedom	Children must work to support farming
Varied hunting, gathering techniques, hedges starvation	Tried and true methods, crop loss leads to starvation
Part of natural world	Control nature to serve

With free play and exploration comes learning that is self-directed and specific to the individual. Learners are able to pursue, driven by their inventiveness and creativity, that which is most interesting and provocative to them, fostering the development of passions that drive further inquiry and learning. Self-discovery is ideal for learning.

Jerome Bruner called this effective surprise, "Surprise brings the mind and body to a state of alert, and the things that students have discovered will be remembered for a longer period of time and be put to use."[33] This heightened state comes from taking action, without which there is no discovery, not from demonstration or being taught. Passive learning functionally removes the possibility of surprise and devalues emergent opportunities for deeper understanding because it is boring and bland. Our practice of teaching by subject in school further reduces the opportunity for surprise and emergence, though we know that innovation and creativity is born where domains crossover. Both Mihaly Csikszentmihalyi and Ken Robinson assert that it is integrated and interdisciplinary explorations, where typically unrelated information is connected, that leads to breakthroughs.[34,35]

Trial and error is a natural way to learn. Watch any toddler learning to fit shapes into correspondingly shaped voids and they try each one until the correct shape is discovered. Yet in school, children are typically discouraged from iterative exploration because failure is not valued. This devaluation is in stark contrast to its embrace within the world of innovation, another way in which formal education is in opposition to real-world context. The experiential, studio-based exercises connect the theoretical learning with tangible representations of learner's understanding. Bringing their designs to life through prototyping provides students with a hugely valuable opportunity to see and touch their ideas and refine them through the multisensory feedback they provide, effectively "re-intellectualizing shop class".[36]

Experiential Learning

Experiential learning is more than just outdoor education. The key principles are that learners have a direct experience – often a challenge – followed by focused reflection and subsequent growth. Consciously considering and analyzing one's experience increases knowledge, helps with skill development, provides clarification of values, and develops learner's capacity to contribute to their communities. The big advantage to experiential education is its ability to actively engage learners with the subject matter, the facilitators, their peers, and themselves. This all looks very similar to how making is described in Maker culture. Makers develop problem-solving skills by being playful and having fun, by collaborating and sharing successes and challenges, by staying aware of context and how explorations apply in the real world, and by embracing failure as a way to get closer to a solution and soaking up feedback to refine thinking and iterations. However, there is a tendency for Makers to limit their explorations and discoveries to projects that focus primarily on process and learning. They miss the opportunity to concurrently put their efforts towards meaningful cultural contribution. If all that effort and creativity can produce inspired, innovative and progressive results, shouldn't they be harnessed and contribute to the greater good? With respect to context, nothing seems more powerful than improving other's lives while learning and developing crucial skills.

Experiential education is not solely outdoor education or field trips or school food-growing programs. The same principles apply to hands-on work like designing and making. Experiential learning is about taking action. Discovery comes from taking action

and often leads to surprise. When learners are surprised they enter a state of heightened alter – in mind and body – and have better learning retention. The typical planning associated with classroom lessons and exercises removes surprise and, therefore, the opportunity to put learners in a state of arousal conducive to better learning.

According to the Association of Experiential Education[37], the principles of practice are:

- Carefully chosen experiences are supported by reflection, critical analysis and synthesis.
- Structured experiences promote learners to take initiative (self-directed learning), make decisions and be accountable for results.
- Learners ask questions, investigate, experiment, follow their curiosity, solve problems, take responsibility, employ creativity, and construct meaning from their experience.
- The experience is perceived as authentic because learners are engaged intellectually, emotionally, socially, soulfully and/or physically.
- The results of the learning are personal and form the basis for future experience and learning.
- Various relationships are formed and nurtured, including learner to self, learner to others and learner to the greater environment.
- Because outcomes are unpredictable, facilitators and learner may experience all or some of success, failure, adventure, risk-taking and uncertainty.
- All participants and facilitators have the opportunity to explore and examine their own values.
- Facilitators are there to coordinate the learning experience by designing the experience, presenting problems, setting boundaries, providing support to learners, insuring physical and emotional safety, and encouraging spontaneous opportunities for learning.
- Though facilitator biases and preconceptions are inevitable, it is their responsibility to consider how they influence the learner.
- The design of the learning experience includes the possibility to learn from natural consequences, mistakes and successes.

It's very easy to connect the dots between experiential education and the design-making process. Companies like Herman Miller are conducting research that illustrates the same connection.

> *"…there is a direct correlation between effective learning and the experience of constructing a meaningful product. Furthermore, it's been shown that encounters with tools can promote self-discovery and new thinking, which support social and technological innovation."*[38]

In the late 80's at MIT, Seymour Papert developed the theory of constructionism that takes Piaget's Deweyan-inspired constructivism theory one-step further by adding the importance of context. That is, one learns by "building knowledge structures" but that learning is best promoted when the learner makes something tangible that then exists in the real world.[39] Making supports and improves learning. In comparing constructionism with constructivism, Edith Ackermann of the MIT media lab explains that Papert's insistence that "diving in" to learning, creating an intimate connection rather than a more distant, theoretical separation, is a "powerful means of gaining understanding".[40] One must "become one with the phenomenon under study". Discovering new perspectives and developing deeper understanding creates empathy.

Hands-on learning is particularly important to young children. Although our understanding of the differences and inter-connectedness of the left-brain and right-brain have evolved since Sperry first suggested the theory, we do know that by using more varied parts of the brain, the better one's retention of information.[41] Development of the two hemispheres also occurs at different stages. Between the ages of 4 and 7 the right side of the brain is developing, so learning should include mostly spatial and visual stimulation. The left side doesn't start to develop until age 10 or 11, at which time more

analytical and language learning can be introduced. Thus the importance of art projects and play for younger learners. These manual activities are not only fun and engaging – critical elements to cement a love of learning – but also develop fine motor skills. These precision skills only improve with practice. This research and the concepts it supports gives strong support for Mitchel Resnick's premise of Lifelong Kindergarten to be discussed later.

The connection between the mind and hands is actually much stronger then once thought. According to neurologist Frank Wilson, author of *The Hand*, "the hands and the brain grew up together".[42] This co-evolution has lead to a unique relationship that is deeper than other sensory interactions where, because of that connection, truth is better perceived and cognition is better sustained. For example, as a woodworker I am constantly deferring to my hands to inform me of the smoothness of a sanded surface. A freshly sanded tabletop might appear perfectly smooth upon visual inspection, but might actually have a small imperfection or rough spot, revealed only by lightly running my fingers over the surface. The first thing most people do when I present them with one of my finished pieces is to run their hands over the wood. Seeing the beautiful grain and organic colours and patterns of the wood does nothing to satisfy their senses. Only by touching and exploring the object with their hands are they truly satisfied that they have fully experienced and appreciated what lies before them. Furthermore, it has been determined that "some tactile processing that we have previously attributed to the brain takes place in the hands, rather than in the brain as all have presumed".[43] The deep

neurological connection between the brain and hands and the disproportionate grey matter allocated for processing that stimulus is best shown by the Homunculus.

Frank Wilson explains that "at specific stages of development, there is no substitute for physical interaction with the physical world"; virtual and/or cognitive stimulation alone is not enough. With respect to young learners, he warns that "the mistake is thinking you can educate the mind by itself", a fundamental mistake when the "marriage of hand and mind" should be the learning objective. In fact, it is common that those who end up working in the fields of science and technology were drawn to their choice from out-of-school experiences like building backyard rockets, taking apart television sets or just playing with things.[44] This interest and curiosity was the seed for their motivation to study science. Not every scientist was born an academic, however. The young tinkerer or hacker is just following his/her curiosity, having a conversation with one's surrounding environment and the objects within. It is this conversation, needing tangible expression to be adequately and deeply considered, that Ackermann describes in reference to Papert's constructionism.

> *"To Papert, projecting out our inner feelings and ideas is a key to learning. Expressing ideas makes them tangible and shareable which, in turn, informs, i.e., shapes and sharpens these ideas, and helps us communicate with others through our expressions. The cycle of self-directed learning is an iterative process by which learners invent for themselves the tools and mediations that best support the exploration of what they most care about."*[45]

Papert gave new focus to the context or situation of learning and the functionality or utility of those tangible manifestations created to support one's evolving understanding.

Figure 10. How can we best support learning?

The Ideal Learning Environment

The ideal learning environment fosters lifelong creativity, taking calculated risks, experimentation and innovative thinking.[46] Wagner, in his study of young innovators and their early life at home and at school, found that his subjects consistently had and were nurtured to have a mindset of curiosity, interest, exploration and questioning.[47] They were able to weave learning with life experiences, making it integrative, and received facilitation rather than strict direction. Learning has its greatest value when it is self-direct, when the learner seeks answers to questions that are confounding. Noam Chomsky makes reference to early classical liberal thinking when he explains that "education is a matter of laying out a string along which the child will develop, but in its own way. You may do some guiding."[48] Furthermore, learning opportunities that are multidisciplinary, experiential, collaborative, creative and required them to teach their

new learning are ideal. This is the exact environment that is created in design-making workshops. According to Orr "design competence requires the integration of first-hand experience and practical competence with theoretical knowledge."[49] Making becomes the harvest of a concept.

Doug Stowe, a teacher who's blog Wisdom of the Hands, dedicated to sharing the concept that our hands are essential to learning, believes that "Without the opportunity to learn through the hands, the world remains abstract and distant, and the passions for learning will not be engaged."[50] Hands-on work stimulates greater engaged participation and active learning. All the senses are necessary allowing all types of learners to benefit from the experience. Certainly kinesthetic and tactile learners appreciate hands-on learning opportunities, but they are also engaging to auditory learners who talk about what they're doing, and seeing what everyone else is doing helps visual learners. The collaboration – time spent in conversation, exchanging

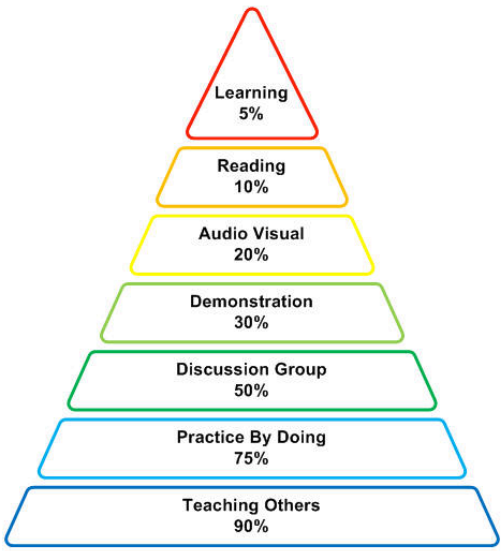

Figure 11. The Learning Pyramid (http://learningempowered.com/topography/)

information, working side-by-side on a common goal – is perfect for social learners.[51] The opportunity to teach others during hands-on work is likely its greatest impact on learning (Figure 11). The command of knowledge and understanding necessary to explain and demonstrate to others allows learners to validate their understanding and leads to the most robust learning. Workshops are lead by a facilitator, whose job it is to create an environment for learning to take place. Some information is taught when necessary, just as a certain amount of rote knowledge is needed for conceptual learning to take place. More often, however, learners are engaged in group activities and explorations that create the right environment for learning to occur from doing, collaborating and trial and error.

A focused attention to detail comes from working with one's hands that, in turn, influences one's responses to and perception of everything.[52] Knowing and doing do not need to exist separately. Einstein said "Knowledge is experience, everything else is just information". There are examples of programs that are providing a similar 'concept to fabrication' methodology. Paulo Blikstein's 'Makers-in-Residence' program at Stanford is an immersive, full-day program that takes students deep in to the design process and provides the opportunity to work in a well-equipped design lab.[53] Schools aren't teaching innovation and collaborative problem-solving, though they are fundamental skills for any STEM (science, technology, engineering, math) career. Blikstein recognizes that "most high school students will graduate without the experience of having ever designed a solution and built a working prototype." In his 'FabLabs', Blikstein has

students designing and building in small teams and exploring solutions to problems that get integrated into an already existing product or process. There is a clear connection between theory and practice. In every case, the advantage and reason to extend the concept into something that is actually created is to foster learning. David Orr asserts that, "design competence requires the integration of first-hand experience and practical competence with theoretical knowledge".[54] Constructionism, a learning theory defined by Papert, views "learning as a reconstruction rather than as a transmission of knowledge".[55] That is, the action of creating a material object is a very effective way of learning. Design-make experiences provide the opportunity to learn through the design process and that learning is cemented by making a representation of that which is designed.

Collaboration, Facilitation, Mentorship

A major component of the design-make experience is collaboration. Facilitators are there as a leader for the process, but the learning is shared through a delicate balance between demonstrations, providing support and encouragement during explorations, and promoting peer-to-peer learning. Creating the right environment for positive collaborative dynamics is vital for learning groups to be effective in reaching their common goal. Empathy is an important part of design, but also essential to collaboration. By sharing responsibility for maintaining a neat and organized studio, working in a variety of collaborative situations, and being mentored and mentoring others with less experience and skill, comfort levels between learners rise,

communication improves, trust is established, and bonds are formed. These relationships are fundamental to nurturing collaborative skills, social intelligence, creating risk-friendly atmosphere, and efficiency in program execution. When a collaborative group takes on uncertainty and explores new territory, the risk is shared, effectively reducing the perceived risk by each individual. The group becomes a team, focused on the task of designing and making, where the whole is greater than the sum of its parts. Blikstein found that his students learned perseverance during his workshops.[56] Because students could clearly see the end goal, they saw a reason to not give up. In more traditional formal education environments, they would quit because the learning objectives weren't clear. The necessary feedback is present from these exercises, as is the communication and shared insights that come from ideation, iteration and collaborative execution. Having a diverse group contributes to the efficacy of its actions. An older learner with more wisdom and experience compliments a younger learner that might be more familiar with certain materials or have greater comfort and skill with technology. Learner's varied skill sets and perspectives contribute to the varied, multidisciplinary view critical to the design process.

Facilitators must be leaders that can achieve the perfect balance of hands-on and hands-off. For the collaborative process to work, learners must contribute to their skill development and learning as much as they receive. Acting as a guide and mentor, facilitators create the opportunity for self-discovery in learners and the group as a whole.

Doug Stowe describes the delicate balance needed to be an effective learning facilitator.

> *"By doing, we learn at greater depth. Mentors help to frame the experience and direct it toward greater meaning, both for the student and for the society at large."*[57]

Learning occurs through behavior modeling and co-creation rather than information consumption. Facilitators have the challenge and responsibility of encouraging a non-competitive environment to maximize a group's potential. They must strive for the precarious balance between offering their expertise and stepping away to allow learners to lead and learn peer-to-peer. Creating new facilitators can prove challenging, but by having experienced design-makers apprentice to established facilitators they learn from the best role models. Below is a list of traits shared by great mentors (Table 4).

Table 4. Traits of Great Mentors[58]

1. Confident with different background
2. Generous with time and resources
3. Self-aware – have wisdom not just a title
4. Honest
5. Speak in specifics
6. Discreet
7. Offer different perspective

Figure 12. Mentoring.

Integrative and Interdisciplinary Learning

Of great value to designing and making is the integration of learning domains. Learning through a hands-on experience or about systems thinking or the value of collaboration or design thinking concepts and practices or how to best take a concept to fabrication, individually are excellent practices for encouraging learning. However, learning about all these elements together and exploring the connections and synergies that emerge is a very unique and powerful learning experience. Learning occurs through the exploration of topics where different disciplines are not separated, but rather integrated to support the investigation. Questioning, inquiry, exploration, discovery, and problem solving are the drivers for learning that lead to information gathering and eventual understanding from a range of domains. Connections between prior and current explorations are made as learning is integrated over time and from experience. Problem-solving is fundamentally interdisciplinary and requires accessing knowledge and skills across an

array of those available to individuals and the group as a whole. Learning varied subjects results from the necessity to form new understanding, a basic strategy of design. Solving complex problems encourages learners to identify the interrelationships within and between systems. Though specialization is inevitable as culture evolves and the quantity of information grows, we put ourselves at risk by compartmentalizing knowledge. Experts, by limiting the interdisciplinary range of their understanding, similarly limit their systems literacy. To be discussed further, creativity typically happens at the intersection of domains, where changing contexts and lateral thinking spark new insights, understanding, and innovations.

A Graduated System of Learning

Learning should always build on what one knows. By beginning with simple concepts, new learning can be "scaffolded" onto previous learning as it increases in complexity and moves from concrete to more abstract principles. This style of learning is easy to personalize because learners can add to their knowledge and experience as it is formed, without having to follow a set course or pace. As one moves to a new project, with a new group, working towards new objectives, learners build on past knowledge and experiences. A graduated system of learning creates opportunities for more experienced and skilled learners to take on greater responsibility through opportunities to lead, facilitate, demonstrate, assist, and mentor less experienced learners. Mihaly Csikszentmihayi relates complexity to enjoyment.[59] Without the increased challenge of greater complexity, learners experience less enjoyment in what they are learning.

Furthermore, uncertainty, complexity and the need for a creative response to stimuli will keep one's efforts creative and playful – also contributing to enjoyment.

With more knowledge and skills the scale of objectives can be increased accordingly, fostering deeper insight into more complex principles. In particular, systems thinking, including further exploration of biomimicry principles and integration of ecoliteracy into process and objectives, offers multiple opportunities to challenge and deepen understanding through greater complexity. The interconnectedness and patterns characteristic of systems exploration provide ample opportunity to challenge experienced learners and foster a more holistic way of problem solving.

Project-Based Learning (PBL)

Jackie Gerstein is an educator and blogger. She writes extensively about how educators can bring making into the classroom and the value of that integration. She outlines a number of better learning strategies.[60] First is productive failure where learners benefit from overcoming perceived failure that leads to better performance in the future. Research has shown that learning done in shorter sessions and practiced often allows more stimulation of neuronal links over time. The breaks between practicing afford more creative and varied perspectives on sticky problems. These incubation times can lead to flashes of insight, typical of the creative process. New perspectives also come from being playful about the learning. Don't give up – play with the problem and use alternative ways of considering. Don't forget about context. Give your learning

significance by relating it to the real world in multiple contexts. Learning by doing is a perfect way to provide context and elicit better retention and understanding.

In Warren Berger's book *A More Beautiful Question*, he emphasises the need to ask questions and to not be afraid about asking. Questions aren't just for those that are beginners, in fact, "most creative, successful people tend to be expert questioners….raising questions no one else is asking – and finding powerful answers."[61] Children are naturally curious, but in formal education programs questioning is often not nurtured and is actually deterred. We have to remember to encourage questioning and curiosity by stimulating inquiry. That's how innovation begins – finding answers to one's questions.

The design-make process is a form of project-based learning. It is also inquiry-based learning in that it usually starts with a question to be explored. This type of learning requires a skilled and nimble facilitator, someone that can guide and redirect learners when needed. Facilitators need to have a deep understanding of the purpose and methods of this strategy and know about what the project is and why it is being pursued. It is necessary to guide learners in exploring problems or curiosities that have a relevant, meaningful context to their lives so they will be driven by self-motivation. As a guide, the facilitator strives to assist learners in choosing something that will engage them deeply by feeding their passions and interests. The real learning happens upon reflection, when learners compare past experiences with existing knowledge and new learning. PBL is

most engaging when it is hands-on and experiential, involving all the senses, projects that are fun and provide immediate, real feedback – sounds a lot like experiential education. The result is a stimulating, multidisciplinary experience that fits naturally into and informs learner's lives.

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Promoting Creativity

Figure 13. The Creativity Gap[1,2,3,4,5]

The driving force of learning is curiosity. Children begin life filled with curiosity and a hunger to understand the world. As I live with three young boys of my own, I am constantly in awe of their propensity to be enthralled and excited by most everything. This sense of wonder at the myriad enthralling features of our world is, however, tenuous. If opportunity is not available for children to feed this reverence it will be extinguished. A child's sense of wonder must be nurtured and requires 'the companionship of at least one adult who can share it, rediscovering with him the joy, excitement and mystery of the world we live in".[6] Rachel Carson suggests that it can only be felt, and those early feelings must be encouraged, supported, and legitimized.

Once children have reached middle childhood, between 7 and 14, they start to make a home for themselves in the natural world. Edith Cobb, unlike most child educators,

recognized middle childhood as "a special period… when the natural world is experienced in some highly evocative way, producing in the child some sense of profound continuity with natural processes".[7] In Children's Special Places, David Sobel insists that children at this stage of development build forts and dens from a need for privacy, independence and self-sufficiency.[8] Building their own shelters, organized spaces for which they the feel ownership, helps them establish not just a physical place for themselves in the world but also a figurative one. As parents and learning facilitators, we must recognize this timely opportunity to encourage and coax children to explore their local surroundings, build simple places of safety and personal expression and establish a deeper understanding of themselves and their world. Most people lose their

Figure 14. Group siding.

sense of wonder and feelings of awe with age, but creative people seem to somehow maintain a curious mindset.

Mihaly Csikszentmihalyi conducted extensive research of many creative people for his book *Creativity*. He explains that creative people define problems by being patient and not rushing to define them; looking at a situation from multiple perspectives and various angles; leaving formulation undetermined for long periods; considering different causes and reasons; testing their hunches, first in their minds, then in reality; trying tentative solutions and checking their success; being open to reformulating the problem based on feedback; and entertaining a large range of possibilities, giving themselves a wider, less predictable range of options from which to choose.[9] These perspectives can form the basis of an analytical system and encouraged in our children as they problem frame.

Creativity and innovation are not the same thing, but they can often be substituted for

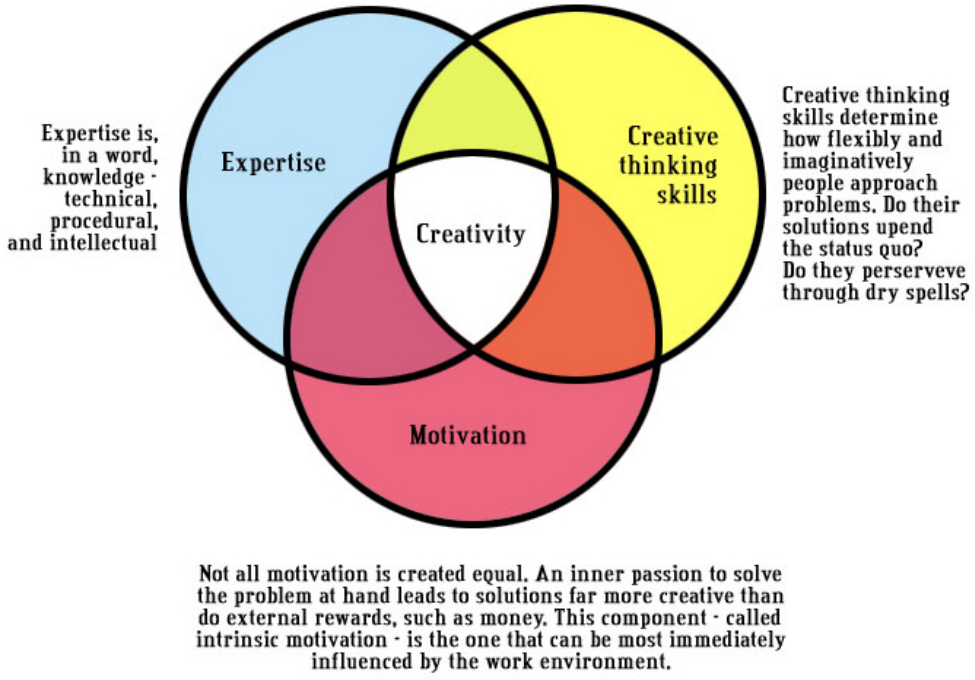

Figure 15. The Three Components of Creativity (http://bring3take3.blogspot.ca/)

each other in a process or understanding. In his book *Creating Innovators*, Tony Wagner presents this diagram (Figure 15) and suggests that the same components that contribute to creativity also are needed for innovation.

Though there are three major components, Amabile explains the importance of intrinsic motivation over the other two.

> *"Expertise and creative thinking are an individual's raw materials – his or her natural resources, if you will. But a third factor – motivation – determines what people will actually do."*[10]

The hard skills can be developed through learning and experience, but motivation comes from within and is much harder to facilitate. Surprisingly, motivation, which I suggest includes grit, perseverance, and self-control, might be the contributing factor that most separates creative people from others. The drive to be creative seems to be more important than creative skills themselves. According to Csikszentmihalyi, "creativity …is a process by which a symbolic domain in the culture is changed".[11] Innovation is about reinventing, improving or changing for the better something that already exists by creating value from its widespread implementation.

In Lego's Defining Systematic Creativity report, experts investigate and discuss the nature of creativity, how to encourage its development in educational environments and the necessary teaching strategies that can be used to stimulate creative thinking. The creative process hinges most significantly on one's ability to control and balance

divergent and convergent focus. Mastery comes from imaginative thinking that follows an unpredictable path through mostly new and unknown territory. Within the report, Csikszentmihalyi suggests there are five distinctive steps to the creative process with accompanying mindsets.[12]

1. **Preparation:** becoming immersed in problematic issues that are interesting and arouse curiosity. *Mindset: Curiosity*
2. **Incubation:** ideas churn around below the threshold of consciousness. *Mindset: Mental readiness*
3. **Insight, or Illumination:** the "Aha!" moment when the pieces of a puzzle falling together. *Mindset: Confidence*
4. **Evaluation, or Verification:** deciding if the insight is valuable and worth pursuing. *Mindset: Positive framing*
5. **Elaboration:** translating the insight into its final work. *Mindset: Commitment*

It is important to note that this process is not linear, but rather that the different elements of the process can be returned to at different times and may occur over a short interval or over many weeks or months. Csikszentmihalyi clarifies that creativity is a "recursive process of intertwined feedback loops and iterations (especially in terms of how insights are refreshed and updated by ongoing processes of incubation and evaluation)".[13] The creative idea may be the product of one large insight or might be the result of a group of smaller powerful ideas. These steps are key "thresholds" and allow tracking of the creativity process and are for purposes of communicating that process between the creator and an audience. The associated mindsets support an optimal creative process. Curiosity drives learning through questions and wonder while mental readiness is a state of relaxed, alert receptiveness. Confident learners are open-minded,

can handle risky and uncertain situations, remaining patient, inquisitive, and empathetic. Positive framing involves a sequential plan with clear goals and commitment comes from the perseverance to see the process through to the end. Encouraging and creating a supporting environment for these mindsets promotes creativity. Parents, facilitators, and role models wanting to nurture creativity in children should practice the following:[14]

- Respect children's opinions and self-expression
- Encourage daydreaming and imagination, curiosity and questions
- Give children opportunities to make decisions
- Enjoy being with children and celebrate their accomplishments
- Avoid being judgemental when children are working on projects
- Provide skills and information for projects
- Set appropriate guidelines and limits

Put forth in *Glimmer*, Warren Berger's book written in collaboration with Bruce Mau, are ten design principles (Table 5).[15] They get to the heart of how designers think creatively

Table 5: The Glimmer Principles

Universal

1. Ask stupid questions – no question is really stupid, what makes a question seem stupid might be why it is important to ask
2. Jump Fences – reckless leaps and smart recombinations
3. Make Hope Visible – picturing possibilities and drawing conclusions

Business

4. Go Deep – figure out what people need before they do
5. Work the Metaphor – find out what is it really about and bring it to life through designed experiences
6. Design What You Do – design the way you behave – intentionality

Social

7. Embrace Constraints – do more with less; don't fight it
8. Face Consequences – design well, know what will happen if you don't

Personal

9. Begin Anywhere – small actions are more important than big plans
10. Design for Emergence – apply the principles of transformation to everyday life; plan for possibilities but allow for surprises

about design. The list prompts the designer to consider all that is necessary for good design and check to see that nothing has been left out.

Creativity requires thinking and considering in unusual ways. According to Teresa Amabile, "creative thinking refers to *how* people approach problems and solutions—their capacity to put existing ideas together in new combinations."[16] One must try-out ideas and inspirations that might not work and seem too wild to even consider because without exploring these fringe or outlying possibilities key revelations might be missed. Something that appears at first too unfathomable may turn out to be just that, but by considering the possibility, other ideas or inspiration might emerge and be significant to the process. It is this playful nature of these explorations and investigations that often leads to important discoveries. Amabile has also consistently demonstrated through her research that it is intrinsic motivation – a person's internal desire to do something, their passion and interest - that has the most impact on creativity. What is more, research indicates a playful mood improves creativity and insightful problem solving.[17]
Exploration requires an open mindset and intentionally trying out a large array of possibilities. There are three dimensions to divergent thinking, each of which can be consciously developed and enhanced to support the creative process.[18] *Fluency* is a measure of quantity; produce as many ideas as possible; make sure those ideas are different from each other, *flexibility*; and keep it *original* by generating unlikely ideas.

The New York Hall of Science has an initiative called Design-Make-Play (DMP) that has been investigating methods of STEM learning that engage children's interest in exploring, creating and making. Their researchers see creativity as a process that must generate a range of solutions from innovative thinking and doing techniques, including divergent thinking and improvisation.[19] For this process to work, generated solutions must include making something. The engagement comes when children are put into action and are given the autonomy to explore and create on their own or in small groups.

Figure 16. Engaged in Learning

Another key feature of creativity is that it typically involves crossing the boundaries of domains.[20] As we see in academic and professional life, specialization is the rule rather than the exception. However, it is specialization that limits one's ability to consider a problem from an interdisciplinary perspective and the reason collaboration between people of varied skills and experience is imperative. As leaners, children should have a

broad range of experiences and skill development to encourage creative thinking. It is important that they learn to be original as well as competent.

Flow

Flow, or flow state, is the optimal experience and performance that comes from a balance between challenge and ability. Some people might call it being in the 'zone', but the state is the same. Mihaly Csikszentmihalyi developed the concept of flow and described it in detail in his book *Flow: The Psychology of Optimal Experience*. He describes flow as something we make happen and a way to experience true happiness.

> *"...when a person's body or mind is stretched to its limits in a voluntary effort to accomplish something difficult or worthwhile…when consciousness is harmoniously ordered and they want to pursue whatever they are doing for its own sake."*[21]

Certain conditions are necessary to reach a flow state (Table 6), but not all are needed for flow to be experienced.

Table 6: Csikszentmihalyi's Conditions for Flow[22]

1. ***Clear goals –*** attainable and align appropriately with skill set and abilities
2. ***Concentrating and focusing –*** on a limited, deep field of attention
3. Loss of ***self-consciousness –*** the merging of action and awareness
4. ***Distorted sense of time –*** subjective experience of time is altered
5. Direct and immediate ***feedback –*** recognize successes and failures with appropriate behavioral adjustments
6. ***Balance between ability level and challenge***
7. Sense of personal ***control*** over the situation or activity
8. Activity is ***intrinsically rewarding –*** effortlessness of action.
9. ***Action awareness merging –*** focus of awareness is narrowed to activity

We feel in control of our lives, enjoying every moment, and derive a deep sense of fulfillment – this is happiness. These best moments are a result of deliberately pushing

one's physical or mental abilities to the edge to overcome meaningful challenge. Often one's sense of time disappears from consciousness and the task at hand is so satisfying and enjoyable that nothing can interfere. Children in a flow state are hyper-focused and enjoying what they are doing so much that they don't want to stop. From a learning and developmental perspective, this is where we want are children to be. The multisensory nature of hands-on, project-based activities makes them ideal environments for promoting flow. If "insight presumably occurs when subconscious connection between ideas fits so well that it is forced to pop out into awareness"[23], as Csikszentmihalyi states, then those insights are likely to come from being in flow state.

Continued enjoyment of an experience comes from appropriate increases in complexity. During creative, engaging, and meaningful activities, the brain's pleasure centres – the septal zone – are activated contributing to the happiness associated with flow.[24] Without the challenge inherent in greater complexity, learners lose their interest and intrinsic motivation. Accordingly, design-making experiences follow a course of increasing complexity and challenge to suit learner's skills and abilities as they develop. During creative, engaging activities the brain's pleasure centres – the septal zone – are activated. The creative mindsets mentioned earlier, when cultivated, allow learners to follow a self-directed learning path to flow state, forming a self-reinforcing loop.[25] Making, the constructed, shareable version of one's ideas, provides a valuable means of reflection on that idea - for the learner and to receive other's input. A new idea that is valuable to others not just ourselves is an innovation.

Play

Merlin Donald explains that play is actually quite serious in its implications. Through play children (and adults) build the "cognitive platform" for the skills they will develop throughout their lives.[26] That is, it is clear that play helps children develop their capacity to be creative and abilities to see themselves objectively interacting with and in the real world, but play also builds crucial brain structure and neural pathways. Humans are born with a biological drive to play freely and mental growth is stunted with a lack of opportunity to play.[27] Gray explains that "play is the means by which children learn to make friends, overcome their fears, solve their own problems, and generally take control of their own lives."[28] Written in a 2010 Fast Company article produced by Frog Design, drawn from their publication, *Design Mind*, was, "A playful mind thrives on ambiguity, complexity, and improvisation, the very things needed to innovate and come up with creative solutions to the massive global challenges in economics, the environment, education, and more."[29] We need to see play not as a waste of time or as the antithesis of productivity, but in its true light, as a state of heightened brain functioning and a source of potentially world-changing inspirations. Peter Gray describes the challenge in *Free to Learn*.

> *"Perhaps play would be more respected if we called it something like "self-motivated practice of life skills," but that would remove the lightheartedness from it in thereby reduce its effectiveness. So we are stuck with the paradox. We must except play's triviality in order to realize its profundity."*[30]

Unfortunately, play appears to be changing from a time for children to imagine and be resourceful to a time of parent-prescribed activities. In fact, according to Howard

Chudacoff, a professor of History at Brown University, "children have become less skilled at transforming everyday objects into playthings".[31] Gray defines free play as "play in which the players themselves decide what and how to play and are free to modify the goals and rules as they go along."[32] The key here is that the decisions are made by the players involved and not dictated by an external structure or individual in a position of authority. Csikszentmihalyi notes the necessity of context for creativity.

> *"Creativity does not happen inside people's heads, but in the interaction between a person's thoughts and a sociocultural context."*[33]

The benefits of free play are even greater when the group comprises children of different ages. Older children learn empathy, how to nurture and cement their own learning through demonstrating to and teaching younger players. Younger players have the benefit of the greater skill and experience of older players. Just watching is an important part of learning according to David Lancy, an anthropologist, who describes observation as the single most important form of learning.[34] Through social play children learn cooperation, attention to one another's needs, consensual decision-making and negotiation. This range of skills is imperative to keeping the game going. If there is a lack of flexibility on the part of some or all of the players, people will drop out or the game will end. Gray astutely explains the complimentary nature of curiosity and play.

> *"While curiosity motivates children to seek new knowledge and understanding, playfulness motivates them to practice new skills and use those skills creatively."*[35]

He goes on to define five characteristics of play; an activity in which means are more valued than ends, that is self-chosen and self-directed, where the rules come from the minds of players, that is nonlinear and imaginative, and involves an active and alert mind.[36]

Research conducted by Barbara Fredrickson indicates that positive emotions broaden our perception and range of thought.[37] This wider expanse of focus seems to improve the likelihood of creative thinking because we see more, in more different ways, and in new combinations. When players are playing for fun, all their attention can go towards skill development and the happiness that comes from challenging themselves to always

Figure 17. Children Learning Through Play

improve. Failure is no longer a worry and the reinforcing nature of enjoyment motivates lots of practice and, therefore, further skill mastery. "Play is natures way of teaching children how to solve their own problems, control their impulses, modulate their

emotions, see from other's perspectives, negotiate differences, and get along with others as equals."[38]

It's hard to argue with the value of that kind of independent learning. It's time we as parents, as educators and as a society realize the positive developmental opportunities inherent in mixed-age, free play and put at least some of the responsibility of learning back into the hands of our children. When we truly value play as a forum for growth and extend trust to our children that they never should have lost, the rewards will be deeply engaging, self-directed learning for them and a brighter future for us all.

Life-long Kindergarten

Pablo Picasso is often quoted as saying, "Every child is an artist. The problem is how to remain an artist as we grow up." Mitchell Resnick is one of the expert researchers involved with the Lego reports. He is also concerned with maintaining our inner-artist as we grow up and promoting playfulness through the idea of life-long kindergarten.[39] One of the most important aspects of play is the opportunity for children to develop their creative thinking skills that include imagination, testing, boundary pushing, exploring alternatives, processing feedback, and coming up with new ideas. Alison Gopnik, a professor of psychology at UC Berkeley and leader in the study of children's learning and development, explains the power and importance of play.

> *"…exactly the same abilities that let children learn so much about the world also allow them to change the world…Children's brains create causal theories of the world, maps of how the world works. And these*

theories allow children to envisage new possibilities, and to imagine and pretend that the world is different."[40]

At the core of creativity is creating itself – turning ideas into something tangible and real. Those creations are one's ideas brought to life, providing further and deeper exploration and understanding of that idea and its associated possibilities and limitations. Making and learning become a reinforcing cycle. Playing and making are not just activities, but also ways to be in and understand the world that should be offered at any age not just in kindergarten. The collaborative nature of kindergarten-style learning allows peer-to-peer teaching and co-discovery without the typical authoritative classroom model where the teacher is the dispenser of information. Tinkering, what Resnick describes as "a playful, exploratory, iterative style of engaging with a problem or project"[41], allows people to try out and refine new ideas recursively to make them better. In this way, tinkering is a playful way of designing and making using a bottom-up rather than top-down approach. Instead of starting with a plan, by exploring and experimenting with materials and process, tinkering informs the direction and objective of learning. This interaction between learner and material is like a conversation. Tinkering can stimulate and provoke specific, self-directed explorations. This process of playful exploration that leads to a directed search for understanding is hugely valuable to our children's future. Information is widely available and constantly changing, that makes staying current impossible. It is more important to be creative and comfortable with ambiguity than command quickly out-of-date knowledge. Tinkering teaches mental agility and adaptability.

Tinkering activities provide immediate feedback to the learner, allowing for quick learning and seeing obvious links to causation. Immediate feedback and cause-effect recognition are fundamental characteristics of experiential learning as described earlier. With tinkering, the parts and connections are revealed as objects are deconstructed or assembled, giving deep insight into relationships and process. By starting simple and slowly increasing complexity, tinkering and is accessible to all learners independent of ability or experience. Learners naturally move from simple to more complex combinations and goal setting. To promote tinkering and curious exploration, learners should be encouraged by presenting themes rather than specific projects, encouraging a diversity of ideas and investigations, keeping the supporting environment plastic, promoting collaboration, asking questions not giving answers, and cultivating deep reflection and a 'big-picture' perspective.

Innovation

To be innovative one has to be creative or use creative problem-solving to make change for the better. Returning to the Three Components of Creativity diagram, let's consider how one develops expertise, masters creative thinking skills and finds the intrinsic motivation that leads to innovation. Children and young learners need to be nurtured through their social interactions, learning environment, teachers and mentors and their home life. We are talking about culture. A culture of teamwork, cross-discipline problem-solving, intrinsic incentives like exploration, play and empowerment (agency). Wagner suggests a set of skills for every student to master (Table 7).

Table 7. Seven survival skills for students

1. Critical thinking and problem solving
2. Collaboration across networks and leading by influence
3. Agility and adaptability
4. Initiative and entrepreneurship
5. Accessing and analyzing information
6. Effective oral and written communication
7. Curiosity and imagination

However, those qualities are not sufficient on their own. From the more recent research he did for Creating Innovators, and talking to parents of young innovators, Wagner suggests other necessary qualities including perseverance, a willingness to experiment, taking calculated risks, tolerating and even embracing failure, and a capacity for design thinking along with critical thinking.

Paul Tough describes similar findings in *How Children Succeed*. In the mid-1960's, trying to find appropriate interventions for systemic poverty issues, experiments were run with three- and four-year-old children of poor, low IQ parents in which teachers at Perry Preschool near Detroit tried to develop the 'soft skills' deemed necessary for success.[42] These are traits like persisting in the face of boredom, the ability to delay gratification, and following through on plans. After three years of analysis of the data that spanned decades, researchers found some interesting results. The experiment was initially considered a failure because improvements on cognitive tests did not last past the third grade as indicated on IQ tests. However, this deeper analysis performed by James Heckman, an economist of all things at the University of Chicago, and his team discovered that noncognitive skills like curiosity, sociability and self-control provided as much as two-thirds of the total benefits students received from their time at Perry

Preschool.[43] Instead of raising the preschooler's intelligence, educators had improved student's behavior and social skills. The key was a nurturing environment and excellent role modeling that fostered the development of the 'soft skills' described above.

Figure 18. The Freedom to Learn by Doing

Design thinking is a process of creative problem solving that puts humans and good user experience first. It starts with an understanding of the goals and objectives of all stakeholders and leads to purposeful, pragmatic, solutions that are efficient and well designed.[44] Tim Brown of IDEO proposes five characteristics of design thinkers: empathy, integrative thinking, optimism, experimentalism, and collaboration.[45]

Wagner's research revealed a number of specific experiences that young innovators had growing up.[46] Time to play was a significant contributor. Time to play and explore and imagine, away from the direct supervision of adults, allows children to take risks and follow their own judgment. Parents of young innovators limited technology and screen

time, nurtured and respected what they saw developing and encouraged and made time for free-choice reading, another form of play. Parents should encourage their kids to develop their own passions and, as they grow older, to allow their passion to inform the purpose they see for themselves. David Orr reminds us to allow our children to find their calling before they find a career.[47] One's calling is not primarily about financial or professional achievement, but rather one's larger purpose driven by deep values and an 'inner conversation'. It is important that young learners are encouraged to see how they can be of service within their community and the world at large.

Figure 19 shows the components of creativity and innovation – expertise, motivation, and creative thinking skills – and their contributing elements, illustrating the importance of these relationships and how they are fundamental to an environment that supports and promotes creative exploration.

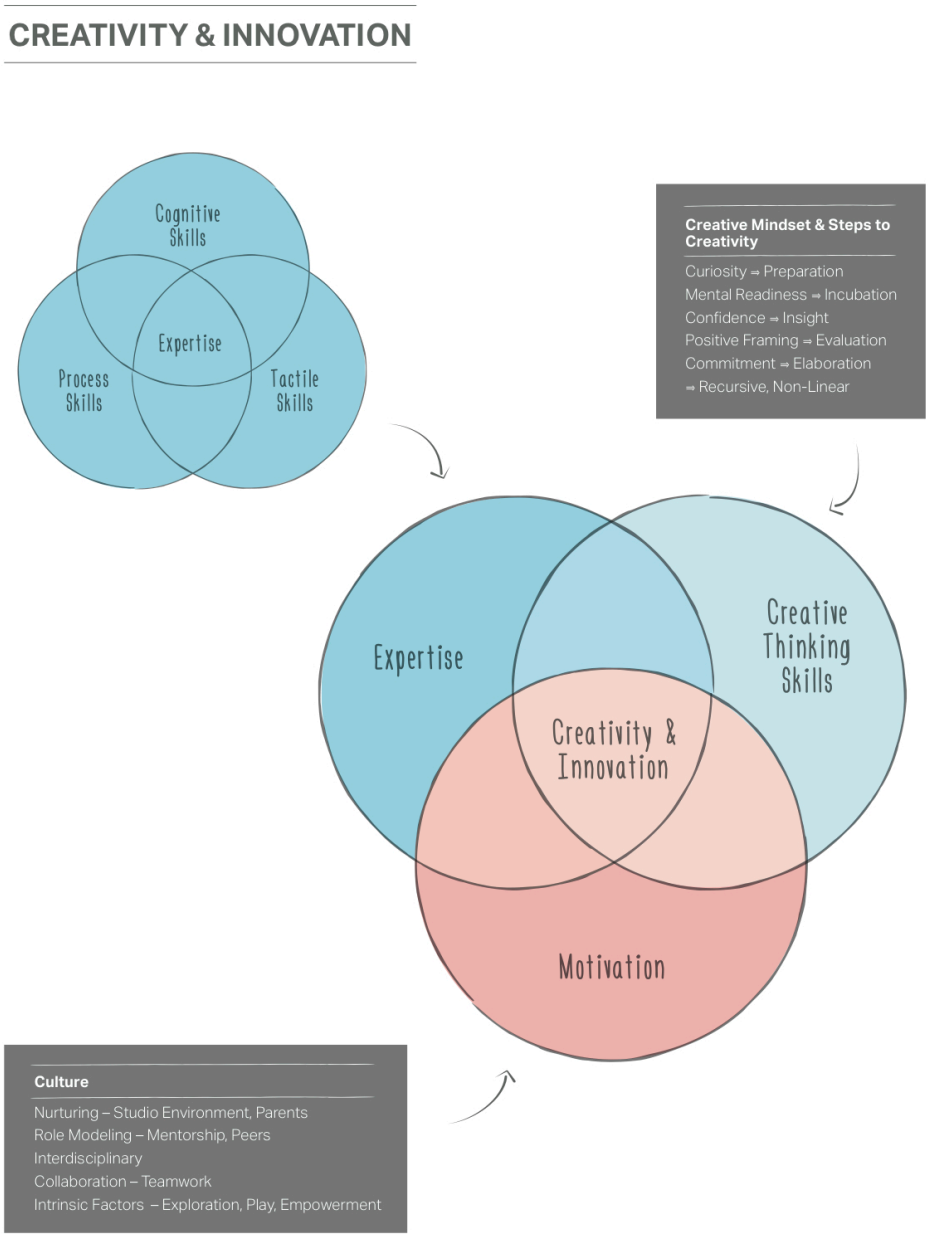

Figure 19. Creativity and Innovation

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Figure 20. We are all Designers

We are all Designers

Design is an excellent, systematic way to understand a given problem or opportunity through deep research and first-hand observation, ideation, prototyping, and testing of proposed solutions or interventions. Children should learn from a young age to seek a holistic view, to look deeply when deciding how to frame a problem and to go through a process of experimentation, iteration, feedback and multidisciplinary collaboration to arrive at possible solutions. These are methods and systems that should form the fundamentals and foundation of education and how children learn, think and act. By going through a process of design and *also* fabrication one is able to bring the results to life, the idea to fruition. Without fabricating or making the physical representation of an idea, that idea remains nebulous and conceptual, living only in the theoretical rather

than coming to life as something tangible. Making results in deeper understanding and a sharable representation of one's thinking that can be evaluated by the maker and others.

Designing isn't just about coming up with good ideas, reinventing something or improving a solution. Design is a creative and playful process where one explores specific possibilities dictated by the constraints of the problem and environment in which it exists. The designer not only uses his/her own knowledge, experience and skills, but also information collected from those who will be effected by the proposed intervention, the stakeholders. Typically it's a collaborative process and it's like a game. If learning is game-like and fun and coming up with new ideas is fun and problem-solving is fun and working together as a team is fun then the associated learning becomes very robust. Design is concerned with real-world associations; problems are framed and solved in a specific context not as purely theoretical. This tangible, applicable nature of design adds to the sense of accomplishment a designer experiences and the satisfaction that comes from creating those things. Having fun should not be relegated to leisure time, but should be a fundamental part of the work we do. Fun work is play. We should be more playful. Playfulness seems to be missing for the most part from the world of education and professionalism. If it is important to make sure we develop life-learners rather than children that think learning happens only in school, then learning needs to be attractive; it needs to be fun and playful.

Figure 21. Balloon Launchers

Design Competence

To be competent in design one must attend to first-hand experience. That which is directly experienced stimulates all of one's senses, holds one's attention in ways that reading, watching or listening on their own do not, and that has, by existing in the real world to be experienced, authentic context. All of these inform the designer in ways that theory and other's findings do not. Design competence is practical. Not only is it to be experienced first-hand, but it also seeks purpose, utility and function. Theoretical knowledge too is a necessary piece of the puzzle, used to inform and deepen design. The vast reserves of knowledge and theorizing that have come before are to be applied and considered to paint the clearest understanding possible. It is not enough to see design in the compartmentalized light of isolated places or things, but rather as the systems in which they exist and interact. As designers we must consider the relationships between parts, the connections between and within systems, and the networks they

form. As David Orr told the graduating class of Penn University in 1998, "you must see Design as a large and unifying concept—quite literally the remaking of the human presence on Earth."[1] Because we are only one component of the Earth-system, we must design for and with nature. Only though a systems-based consideration and one that is aware of the purposes and consequences of any design with respect to the natural world, can we accurately decide what is worth doing and what is not.

Design Thinking is a systematic and human-centric way of approaching a problem or opportunity. It involves an initial broad scan of the problem territory, referred to as inspiration, to decide if indeed the problem is properly framed and to confirm through direct observation user's and other stakeholder's wants and needs. Those stakeholders inevitably include the environment in which the intervention will exist. Possible solutions and new possibilities are conceived, developed, and tested through divergent and convergent assessment and iterative prototyping. This early stage of ideation is fun and uninhibited. This is a time for volume of ideas where even outlandish suggestions can inspire more refined solutions later in the process. As Oliver Wendell Holmes Sr. said "A mind once stretched by a new idea never regains its original dimensions."[2] In the design-make studio, design thinking is applied at the very beginning of the problem framing or investigative stage. Multiple and varied options and ideas are explored initially, supporting a divergent and wide-sweeping approach. Through this 'deep dive' of inquiry, learners can determine what information or expertise must be sought. Part of the collaborative process, aside from working openly and prolifically as a group, is to

determine what outside help is needed, be it more information or people with specific understanding, skills, or experience. The group must establish a dynamic of quick experimentation and representation. An intervention is refined by constant efforts to understand the user and their environment in the context of the proposed iteration and attending to the resulting feedback. Prototyping should be driven by a desire for better understanding that comes from rapid, successive refinement, where learners fail early, fail fast and, fail often. The purpose of prototyping is not to finish an idea, but rather to decide what works and what does not work about the current iteration and how that knowledge can inform the next. This is not a linear process, but cyclical as groups return to inspiration and ideation as often as needed for refinement.

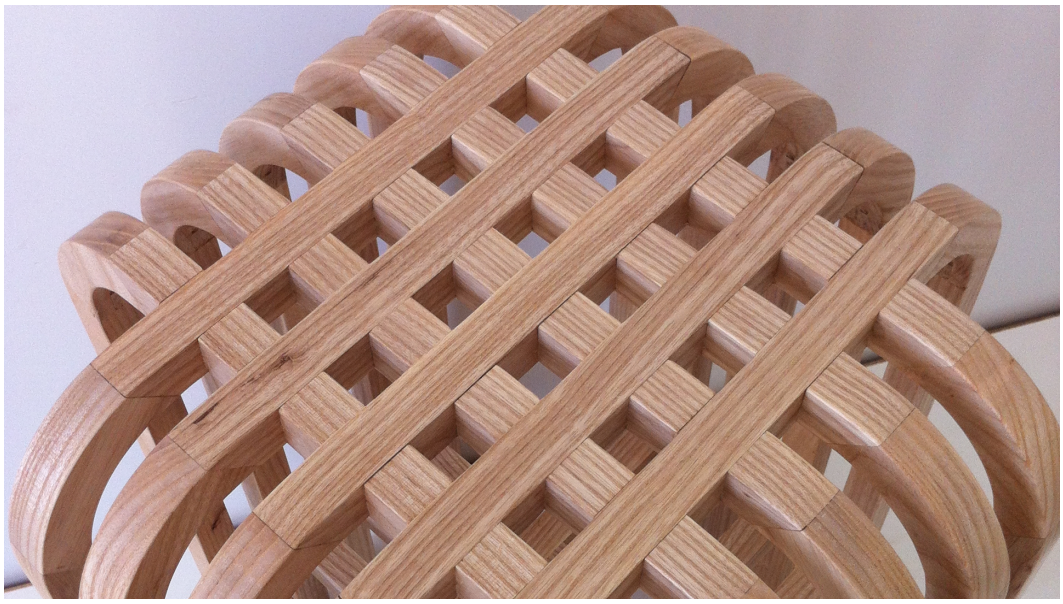

Figure 22. Prototyping

The ambiguity and complexity inherent in problems that are explored through designing and making require learners to have a playful open mindset. Improvisation and a flexible

perspective support deep exploration and creative solution forming. Prototyping is accessible and second-nature with the hands-on, material-rich nature of the design-make studio. Learners make discoveries and better understand their ideas as they build and refine them. Because collaboration and sharing are fundamental to problem consideration, learners are not only having fun in a vibrant, free environment, but are also driven by an active, curious atmosphere where other's iterations can inform and inspire. Groups are encouraged to show not tell through clear visual and physical representations. Ideas are presented through storytelling that provides context and relevance to proposed solutions. Design thinking provides structure to the investigative, iterative, and collaborative process of problem framing and solution refinement, thus, developing design competence..

Ecological design

Ecological design is the "careful meshing of human purposes with the larger patterns and flows of the natural world and the study of those patterns and flows to inform human purposes."[3] Orr also explains that it is "the practical application of the concepts of interrelatedness, systems, and long time horizons."[4] Ecological design connects design with what surrounds us – life. Good design – design that sees its place within a larger, connected context and considers its complex impact – is what our children should be learning. To cultivate anything else would be unfair and destructive to the development of a true and complete understanding of the potential of design. Design should inform education and education should be about design.

An idea is brought to life and made tangible through the design process, without which there is no making. Though many exercises of making are a product of following someone else's design, for the made object or experience to be an authentic representation of a person's ideas and understanding it must also come from the maker. The value of making provides a much deeper learning experience because of the design process: gathering information to instruct problem formulation, the subsequent arrangement of components to form the first of an iterative sequence of possible solutions, and subjecting those possibilities to the feedback offered by stakeholders considering their accuracy and appropriateness. The challenge of creating good solutions is directly proportional to the complexity of the system in which the problem exists. We must be humble and honest enough as designers to admit that many of the problems we are trying to solve exist as part of systems that are so hugely complex that we are left with certain uncertainty. Our models end up as incomplete as is our understanding. It is the process of trying to understand, to search for the most complete consideration of the multitude of related and interacting variables, however, that our children must learn. By entertaining all stakeholder perspectives, by forming a multidisciplinary team to co-create possible solutions, by returning to those stakeholders for their input on proposed interventions, and using their input to create the next iterative possibility they learn creativity, critical thinking, problem solving, empathy, how to collaborate and be a team player, and the perseverance and grit to keep iterating.

By looking at nature to inform our design perspective, we learn from the most balanced and ancient system we know. For example, in nature there is no waste; the waste from one cycle is the food for another. Yet our own systems, like industry, do not share this cyclical structure and we are left with growing waste, accumulating without a complimentary structure to deplete that waste as its fuel.

These 'broken' models make our job as facilitators of learning much harder because all around them learners are exposed to systems that do not reflect these basic principles. The more time learners spend as students of nature, allowing their experiences in and understanding of nature to permeate their designs, the better their designs will be. Sim Van der Ryn, founder of the Farallones Institute in California and ecological design pioneer, suggests guiding principles for ecological design (Table 8).

Table 8. Five Principles of Ecological Design[5]

1. Solutions grow from place – let solutions be context-specific; suited to and informed by locality
2. Ecological accounting informs design – consider ecological costs and benefits and design accordingly
3. Design with nature – work with the patterns and processes favoured by nature to minimize ecological impact
4. Everyone is a designer – solutions are the product of collaboration between designer and all stakeholders
5. Make nature visible – the design experience and experience with the design promotes mindfulness and responsibility

Self-design or self-organization is the spontaneous increased levels of coherence and resilience that come from the multiple interactions that occur in a whole system.[6] The significance of this phenomenon with respect to learning can be seen in the design process. If our children learn to design collaboratively, the system in which they are designing – the design team – provides the multiple interactions described above and

can result in emergent solutions or self-design. This process is a result of three factors.[7] The first, seeding with diversity, refers to the variation or multidisciplinary background of designers involved. As mentioned earlier, diversity feeds creativity. Furthermore, there seems to be a certain threshold of complexity that is necessary for self-organization, as there likely is a perfect number and amount of diversity that is ideal in a collaborative team of designers. Intelligence webs are the second factor and refer to the holistic responses to local perceptions and actions that lead to system-wide harmony, "a dance in which the elements of the system can resonate together, sharing information locally in a way that produces large scale integrity."[8] Design that is well informed by all stakeholders will undoubtedly be better received and better meet desired outcomes. Finally, the third factor is emergence, organization that could not have been predicted from the system components but results from their interaction. As designers, we intentionally design with all variables and information available, but are also open to results and outcomes that could not have been foreseen and embrace the whole that is greater than the sum of the parts – just as it is in nature. It is the feedback that comes from putting forth an iteration that is the most valuable to assessment. As we have seen, making makes design real and provides a more complete understanding by grounding our ideas in tangible reality.

Design-Based Learning

Designers are excellent problem solvers. They work in the real world; everything that they design – objects, services, or experiences – must stand the test of living in the

environment in which it is applied. Design is true praxis in that the process of designing and developing the best-fit solution informs and changes the problem framing and proposed intervention. What was considered the problem at the beginning of the investigation changes based on discoveries made along the way, that, in turn, alter the drivers for any proposed solution. Thinking about how to proceed changes the desired outcome. Practical application forces designers to manage the complexity of real-world systemic interrelationships. By taking project-based learning and adding design to the framing and processing of ideas and potential solutions, learners apply a systemic approach of problem identification, research and prioritization, testing, and evaluation.[9] Furthermore, a version of performance-based assessment is available to facilitators and learners through the efficacy of proposed solutions and reviewing individual portfolios as they grow and evolve.

Figure 23. Investigative Learning

Throughout design-based learning, learners remain active participants, investigate within

a range of domains and disciplines, test their solutions in the specified context, and consider multiple perspectives. In this way, learning is robust, fun, and creative. Learners that take on the role of designer develop a sense of personal investment in the endeavor, resulting in more uninhibited investigation, insight that inspires informed skepticism, and generally a deeper understanding of the factors and drivers at play.[10] The designer holds significant responsibility in his/her role and must command a broad range of knowledge, thinking and mindsets. Leonardo Da Vinci reminds us that creativity and inspiration are born at the intersection of domains.

> *"To develop a complete mind, study the science of art, study the art of science. Learn how to see. Realize that everything connects to everything else."*[11]

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[2] Oliver Wendell Holmes Quotes. (n.d.). Quotes.net. Retrieved November 24, 2015, from http://www.quotes.net/quote/4003
[3] Orr (2004) 109.
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[9] Davis, M. (1998). *Making a Case for Design-Based Learning.* Arts & Eductaion Policy Review, 100 (2). Retrieved from https://www.ncsu.edu/www/ncsu/design/sod5/phd/resources/Davis_Making_a_Case.pdf 2.
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Figure 24. Making deepens understanding

Making deepens understanding

When I think of young children in kindergarten, I see a light-filled room buzzing with activity. Children are spread out in different pockets of small groups, building towers with blocks, wearing Dad's old shirt backwards with a gloopy paintbrush at a painting easel, or lying on some comfy beanbag chairs in a corner nook, pouring over picture books and laughing to each other. There's lots of laughing and talking and working together. Inevitably, someone or some group is building something; a garage for toy cars, a block tower, crafting a paper mache bridge, or drawing a spaceship as it travels to Mars. Children are learning by doing, by taking an idea that came from inside themselves and creating some version of that in the real world. To make is to bring into existence by shaping or changing material or combining parts.[1] Making is part of thinking. Making is how leaners try out and refine their understanding. Making is fun and

playful. Aristotle said, "For the things we have to learn before we can do them, we learn by doing them. Men become builders by building."[2]

Why does making eventually disappear from classrooms as children get older? Is it less useful as children age? Is it harder to motivate older learners to explore their ideas and conceptual understanding through representations? Certainly there is more focus on reading, writing, and arithmetic, but not by choice. As children enter elementary school testing, including standardized tests, becomes more common and makes quantifying progress and knowledge command easier, but how has learning evolved for learners? A learning pedagogy like Resnick's Lifelong Kindergarten suggests that the exploratory, self-directed, and playful nature of early learning should be maintained. Learning should be a personal journey whenever possible and one motivated from within our children. By slowly scaffolding complexity onto previous explorations, learners gain knowledge from questioning and forming their impressions into objects that live in real-world context. Skills develop from practice and repetition. Design-make projects remove the mystery about fabrication that children often feel and open learners up to the possibility of understanding, repairing and making other things. The anxiety associated with making something when one has no experience is overcome after gaining skills and experience in the studio environment and that confidence translates to other manual endeavours. Designing and making require learners to integrate a wide range of information gathered first-hand. Learners use trial and error to explore and discover what they seek; no one is giving them the answers. The independence and intrinsic motivation to keep

searching and probing through iterations and absorbing feedback requires a tenacious attitude towards refinement. It takes resilience, adaptation, varied perspectives, cognitive agility, creativity and the social intelligence to collaborate effectively. Above all else, children learn to problem solve creatively and effectively. They develop the confidence to patiently frame problems despite uncertainty, quickly communicate their understanding and inclination by making them tangible, and reworking them to embody emergent learning that results from sharing and collaborating. Making is not just for specialists and experts, but accessible to all. As Thoreau waxed sentimental in *Walden,*

> *"There is some of the same fitness in a man building his own house that there is in a bird building its own nest….Shall we forever resign the pleasure of construction to the carpenter?"*[3]

Making is part of thinking.

I have established the neurological link between the hands and brain but there is also the integration from the perspective of process. Referencing Richard Sennett's book *The Craftsman*, David Gauntlett suggests that thinking and making are part of the same process.[4] A craftsperson makes no separation between thinking and making. That is, one does not think and then move to the practicality of making, but rather the two are intertwined and occur concurrently. Even in 'unmaking', where something is broken and taken apart, there is necessary synergy between cerebral and manual efforts. The act of breaking something down into its constituent parts, disassembling the often mysterious innards of a vacuum or non-functioning lawnmower or old fax machine, is very much like

"exploring another person's ideas" according to Gever Tulley.[5] Again, the idea of a conversation or discourse between designer and 'breaker' can be imagined as the hidden secrets are revealed, shedding light on the constraints under which the designer formed their design, be they physical, economic or subject to market trends. According to semiotics, the study of signs, learners "develop meaning because they compare their own ideas with those of the referent or object."[6] Pierce's semiotic triad model describes the dynamic and nonlinear relationship between the sign or representation that is created, the referent that is being represented and the meaning or personal interpretation made. The more varied the representation (made object) the deeper the learning. It is a small stretch to substitute unmaking something for making something – the learning is comparable. The effect is additive and evolving; learners garner more meaning from creating (or breaking) multiple representations. It is a process of testing and adjusting one's understanding through successive versions of the idea or object, no matter the medium.

So we build deeper understanding by making what we want to know. This is common practice in fields like science, architecture and engineering and is a version of iteration if multiple representations are created. The architect builds scale models of the house he has designed to experience the relationships between elements; the engineer tests load calculations to be sure the theory stands up to real-world application or to better understand a new material or way of using a material; and the chemist builds models of

molecules to discover how the connecting bonds effect shape and connectivity between parts. Major discovers like the double helix shape of DNA came from physical modeling.

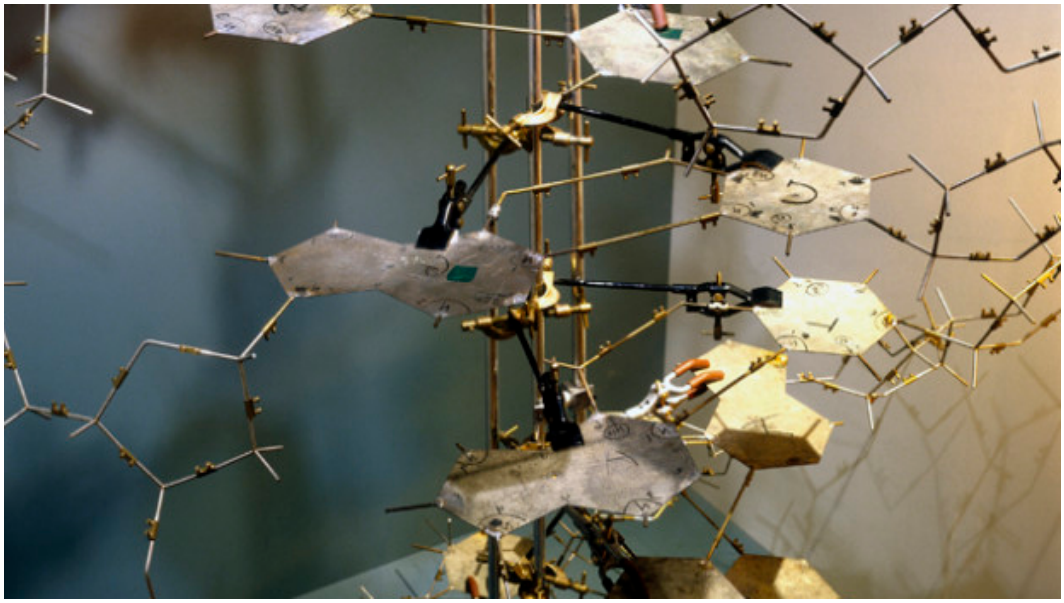

Figure 25. DNA Model (http://www.sciencemuseum.org.uk/broughttolife/objects/display.aspx?id=6145)

Until Crick and Watson represented their calculations and theory with models made of a variety of media, the true shape of DNA remained uncertain. Today powerful software allows for virtual modeling that could be considered as revealing if not more revealing than physical modeling. However, the physical manipulation and tangible, tactile nature of the 'real-world' model reveals much that a virtual model cannot. For one, the process of creating the model is extremely informative, with a step-by-step plan or design, choice of materials, collaborators,… - a true design-make exercise. Making has such immediate connection to consequences that it could serve as an excellent learning experience for those who don't see or experience directly the cause and effect associated with their actions. Matthew B. Crawford, author of *Shop Class as Soulcraft*, asks the question half jokingly "Why not encourage gifted students to learn a trade, if

only in the summers, so that their fingers will be crushed once or twice before they go on to run the country?"[7] No doubt an experience like that would leave a deep imprint on one's memory and would translate more generally into considering the ripple effects associated with any decision.

Richard Sennett suggests that making involves not just thinking but feeling as well and that crafting is like thinking with the hands, a process of manual exploration that leads to finding answers to questions.[8] This problem-solving process is the impetus for new questions and new explorations. In this way, a cycle of inquiry is created in which solutions spark new problems in the maker's mind. Engaging one's hands also engages one's mind. This is key to the inclusion of making in education. Advantages to a hand-mind approach to learning beyond engagement include an understanding of quality and producing learners that are experienced at applying their knowledge to real-world situations.

The Maker Movement

The Maker Movement has been growing steadily for the last number of years. Dale Daugherty started Make Magazine in 2005 and Maker Faires began the year after as a response to makers wanting a venue to share their ideas and inventions. Sharing is an important component of the Maker Movement. There are Maker and Hacker spaces all over the world where adults and often children can come together, take classes and use equipment to create the things they want to bring to life. Making is becoming so

popular, in fact, and provides such an appropriate medium for teaching that it has stimulated deep discussion about how to integrate making into education. Proponents of making have conducted extensive research and studies exploring how makers benefit from the process with respect to learning, evidenced by the range and quantity of sources referenced in this report.

Louis Gomez, learning scientist, suggests that making offers new opportunities to address four needs facing education today: competence, knowledge, intelligence and self-instruction (Table 9).

Table 9: Four Needs Facing Education Today[9]

Competence: the ability to explain natural phenomena, to ask pertinent questions, and to articulate and defend arguments on a wide variety of subjects. **Knowledge:** awareness of a body of information shared by well educated others, that is, a body of information that is traditional as well as expanding and emergent. **Intelligence:** the ability to discern the essence of an issue and apply appropriate constructs to solve a problem or draw a conclusion; and social, the ability to work well with others. **Self-instruction:** the ability to construct knowledge, to develop social skills, to engage in various intellectual domains, and to self-monitor one's advancement in learning.

Makers create the solutions to their questions through extremely creative means of combining interdisciplinary knowledge, skills, and experience, with tenacious drive to find answers, and a nimble mindset. They are able to switch their direction of inquiry in response to their immediate findings. They are also amazing storytellers, able to relate with equal excitement their dead-end efforts and their crowning successes. The following two tables describe the typical maker profile (Table 10) and how makers engage in learning in a unique way (Table 11).

Table 10: Maker Profile[10]

Solve unfamiliar problems and communicate well
Tell complicated stories quickly
Good at "pivoting," the willingness to rapidly switch approaches when a better option presents itself for a particular purpose
Persistence in the face of repeated setbacks
Inherently collaborative, routinely seeking the expertise and guidance of others

Table 11: How Makers Engage in Learning in a Unique Way[11]

Telling compelling stories
Learning from feedback
Finding collaborators
Engendering delight

Over and over again those in the Maker Movement talk about the same foundational principles they follow.[1213]

- It's the 'doing' that matters – taking action and turning ideas into something you can touch and share.
- Anything learned is free to anyone interested – it's about creating community and being part of the conversation of making.
- Don't worry about lack of skill or experience, give it a try – you will love it, learn something, accomplish something you didn't think you could and meet some great people.
- If at first you don't succeed, try, try again – don't expect to get it right the first time, enjoy the refining and practice that is iterative design.
- Make it beautiful – the joy of making is at least partially about how it looks.
- Find a guru – they might be younger than you or 40 years older, but they can help guide you on your journey; it's more fun discovering together.
- You learn what you want – it's a personal journey of discovery and you will know more after than when you began.

Although making things that will serve a purpose is and very useful, especially with kids, the real value comes from how it helps the maker make sense of the world. The integrative nature of making calls on a range of valuable skills like critical thinking and problem solving. The engagement in learning that makers display is a crucial element of

their behaviour. In what other voluntary circumstance to people of all ages show such a commitment to something that is entirely satisfying just for itself? There is no external gratification, only intrinsic motivation and that is an invaluable quality in a learner. Makers develop the 'I can' mentality. Stewart Brand, the publisher of the *Whole Earth Catalog, explains,*

> *"A hacker takes nothing as given, everything as worth creatively fiddling with, and the variety which proceeds from that enricheth the adaptivity, resilience, and delight of us all."*[14]

Technology

Where does technology play into the design-make process? The reader will have noticed the exclusion of technology from most of the content herein. That has been intentional, but also must be addressed. Virtually all maker and hacker spaces and programming are based around technology and new personal technology like 3D printers, laser cutters, CNC machines, and other digital fabricators. Technology, however, ends up coming between the learner and what is designed and made. Listen to Seymour Papert, MIT professor and proponent of constructionism.

> *"Where the computer's true power as an educational medium lies – in the ability to facilitate and extend children's awesome natural ability and drive to construct, hypothesize, explore, experiment, evaluate, draw conclusions - in short to learn – all by themselves."*[15]

Where traditional ‘analogue’ tools are used in the maker’s hands, assisting in representing the ideas that are to be explored and better understood through creation, computer-driven machines end up doing the actual work and the designer-maker is relegated to programmer. What is lost in this exchange? What advantages do more traditional maker implements and tools offer our children that technology does not? Certainly the intimacy of direct material contact is forsaken with the use of intermediary technology. There is no testing the smoothness of sanded wood with one’s incredibly sensitive fingers. Lost are the subtle variations and imperfections that come with creating with one’s hands, the most human of a creations characteristic. Missed is the feel of the clay as it squishes between one’s fingers or slides smoothly between poised hands as it spins on the potter’s wheel and is thinned or thickened with a measured touch.

Figure 26. Hand Shaping

Gone are the burning sparks and molten metal that come from welding or the satisfaction of the cutting flame as one's torch slowly works through quarter inch steel. The immediacy and personal investment in one's creation is forfeited for programming a machine and sitting back as it goes to work. What once was a time for focused and intimate interaction with a chosen medium has become an exercise in patience, as one's idea is rendered effortlessly from a series of ones and zeros. The human expression is there on a macro level but is lacking on the more micro and tactile interface. The sense of accomplishment and satisfaction of approaching mastery of a skill, the appreciation for the time invested in that effort, the deep pleasure that comes from reaching a flow state from the focused concentration and challenge so much a part of making, and the heart-breaking realization that a mis-measured piece must be remade, cementing the need to 'measure twice, cut once', all are opportunities for learning that have an immediacy seldom experienced elsewhere. An advantage that technology does provide is emancipating the maker from the necessity of having skilled hands and a feel for form and composition. These elements can be left to the computer and one can still be a maker. Neil Gershenfeld describes digital fabrication as a way to "finally fix that boundary between art and artisans".[16]

Technology is all around us and only will become more pervasive and integrated into our lives and minds. There is ample opportunity for children to learn and use technology, but so little time for them to discover and develop their manual competency, explore their ability to design and create with their own hands, come to understand materials

through intimate contact, and learn basic principles of science and nature through direct experience. Technology of all sorts is a powerful tool to be used to save time, to communicate clearly, to share, and to support and complement the process of designing and making. For example, CAD (computer aided design) provides an easily edited, sharable, and very accurate means of developing an idea into a rigorous model. Should it, however, completely replace hand sketching? If making is thinking with the hands, then the exploratory nature of initial hand sketches is an invaluable means of ideation and form development not to be substituted with key pressing and mouse clicks. Its hard to see the same value in a tablet passed between designers as the iconic napkin going back and forth as a shared sketch takes form and describes future intention with quick slashes of a pen.

In the studio technology can be a powerful complementary tool for presenting plans, sharing ideas, connecting, and recording activities and goals. Technology is also a great source for information, ideas, and inspiration. There is extensive use of technology in the maker and hacker world that include 3-D printers, laser cutters, CNC routers, robotics, drones, and a whole range of technologically based implements. There's no question that children will have more and more access to technological devices and implements and will need to develop a strong proficiency and comfort with them to support their learning and future career. The choice to keep these tech-based tools and machines separate for the most part from the studio space is to allow a more hands-on approach where learners must invest more of themselves into the ideas and projects that

they pursue – more so than they would if implements like digital fabricators were available to them. Learners begin with raw materials and create from nothing. A heightened sense of responsibility is needed to stay safe, but the blister that forms from repetitive sanding or filing has its own immediacy and lesson to give. It is, however, in-line with the studio philosophy to actively design and build certain digital tools from a kit or set of instructions. Through this method, learners have to follow the plans and be actively involved in selecting and ordering the correct components. This kind of design-make project, in which learners are making tools for use in the studio, provides opportunity for personal investment into the studio tool set and is consistent with the philosophy of generating tangible artefacts.

Personal tablets can be useful tools in the studio to create, review, and share models and to provide better understanding and develop a clear strategy or plan for execution, but not at the expense of the personal investment and expression that is more typical to analogue-style building. The power to create and quickly edit 3-D models and seamlessly manipulate their relative position, proportion, and orientation in virtual space should not be overlooked. The ability for technology to break down barriers of time and space, allowing communication and sharing of learning across great distances, supports extended community development. Besides gathering and storing information, possibly technologies most important offering is its ability to support connecting and communicating between other designer-makers. Not solely as a virtual community that lives entirely in cyberspace, but a first step to physically connect people in real life by

sharing ideas, helping to organize and manage scheduling, and bringing people together to pursue common goals. The ability to connect with others over the design-making process, across time and space, internationally and nationally, is basic to the maker movement mentality and has great value.

With the advent and explosive growth and proliferation of social media in all its varied forms, there accompanies a belief that, through these virtual means of sharing, we as a society – and on a global scale – are more connected and 'social' than ever before. Mark Zuckerberg, co-founder and CEO of Facebook and "the social media revolution's chief-rewiring officer"[17], strives to facilitate and automate ever-more sharing through his social operating system. Findings, however, indicate that, not only are we giving up the last shreds of our privacy by sharing even the smallest details of our lives, but we are spending increasingly less time with our neighbors cultivating community in the real world.[18] The more pressing fallout of this social reorganization is evidenced in massively declining levels of empathy. Analysis of 72 separate studies performed between 1979 and 2009 found that empathy had dropped by 40% in current American college students compared to those in the 80's and 90's.[19]

Sherry Turkle, director of MIT's Initiative on Technology and the Self, describes the loneliness of heavy social media users as "alone together" and has shown that constant networking is eroding parent-child relationships.[20] People are spending more time with technology and less time together, relying on virtual reality – an oxymoron if one ever

existed – rather than face-to-face interactions to maintain and cultivate relationships. Of concern to learning facilitators and learners is the claim that social networking is shortening our attention spans and fragmenting our brains. Creative thinking is at risk according to Nicholas Carr, author of *The Shallows: What the Internet Is Doing to Our Brains* as we become better multitaskers.[21] We spend less time in solitary, single-minded concentration typical of book reading – and making – and the majority of time juggling multiple screens on our computers or smart phones. It is a fallacy to believe that technology itself will provide answers to our most pressing, complex issues. Rather, it is the minds of those designing and building the next best thing that create the novelty and innovation that drives our efforts to find more sustainable practices. David Orr reminds us "no improvement in our gadgetry and technology alone is remotely adequate to our situation without a profound change in our mindset."[22]

Industry Disruption, Consumerism, Entrepreneurship

Makers certainly have the opportunity to disrupt industry. Their use and distribution of opensource hardware and general sharing of ideas, findings and feedback make advances faster, cheaper and more varied because they are fed by a diverse group of experts and experimenters. It is likely that if making continues to become more popular and mainstream within society it will cause a gradual shift from consumerism to creationism. Neil Gershenfeld, professor at MIT in the Center for Bits and Atoms, concludes that, "Making is also seen as a way to disrupt industry, create entrepreneurial opportunities and change consumerism for the better."[23] Consumers and creators will be

Figure 27. Building a hydraulic power unit according to opensource designs

one and the same. Consider the impact that has on design; the designer *is* the user. From the perspective of human-centric design this relationship is ideal. Designers will have to look only as far as their own needs to understand the desires and behaviours of users. The economics of product design and distribution will also be affected by the increased competition from small, local makers. As consumers demand more customization of their typically mass-produced products, makers can position themselves to be more nimble and able to meet these needs than larger members of industry. This growing maker industry is supported by online skill-teaching platforms like Instructables, Codeacademy or DIY.org for kids and even Youtube; maker- and hackerspaces providing the tangible necessities for prototyping and experimentation and face-to-face support with execution; funding available through crowdsourcing platforms like Kickstarter and and Indiegogo; and gain consumer access and distribution channels from

online marketplaces like Etsy.[24] Distribution is further enabled by falling costs of small-batch production overseas and by the growing number of intermediaries simplifying connections between makers and those producers.

The growing maker economy has much to offer larger, traditional producers to emulate and adopt. These passionate, talented experts, acting as a "broadly distributed innovation ecosystem"[25], can function as a source of research and development at a fraction of typical costs. Makers will develop and utilize new technologies and shape emerging trends. As a creative, innovative, receptive, agile and driven population, makers provide an excellent example for emulation in any industry. As a growing segment, makers, with their ability and tendency to 'hack', will create demand for products that can be altered and reimagined to one's needs, positioning them as active users to the benefit of both industry and other consumers. New and unexpected uses would be discovered and "products can be reconceived as platforms that engage and encourage maker-oriented consumers to tailor products to the needs of individual consumers."[26] Some have even gone as far as to label the maker movement a third industrial revolution, as makers use personal fabrication to disrupt industries, put pressure on patent protection, and possibly even liberate the workforce.[27] Chris Anderson, past editor of *Wired* magazine, thinks the maker movement could lead to "ever-accelerating entrepreneurship and innovation with ever-dropping barriers to entry."[28] Maybe those deeply invested in the virtual world are missing the ability to touch and share their creations in the physical world. Anderson observes, "Making

something that starts virtual but quickly becomes tactile and usable in the everyday world is satisfying in a way that pure pixels are not."[29] Mihaly Csikszentmihalyi says it best in his deep investigation, *Creativity*, "But consuming culture is never as rewarding as producing it."[30]

Agency and Empowerment

In the past, children grew up in a more analogue world spending little to no time with technology. Now, with the pervasiveness and power available through the use of computers, tablets, smartphones, and video games, technology is so integrated in our children's lives that it is hard to imagine life without it. Technology provides a multitude of advantages and support including educational programs; accurate and beautiful ways to share ideas and information; connecting across time and space; and time management systems. A risk, however, with so much technology integration in our daily routines is our passive interfacing. Because technology provides platforms and ways to connect that are so user friendly, we typically accept them as they are and put them to use. Possibly the greatest attribute of making and hacking is that we are no longer passive in out interaction, but become augmenters and producers. Technology does give one the power to customize, improve, and create consumables, but it takes what Agency by Design calls "maker empowerment" to see those opportunities, know how to make the desired augmentations, and confidence and drive to act. They describe maker empowerment as a disposition or "way of being in the world" in which one's reality is plastic and can be influenced by one's actions.[31] This sense of agency comes from one's

conviction that, with one's skills and drive, change can be made. David Sobel came to similar conclusions in reference to the importance of fort and den building in middle childhood.

> *"If we allow children to shape their own small worlds in childhood, then they will grow up knowing and feeling that they can participate in shaping the big world tomorrow."*[32]

In the same way, through designing and making we come to understand how things work, how they go together, and how to 'hack' them. In turn, through this understanding, we regain control over the things we buy and use; we feel a sense of agency that we can change them to fit our needs. Once we know how to change things already in existence, the next step is to make those things ourselves. With greater control and influence comes a great sense of empowerment.

Through maker empowerment we are able to remake ourselves. No longer passive consumers, but active designers, makers, and creators, we discover new passions through our newfound skills and confidence. What stimulates that sense of agency to evolve into taking action? Agency by Design has identified that the ability to make change is not enough to put one into action. It is, rather, a combination of three drivers. Action happens when all three are present: sensitivity, inclination, and capacity.[33] While inclination and capacity refer to one's motivation and appropriate skills respectively, sensitivity refers to noticing that so much of what we interact with is designed and made. Furthermore, Agency by Design found that sensitivity is usually the one lacking from the

empowerment triad because learners don't take the time to notice or miss the opportunity. How does one stimulate sensitivity? Their suggestion is to apply three practices; looking closely, noticing nuances like patterns, details and similarities or differences; exploring complexity, found in objects or systems; and finding opportunity.[34] By asking children to take notice of our made world, we can foster growth of their understanding of design and making. This new understanding, in turn, will not only inform their designs and what they make, but also cultivate their sense of empowerment and belief that they can have effect on the world in which they live. According to Ping Fu, founder and CEO of Geomagic, the accessibility of making, with the advent of 3D printers, scanners and other digital fabrication technology, will bring a resurgence of home creating,

> *"We have spent the last two decades capturing the real world, turning it into ones and zeros…. This will reverse in the next decade – physical will become the new frontier, and digital will seem a little bit boring."*[35]

Connecting and Sharing

Connecting with other makers and sharing in the making experience supports the formation of community. The growing popularity of Maker Faires[36] is evidence that the community values sharing and wants to do so in-person, not just virtually. David Gauntlett has been researching why people are so keen to share what they make. Makers are motivated to help others with their projects to support learning, to exchange and improve ideas, and to be recognized for their accomplishments.[37] Specifically for

children, recognition and seeing what others are doing are strong motivators to design and make. DIY.org is an online maker community providing a platform for young makers to share their projects, follow project instructions, and earn themed badges from their completed, posted projects. It is a safe, secure environment where children master skills and can receive feedback from other makers and support from staff as needed through tips, tricks and encouragement. Young makers are active in discussions and giving feedback, part of an online community, and become makers not just consumers – all of which are motivators that Gauntlett found through his research.[38] Through sharing, makers are actively engaging in the world around them and that supports social change.

Being creative and putting your creative artefacts out into the world provides makers an avenue to have impact on their surroundings, create a sense of agency for themselves and others, develop relationships, and gain knowledge through collaboration. Makers find mentors and role models that share their interests and have typically created innovative things, often by taking risks and living as outsiders. These role models provide support, offer bold examples, share expertise, and give feedback within a diverse community of like-minded but very different makers.[39]

Perseverance - Fail early, fail often

How do we build character in our children? What is character? In Paul Tough's book *How Children Succeed* he boils a larger list of 24 strengths down to seven (Table 12).

Table 12: Seven Character Strengths[40]

Grit
Self-control
Zest
Social intelligence
Gratitude
Optimism
Curiosity

Not a particularly surprising list, but I like that grit is at the top. Exciting that curiosity is on that list, as is zest – that I would compare to passion – and self-control, needed for focused and skilled action. However, grit is very different from the rest. Grit has elements of commitment, singular focus, and dedication to achieving that focus – like persistence with a specific purpose. How do children develop grit? It turns out that failing is very important to cultivating grit. Falling down or falling short of one's intended goal leads to much more learning than reaching that goal. It has a lot to do with reflection. When you fail, you spend more time reflecting on why and what happened than if you succeed. Experiential education, at its root, suggests that learning comes not from doing but reflecting on one's experiences. In design-making failure is reframed as iteration, a process of refinement through experience and growing understanding. If one is to learn by doing and doing is like thinking with one's hands, then one must expect to do over and over again. Think of it as manual contemplation. Too much consistent success and lack of failure puts one at risk in two ways; one, there is a lack of familiarity with failure that, in turn, disallows productive reflection and, two, a general lack of opportunity to deeply reflect on process and execution. Ken Robinson says "If you're not prepared to be wrong, you'll never come up with anything original."[41] According to Tough, "the best

way for a young person to build character is for him to attempt something where there is a real and serious possibility of failure."[42] In another article, a teacher contends that her happiest students are those that experience failure, are held responsible for their mistakes, and dared to be their best in spite of related difficulties.[43] The young innovators that Wagner profiles in *Creating Innovators* show similar trends; mentors encouraged them to be creative and imaginative, persevere, and learn from their failures. Many have adopted the attitude of "fail early and fail often" and even fail forward, fail fast, and fail cheaply.[44] Failing is inevitable and challenging, but what matters is how one reacts in these tough situations.

Trial and error is not valued in formal education and that puts it at odds with innovation. The opportunity to touch and manually explore a question or curiosity provides reactions and feedback completely absent from cognitive contemplation. The drive to explore and understand is better supported when failure is accepted as part of the learning journey. With the design-make process, the interest and motivation is in understanding and learning through experimentation and exploration, not in getting it perfect or 'right' the first time. It is a fun and playful process in which little manageable risks are taken that eventually lead to the grander goal. We need more learning that embraces failure as a vital and important part of the process – as it is in making and design thinking – and less value put on a single, perfect result.

Problem-solving skills

Design-making is really about developing creative problem-solving skills not becoming a skilled welder or potter. Learners come to understand process framing; what steps to take, when to take them, and how to do them best. By becoming proficient at collecting and considering all the information needed to teach oneself how to achieve one's goal, learners gain the confidence to handle any novel situation with a systematic approach. Integrating a variety of skills and perspectives allows makers to capitalize on their creative thinking skills, resourcefulness, and tendency to action as part of their initial contemplation. Designing and making provides very specific context, an important framing piece for solving problems. Through the exploration of materials, learners feed their curiosity and create new questions to explore. The more time and larger variety of problems one attempts to solve, the greater one's skill, efficiency, and comfort with the process. Csikszentmihalyi describes how creatives go about framing and considering problems.

> *"Creative people are constantly surprised. They don't assume that they understand what is happening around them, and they don't assume that anybody else does either. They question the obvious – not out of contrariness but because they see the shortcomings of accepted explanations for the rest of us do."*[45]

A massively important feature of the design-make process is how it makes thinking tangible and connects it to one's hands. Jonah Lehrer refers to ones' ability to identify patterns and problem-solve as fluid intelligence.[46] The studio environment that provides materials, space and encouragement for prototyping fosters a learner's ability to embody their ideas so they can be shared and refined, central to the collaborative

culture of design-make problem solving. Without a quick and accurate means of expressing ideas, co-creators stifle the momentum of ideation and the associated excitement and delight. Similarly, the pivoting nature of problem-solving – when an insight causes a redirection of purpose and focus – is managed best by quick expression of the new pathway. The variety of materials, tools, and communication media assures rapid realignment in the group's direction.

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Systems Literacy – a holistic perspective

Perspective is everything. When one needs to understand the details of an object or process, a focused investigation is best. However, to accurately understand something's significance – its behavior, effect on its surrounds and those surroundings on it, and how it is affected by the behavior of others – one needs to take a much wider view, a holistic or systems perspective. Many if not all of the complex problems we struggle with today are the result of human endeavors that failed to incorporate systems thinking in their initial design and execution. The development of that thinking and perspective is fundamental to skilled consideration of complex problems and subsequent solution iterations. It is much easier to learn something than it is to unlearn. If we facilitate systems thinking in our children at a young age, they will naturally think and act accordingly. Project-based learning necessitates a holistic view and fosters the supporting skills like deep assessment, planning and designing, prototyping and testing. Problems and interventions are framed in context and learners must understand relationships, patterns, networks and processes. David W. Orr makes this clear in his address to graduates of the School of Design at the University of Pennsylvania in 2007.

> *"…you must see yourselves as the designers, not just of buildings, landscapes, and objects, but of the systems in which these are components. That means that you must reckon with economic, political, and social aspects of design…"*[1]

Combining systems thinking with hands-on, experiential learning cultivates a balanced network of thinking and doing.

By structuring teaching in schools into separate disciplines, we provide a false and dangerous model of our world as divided and disconnected, when in reality, it is made up of systems nested within systems. We risk graduating students that don't know how to see the patterns and connections in life, care or know how to ask complex questions, and distinguish the significant from the insignificant.[2] Understanding the true causes and consequences of complex problems like international conflict, food security, and global warming is a first step to sense-making. According to Linda Booth Sweeney, systems educator and author, systems literacy combines conceptual knowledge – of principles and behaviors – and reasoning skills including seeing situations in greater context, from multiple perspectives, the path of complex interrelationships, internal system influences, behavioral changes over time, and recognizing recurring patterns.[3] The natural fallout of systems literacy is empathy. By searching for connections between themselves and all that they interact with, children no longer see themselves as outside but as an active, influencing part of the whole. Throughout their growth and development, children will see the interrelated nature of complex problems and not attribute them to a single cause. Booth Sweeney explains,

> *"Instead, it becomes a habit to look for recurring patterns that exist among a wide variety of systems, to seek out indicators of interrelated causes (knowing that very complex causes can leave deceptively simple tracks), and to anticipate how the functioning of a living system will change if a part of the process is changed."*[4]

Children appear to be natural systems thinkers, whose abilities are eroded by the compartmentalized nature of typical schooling. We can facilitate systems thinking by assisting them to see connections and networks, talk about change over time, recognize

repeating patterns, take varied perspectives, anticipate unintended consequences, and question one's own biases and preconceptions.

Biomimicry

The forms and structures seen in nature have been emulated since man began making. After thousands and often millions of years, these are the designs that have evolved to perfection and stood the test of time. They are based on simple but eloquent fundamentals like repeating shapes and patterns at varying scale – fractals. Biomimicry, the practice of emulating models and strategies found in nature (biomimicry), allows us to take advantage of the efficiency, strength and beauty found in the natural world. Janine Benyus explains that, "Biomimicry is basically taking a design challenge and then finding an ecosystem that's already solved that challenge, and literally trying to emulate what you learn."[5] Some of the most impressive and beautiful designs and structures in the built world take their inspiration from nature. Suspension bridges share the same structural principles as spiders' webs; the leading edges of vehicles are pointed like the beak of a bird; modern stadia roofs, like membranes inspired by cell wall structure, are in constant tension; and domed roofs are much lighter and require less reinforcement than other spanning structures because of their multi-dimensional curvature, reminiscent of a sea shell. Nature not only informs the way we design and make, but also the way we organize and interact. In the past evolution was seen as a competitive process, but, from the systems view, we now understand that the strategies successful in evolution are cooperation, networking and co-evolution.[6] Organizations like Biomimicry 3.8 provide

training and resources to support the incorporation of nature's principles and essential elements into design and learning. The programs being offered value discovery and understanding the relationships and networks that form connections, as does the design-make process.

Permaculture, Sustainability, Resilience

A system is "one indivisible dynamic whole whose parts are essentially interrelated and can be understood only as patterns"[7] and the networks they form. The systems view is focused on the whole not the parts, relationships not objects, patterns not contents and context rather than just the object. The systems view is grounded in ecology and nature where "every organism is an integrated whole" and the parts within are other systems nested within that whole. The principles or fundamental precepts of life state that one part's waste is another part's food so matter cycles throughout life, energy comes from

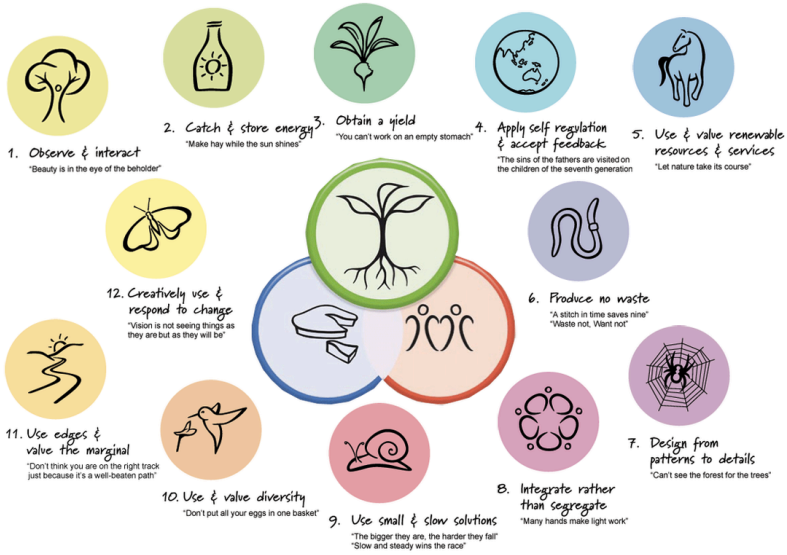

Figure 28. Permaculture Principles
(http://www.soilandsoul.org.uk/index.php/permaculture/permaculture-principles)

the sun and resilience comes from diversity.[8] The principles of permaculture are similar and also grounded in a systems view (Figure 28).

How do we facilitate children learning a systems view of the world? What experiences or learning are necessary to introduce this way of perceiving and what kind of learning environment is needed? Getting people involved in a tangible, experiential process like growing food has proven to be an excellent method.[9] The garden teaches food cycles – planting, growing, harvesting, composting, and recycling – that are embedded in larger cycles like the water cycle and cycles of the seasons. I see the design-make process offering a similar and equally effective metaphor for teaching a systems view. Though the more recent focus on STEM learning is extremely valuable to the future economic terrain, the incorporation of the arts and design to make STEAM has particular value

Table 13: Permaculture Principles and how they apply to Design-Making

Permaculture Principle	How they apply to Design-Making
Observe and interact	Deep research and information gathering; observe users in their environment
Catch and store energy	Solar, wind, micro-hydro, passive-solar
Obtain a yield	The functional object itself; learning
Apply self-regulation and accept feedback	Modify, adjust with use; input from various experts including end users
Use and value renewable resources and services	Reclaimed, repurposed materials with least embodied energy
Produce no waste	Rework, reimagine, upcycle, recycle
Design from patterns to details	Holistic plan to implementation; design constraints dictate execution
Integrate rather than segregate	Attributes, features compliment and support each other
Use small and slow solutions	Iterate based on feedback; use available materials
Use and value diversity	Input from and fabricated by diverse group
Use edges and value the marginal	Creative solutions to problems; small iterations
Creatively use and respond to change	Modular design; iterative versions to manage changes over time

from a systems learning perspective. According to Capra "there's hardly anything more effective than art for developing and defining a child's natural ability to recognize and express patterns."[10] In fact, he explains, artists like da Vinci and Goethe made their most important contributions when scientific theory was dominated by pattern studies. Below I have showed the principles of permaculture in a design-make context (Table 13).

Designing and making foster sustainable thinking and practice because they change the relationship people have with materials, consumable items, culture (including consumer culture), and one's sense of agency. By becoming an active producer, not just a passive consumer, makers gain new understanding of materials, process and economics. This knowledge, in turn, informs their designs and fuels their belief that industry can evolve into a cyclical, waste-free system. Design at its roots is a vehicle for change and betterment not something purely aesthetic. Through the design-making process, people creatively engage in the world around them, sharing their ideas and the manifestation of those ideas. Using nature as the model, design must promote new concepts of production grounded in the principles of sustainability.

At the Center for Ecoliteracy, experiential and systems learning is fostered through hands-on activities with food gardens and composting. The learning process follows a sequence of initial unstructured exploration, followed by concept formation or question forming and, finally, more exploration informed by those questions or concept application.

> *"Experiential learning is vital to schooling for sustainability. Only through direct contact with the natural world will students develop an in-depth understanding of fundamental ecological principles. By working with others to solve real-world problems, they also develop skills at the heart of sustainable living."*[11]

This is the same process that learners follow taking initial ideas through a design stage of ideation, evaluation, and testing. Though learners need to encompass sustainability concepts in their designing and making, the next level of consideration is resilience. Sustainability refers to the ability to maintain something over time, whereas, resilience is adaptability or active change that comes from anticipating influencing factors. Resiliency requires a system to be designed - from the beginning - to adapt with emergent properties before a disturbance forces the need. As in nature, mutations in thinking and practice lead to new ideas that must be filtered for viability. When we include redundancies in our designs we increase the possibility of success through process options and optimization. Diversity in members of a collaborative group ensures varied perspectives and practices. Finally, sensitivity to environmental changes – both within a group or concept and the surrounding world in which it functions – allows feedback to drive the systems inherent flexibility. As the designers and makers of an ever changing and increasingly complex and unstable future, our children must learn to be sensitive to and design for variability and do so through multidisciplinary and integrative explorations.

Entrepreneurship

As described earlier, designing and making are driving new businesses, the creation of new markets and new relationships, as consumers become producers. Products do not

make businesses, however, people do. The sense of agency, of being able to have an impact or make a difference, that makers develop as they take their ideas from something nebulous and conceptual to a tangible result is invaluable. This ability to take action is a fundamental characteristic of an entrepreneur, as is a willingness to invent on the fly instead of getting stuck in arduous and time consuming planning. This attitude reflects the bottom-up style of makers, as they tinker and explore ideas that lead to a focused action.[12] The playful process of testing boundaries and trying-out new ideas through improvising, adapting and iterating as part of designing and making supports the creativity, agility and efficiency that entrepreneurship demands. Yvon Chouinard, climber, outdoorsman, environmentalist, owner of Patagonia, co-founder of 1% for the Planet, explains the necessity of innovation and progressive thinking in his inspiring book *Let My People Go Surfing*.

> *"Only on the fringes of an ecosystem, those outer rings, do evolution and adaptation occur at a furious pace; the inner center of the system is where the entrenched, non-adapting species die off, doomed to failure by maintaining the status quo."*[13]

Entrepreneurs are resourceful and nimble, making use of what is available and adjusting their plan as they apply feedback they receive from their actions. Like designing and making, starting your own business requires a certain fearlessness while managing insecurity and the scary nature of novelty and risk. Driven by dissatisfaction with what is available and recognizing opportunities for improvement or to create entirely new markets, entrepreneurs take on these challenges and must often design and make to

represent their new ideas. Their nimble minds allow them to embrace change and have flexible intentions that adjust to perceived needs. Commonly seen as outsiders, both entrepreneurs and makers are driven to work harder by other's doubt. Chouinard says it best again.

> *"If you want to understand the entrepreneur, study the juvenile delinquent. The delinquent is saying with his actions, 'This sucks. I'm going to do my own thing."*[14]

Being an entrepreneur one must see opportunity and create ideas accordingly, but most importantly be prone to action. Learning to be an entrepreneur requires practical training and excellent mentorship. Canadian programs like The Next Big Thing[15] aim to reward creative and promising ideas with practical opportunities and training for budding entrepreneurs by connecting them with mentors and partners like Emily Carr University of Art + Design. The fear is that great ideas will never find their way to market because the journey is so challenging to navigate. Programs that offer hands-on experiences, mentorship, and process-based learning develop the necessary attitudes and skills to support young minds persevere and not give up on their dreams.

Product-based Learning

Craig Morrison, founder and teacher at TDSB alternative school program Oasis Skateboard Factory, has a unique perspective on problem-based learning. At the Skateboard Factory, students learn to run a cooperative design business. Not only do they design, make, paint, market, and sell their own custom skateboards, but they also

receive tenders from agencies to collaborate on a variety of design projects. Product-based learning is a more entrepreneurial version of problem-based learning where what is created is given market value and sold. In this way, students develop and apply real-world entrepreneurial skills like how to sell themselves and their products, meet deadlines, create professional work, learn from working professionals and get paid for the work they do. The process typically begins with a brief from agency that has approached Craig to ask for their help and involvement creating something. Craig and his students create their own interpretation, in which they make sense of the brief as a group and decide what they want to expand it into and change. After this collaborative ideation, they return to the client with a professional pitch, describing what they want to do, how they are going to do it, and what they can offer. It's then up to the client to consider the pitch and decide how to proceed.

Most of the students that end up in this program are labeled at-risk and would rather be out in the world rather than trying to fit into the strictly defines definition of a student. In the Skateboard Factory they are learning the necessary skills, not within the confines of the classroom, but out in the world, interacting with professionals and producing that of which they and others can be proud. With the need and desire to create professional-quality results come the accompanying responsibilities like deadlines, presentations, skilled communication, and accepting and integrating feedback. The professionals they work with are very supportive and excited to help provide an authentic professional learning experience for the students. Many of them remember how much they disliked

and struggled in school and appreciate the practical, real-life opportunity these students are getting. Students are learning to harness media channels to promote their skills and exceptional work. Another huge benefit to the program is that parents feel a previously absent sense of pride for their children through their success and the artifacts they create. This empowerment comes from multiple sources including the high quality, professional work students produce, that is typically better than that force-fed by incessant advertising. By being producers, students are no longer passive consumers and gain the insight and understanding to critically assess consumerism. In Craig's words,

> *"People see that we're teaching marketing, we're making products, and they say, "Oh, that's about [reinforcing] consumerism." I say we're doing the opposite, we're having these kids become the producers, not the consumers, and we're critiquing consumerism."*[16]

The social change comes when students see themselves past the program, entering the real world as young entrepreneurs with the experience and skills to succeed.

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Design-Making as a Strategic Framework

In this proposed learning framework we will see how the learning components described in this report can be combined and leveraged to create a holistic, hands-on, learner-driven, studio-based program (Figure 29).

It has been my experience – and the experience of many others – that going to school was something very different than the purpose for which it is intended. My love of learning has never faltered, but it was also never fed in the classroom. The multiple reasons for this seemingly unlikely truth have been explored herein. The key to learning is engagement. We engage in learning when we seek to satisfy our curiosity through exploration, inquiry, questioning, and eventual discovery. The search for one answer leads to the search for others and, in this way, learning is self-reinforcing, cyclical and recursive. Engagement comes from people seeking their own questions and following their passions, given the freedom to explore what interests them. In fact, our focus can be so intense that the search for knowledge becomes pleasurable for itself and we attain a state of 'flow', where skill and challenge are at the perfect balance to create optimal performance. Learning is not work; it is play. Playfulness affords a positive mood that broadens our perception and encourages new and unique combinations of experiences that, in turn, supports problem solving and contributes to creativity. When we seek understanding our drive is intrinsic and our discoveries are a product of perseverance and tenacious exploration. Failure is just part of the iterative process, providing feedback and helping to keep a trajectory towards eventual understanding. Our efforts activate all

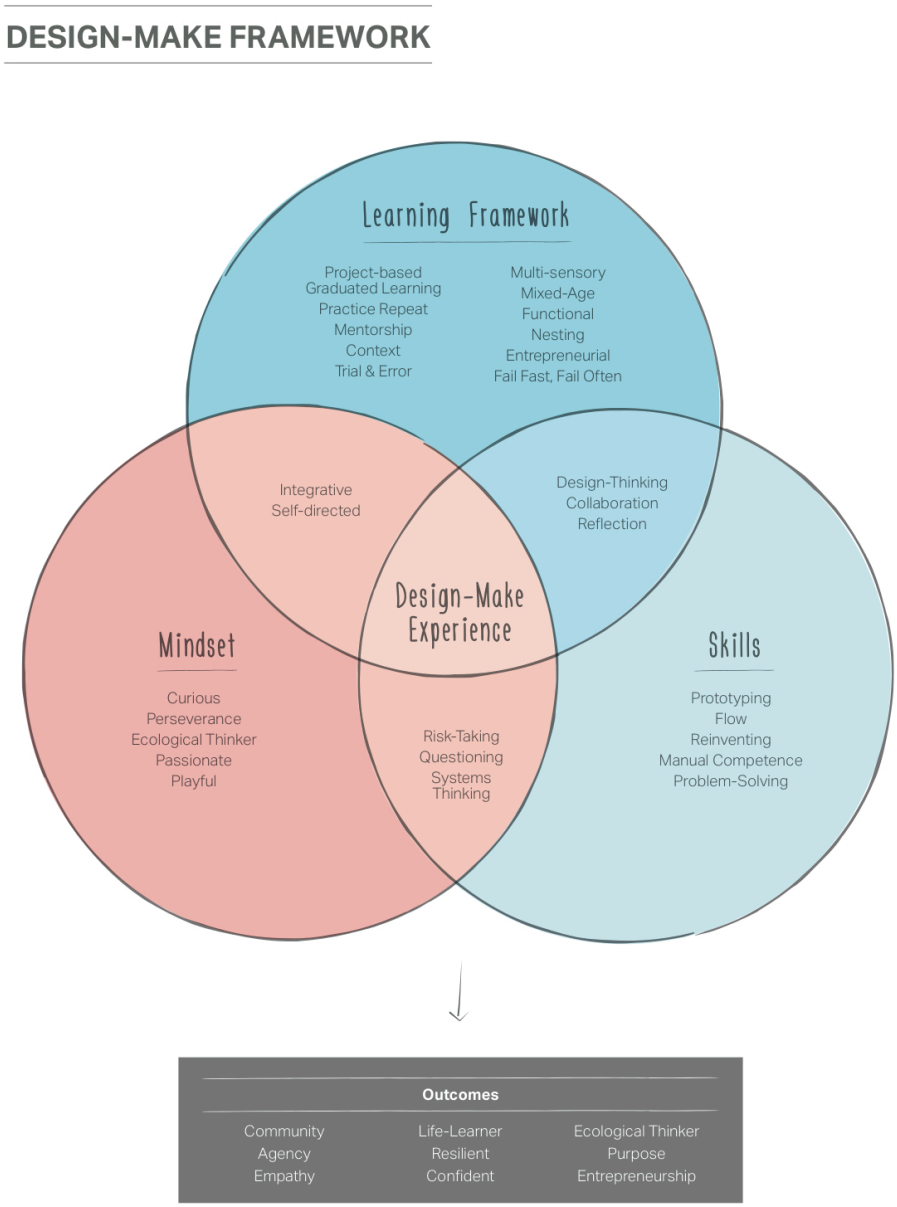

Figure 29. Design-Make Framework

our senses. We might listen to a conversation or public speaker, watch a video or go into the world to observe first-hand, taste incredible foods or the acrid burning of pollution, or touch a fine sculpture or the course roughness of a mountain climbing pitch.

Everyone is a designer with the power to have influence over the things they use and do with the right sensitivity, inclination, and capacity. We have only to look to the natural world for inspiration and role modeling. What better mentor than a system that has been evolving, with all its intertwined and interdependent relationships, patterns, and networks nested within and around each other, for billions of years. Finding our way back into the balanced interdependence that surrounds us, that we have tried for so long to control and put to our advantage, might be the greatest design challenge of all. From the beginning of humanity we have used our abilities to share ideas and knowledge, to create culture, and constantly build on that which came before us. We are natural collaborators, taking simple and concrete understanding and expanding it to complex and abstract concepts through the exchange of knowledge and information. We take risks and understand the opportunity that novelty provides. In an effort to be ever more capable and efficient we have extended our brains and hands with the creation of tools. Designing and making are some of our most fundamental drives and skills that, through culture and exchange, are constantly evolving. Though, in our more recent past, with increased urbanization, specialization, and an ever-quickening pace to life, many of us have removed ourselves from the pleasure of creating.

I present a framework that integrates what we know about ideal learning environments and mindsets with the opportunity to deign and make useful, functional things that serve a purpose and have value. Through project-based explorations that come from the minds of those exploring, learners will follow their own interests and passions, playfully creating things of beauty and utility. These explorations connect the brain and hands, thinking and doing, with the process of gaining knowledge, skills, perspective and experience. These exercises in praxis engage the hands, hearts and minds of learners as they learn through context-specific projects that meet the needs of their community – both locally and at large – after discerning the opportunities and needs that exist. Instead of prescribed learning, this design-make framework allows learning to evolve from the rich experiences that learners design for themselves. They are supported by a diverse group of thoughtful, caring and skilled mentors that guide them by finding a tenuous balance between helping and further questioning. Outcomes and learning are put on display both formally and informally for everyone to share, for learners to see the effects of their efforts and feel the associated pride. Facilitators guide learners to explore their social responsibilities and consider what cultural contribution they want to make with their creations. It is an opportunity to tell a great story. Functional, useful, and valued outcomes are necessary but they must also speak to their place in the world and their potential impact.

The following is a six-part design-make framework to be implemented for children and others wanting to learn from inquiry and exploration in a supportive, facilitated studio environment.

Design-Make Framework

1. Service

From the beginning we engage with the broader context of what design learning can offer and how it can intervene. All programming will include an element of service and how design can provide solutions and answers for challenges in the community. Exploring questions like how can we apply the learning from a specific project to understand and better support my community at large? Design should provide the most benefit to the most people at all times. Learning and outcomes have real-life context and impact.

2. Learning

Programming will be presented to stimulate questions and investigations to satisfy curiosity in a playful, exploratory atmosphere. Ideas are multidisciplinary by nature and promote integrative learning. Inquiry will be self-directed from a problem, idea, or topic that is generated by the learners. Programming is presented so learners grow their understanding in a graduated manner by sequentially moving from the simple and concrete towards greater complexity and abstraction. Perseverance is developed as learners follow their passions and interests.

The process is facilitated by talented, caring, experienced guides that come from all parts of the surrounding community, helping learners decide where their ideas fit within the greater fabric of culture and community. They find the perfect balance between help and redirection through new questions and suggested avenues of exploration.

Programming is offered in mixed-age groups providing learners the opportunity to work with peers of different ages, abilities, skill levels, perspectives, and backgrounds. Older and/or more experienced learners can provide leadership and guidance to other learners with less experience and or skill. Throughout this learning journey comfort with novelty and risk is developed, building confidence and independence.

3. Design

All projects and investigations are based in producing purposeful, functional interventions that have positive impact on the community. Project forming is the process of deciding on a question or inquiry to explore and could involve sketching and describing what it is one's trying to achieve and the process by which they would achieve that goal. Learners are encouraged to make use of all their senses – listening, seeing, touching – throughout the design process. Design thinking methods are introduced through examples and demonstrations like a human-centric and empathetic perspective. Learners are encouraged to quickly move to the iterative process of

prototyping to better understand their interpretations. Evaluation is performed individually and in groups to collect all the needed feedback before each iteration.

There will be opportunity to benefit from various trips and retreats to other locations, either within the city, on the outskirts or to a specific multi-day alternative location. These outings will build skills, provide new, unique experiences, or be part of a larger project for a different location. These will include camping, site-specific building projects, conservation activities, and skill development like rock climbing and other outdoor activities. The studio is a rich and multi-media environment, but programming is not bound to one location. Learning occurs in so many places and ways.

4. Make

It is by making that learners are able to connect their minds with their hands. Creating includes reinventing, reimagining, combining or hybridizing, and upcycling, but it also will include deconstruction and breaking things to benefit from their design and construction. A sense of empowerment and agency comes with experience and growing confidence with tools and materials. Prototyping is an opportunity to deepen understanding through representing one's ideas – often in multiple ways and mediums.

Learners must build manual competence, an understanding of what material, tool, or machine to consider when designing and fabricating and the knowledge and skills needed to use them properly. That knowledge comes only after becoming familiar with

the various options. As the need presents itself, demonstrations of certain skills that could be useful in exploration are given at regular intervals.

5. Systems

Within the outline and planning process for each project, students must decide how they're going to build and create and how the project will affect their lives in a positive way. They also must consider its impact on the world at large from a sustainability point of view, from an eventual waste perspective, and for its impact on markets or the value that it might bring to them in the future. This is part of an entrepreneurial focus that will be designed into most projects. This holistic or systems perspective focuses on the whole not the parts, relationships not objects, patterns not contents and the context in which it will exist. Learners will design for resilience, adaptability to change and see how their projects are nested within larger efforts and smaller ideas are nested within their projects.

6. Sharing

Collaboration is a key component of programming so learners can support each other, develop social knowledge and skills, and effectively give and receive feedback, both formally and informally. These feedback sessions are an opportunity for learners to get to know other people’s project and mentors, to ask questions about them, and to have them stimulate new ideas within their current or future projects. At the end of a program, projects are presented by leaners to parents and anyone else interested with an

explanation and visual storytelling about what they did, why they did it, how they did it, and what they learned. Certain faires will include a market element for learners to promote and sell what they have made. Presentations are also an opportunity to celebrate learner's differences, recognize a specific contribution or something exceptional, and to share respect for each other's accomplishments.

Daily journal entries allow active learners to track their development, insights, challenges, accomplishments, and evolution as design-makers and the impact that the process has on them. Other than written entries, learners will add sketches, take photographs, record videos, take notes, and make audio recordings. Journals can be kept in a physical form or something virtual, for example, a blog kept online. Programming will include tapping local community members to provide a diverse and expert synergy of facilitators, mentors, and motivators. These community members will bring their expertise and experience as special guests or regular contributors.

The Design-Make Studio

Studio projects and investigations begin with exploration into a problem or need in one's community or in the world at large. Purpose and function are fundamental, as is consideration of social and environmental impact. We determine what design can offer and how it can intervene.

The design-make studio is a multi-media space offering wood, metal, ceramic, fabric, electronics, and other means of exploration. It is an integrative space with a wide range of tools and machinery available. Learners use the studio in a self-directed manner, following their curiosity, interests, and passions as they playfully explore and make discoveries. Over-arching topics are used to prompt inquiry and guide exploration. The iterative processes of trial and error and prototyping are encouraged where leaners can quickly represent their ideas and understanding with tangible objects they have designed and made. Failure is seen as part of the learning process and a way to inform eventual solutions or interventions. Open studio time is available to allow leaners time to investigate and make independently with facilitator guidance and support. Explorations in open studio promote a sense of ownership. Learners come to see the studio as a place that is not just for designing and making, but a place for self-expression, freedom and stepping out of typical self-expectations and those of others. The design-make studio is a place to challenge routine and convention, break things, and find refuge. The goal is to have learners – all leaners – know that the studio is theirs and that it reflects them.

There are no teachers in the design-make studio, but rather facilitators that support and guide learners through their explorations and inquiries. There is also ample opportunity for peer-to-peer learning with the mixed-age nature of studio structure. Initial orientation, safety, and skills are provided by more experienced learners as a way for them to cement their new knowledge and understanding through demonstration.

Facilitators are talented, caring, supportive experts that find the perfect balance between hands-on and hands-off support. Learner's questions are typically managed through demonstrations and redirecting them to answer leading questions that will further their understanding. The design-make studio provides a return to apprenticeship and mentorship where learners develop knowledge and understanding through working alongside or emulating those more skilled and experienced then themselves. Furthermore, opportunities are arranged for learners to go out into the real world and shadow and observe experts and professionals working with their skills in their environment. Learning is given authentic context and connected directly with real world examples and experiences. The studio also maintains extensive library of resources and inspirations in the form of books, exercises, videos, web-links, and more.

Collaboration is encouraged and often required for investigations. Learners have a chance to explore both individually and in changing groups. The studio is structured to combine learners across a range of ages, skills, and experience providing them with the opportunity to both nurture and be nurtured. Collaboration is presented as a way to optimize resources and benefit from a range of perspectives and knowledge. Developing collaborative skills is pertinent to future success in life, vocation, and positive sociability and reflects real-world context. By placing the design-make studio within the local community, there is opportunity to both serve and support that community and benefit from its members as contributing experts, presenters, and facilitators.

Programming is provided in a graduated format that increases in complexity and abstraction with learner's knowledge, skills, and experience. Through earlier explorations, learners develop comfort with novelty and risk, systems literacy and the understanding that all design is ecological design. Deeper levels of programming for experienced and advanced learners are offered and include more systemic projects like designing and building shelters, exploring tents and fabrics in tension, or deepening material literacy through investigating flexibility in wood, metal, or plastic. Facilitators might present ideas and projects that can be innovated and disrupted with learner's own ideas. Individual learners or groups of leaners create their own course of investigation and intervention, but follow a similar progression to other learners. This co-creative format promotes and allows structured group feedback sessions and support.

All learners keep a journal of their design-make journey so they can track their development, insights, challenges, accomplishments, and evolution as design-makers and the impact that the process has on them. Other than written entries, learners will add sketches, take photographs, record videos, take notes, and make audio recordings. Journals can be kept in a physical form or something virtual, for example, a blog kept online. Recordings and reflections can be available for others to see and share and possibly comment on, depending on the learner's choice and intention. Feedback and reflection are important components of the learning process that support deepening of knowledge and understanding and the collaborative and supportive design-make

process. Upon completion of a project or investigation, learners prepare presentations to share their learning journey with peers, facilitators, parents and family, and other interested members of the community. This is a chance to cement learning, inspire further investigation, share new understanding and discoveries, contribute to the studio environment, create artifacts to represent learning, and foster a trusting and functional relationship with the local community and its members.

The design-make studio promotes a very process-oriented system of discovery and efforts are taken to allow for emergence. With praxis, practice or the process informs the ends; the means change the objective and so the ends are dependent on that process. Facilitation is provided in a provocative way, instead of being directive. Someone younger rather than highly experienced or older might guide learners, because that younger person has some perspective or 'way' that could positively inform or illuminate one's thinking and understanding. Kurti, Kurti and Fleming suggest guiding criteria for the design-make studio in the following list.[1]

- Invite curiosity – motivates independent learning, gaining knowledge
- Inspire wonder – leads to deeply probing questions
- Encourage playfulness – learn without knowing when at play
- Celebrate unique solutions – foster creativity, inspiration, and innovation
- Ok to fail – part of iterative process; provides pertinent feedback
- Break things – taking apart; nothing is sacred
- Collaboration – share knowledge, help each other, and team work

Process Sequence

The design-make process is described in the following sequence.

1. Exploration – divergent scan of purposeful projects

    - What problem to solve
    - Environment in which made object will live – social, utility
    - Constraints on object – human and site derived
    - Case studies – examples to inform, improve upon, disrupt
2. Project framing
    - Design constraints and objectives
    - Human-centric design
    - Optimizing multi-functionality
3. Materials selection
    - How to choose
    - What to consider
4. Execution
    - Skill development
    - Measuring, cutting, connections, joinery, adhesives
    - Finishing
    - Presentation
5. Reflection and Feedback

Principles and Fundamentals

Certain basic understandings are needed to allow for well-informed designing and making. Much of this will be learned from self-directed exploration, but where it is lacking demonstrations and exercises will be presented to support that knowledge. The following are the basic principles and fundamental understanding that will contribute to thoughtful, functional, practical designs.

Scale and Proportion
- Map making, life drawing, perspective drawing.
- Building scale models.

Structure
- Foundations, balance, forces acting (tension, compression, shear).
- Connections – joints, adhesives.

Simple Machines
- How they work, when to use them.
- Mechanical advantage, different versions.

Material Selection
- Elasticity, density, strength, flexibility, workability, impact
- Cost, texture, colour, insulation, environmental impact

Energy conservation

- Potential, kinetic, elastic.
- Renewable energy sources - solar, wind, and hydro.

Ecology

- Systems
- Biomimicry, permiculture.

Skill Development and Project Examples

Specific skill development is cultivated through repetition and practice, with the ultimate goal of skill mastery. These will include hard skills like measuring, cutting, sanding, and finishing; attention skills through sensory games that will encourage one to pay close attention; sensory skills like tuning of one's auditory, visual, and tactile skills through appropriate exercises and games; design thinking skills involving critical thinking, problem solving, developing multiple perspectives, and forming a human centric focus; form explorations and execution skills including structure, composition, balance, proportion, scale, hand-eye coordination, material selection, and dexterity through interdisciplinary projects like understanding musical instruments; scientific concept exploration like simple machines, energy conservation, thermodynamics, and basic ecology principles; and entrepreneurial skills like understanding product development, marketing, self-promotion, and economic impacts.

Workshops will be offered under over-arching topics where learners can decide how and what they want to explore based on their motivations and interests. Explorations might include but are not limited to topics like musical instruments – electric, acoustic, percussion, and woodwind; sound amplifiers; vehicles and propulsion including engines,

motors, and robotics; electricity and electrical circuits intensives; general and life drawing and sketching; CAD drawing and representation modeling; shelter design and building; alternative energy; food growing, cooking, and storing; clothing from fabrics, textiles, weaving, and tapestry; survival skills, wilderness travel, and camping; papermaking, printmaking and bookbinding; woodworking including joints and jigs; welding; simple weapons like catapults, trebuchets, canons, bows, spears, slingshots, boomerangs, and rockets; flying machines like kites, balloons, airplanes, and projectiles.

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A Better Learning Framework

The following table (Table 14) illustrates how the proposed design-make framework addresses challenges in formal education and overcomes those shortfalls with its structure and process.

Table 14: A Better Learning Framework

Formal Education Challenges	Design-Make Intervention
Creativity	
Teaching inhibits curiosity	Learning is facilitated rather than taught. Facilitators must find a delicate balance between support and staying hands-off.
Lack of freedom	Free choice is given to choose what part of an idea or topic one wants to explore. Learning is self-directed and driven by one's passions and interests.
Lack of play	Designing and making are playful by nature and so is the studio environment. Extensive opportunity to satisfy one's drive to practice and create.
Single correct answer	There are no answers only proposed interventions. Reflection and feedback from implementation dictate the next iteration. Failure is expected and valuable.
Questioning limited	The basis of the design-make process is questioning and inquiry. Possible interventions are arrived at through explorations informed by deep research.
Lack of choice	
Inflexible scheduling	Learners decide what and how to explore. Investigation is not divided by subject or any other arbitrary means and is integrative and interdisciplinary.
No chance to stay in 'flow'	Flow is encouraged because leaners create their own clear goals, can deeply focus, and find balance between skill and challenge.
Not democratic	Free choice and learner input is fundamental to the studio environment.
Labeled ADHD	The studio environment is active and collaborative. Learners are encouraged to create rather than listen and watch. Once a learner has command of a skill, they will be called on to demonstrate and lead.

Formal Education Challenges	Design-Make Intervention
No sense of agency	Function and purpose are fundamental to all projects, as is the service interventions will provide to the community.
One size	
Not individualized learning	Learning is entirely self-directed and self-motivated, driven by one's interests.
Pace dictated by group	There is opportunity to work both individually and collaboratively. Learners dictate how quickly or slowly they move.
Cannot pursue one's own interests	Ideas and projects come from the learners; there is no top-down structure and learners choose their explorations.
Age segregation	Studio time is not separated by age. Mixed-age groups are encouraged and elicit opportunities for leadership, nurturing, and peer-to-peer learning.
Competition	
Testing and ranking	Learners are not marked or ranked. They receive formal and informal feedback from facilitators and peers. Projects culminate in studio presentations and open house.
Collaboration is cheating	Supporting, helping, and seeking collaboration with others is encouraged. Everything and everyone in the studio is seen as a resource to be tapped.
Must lookout for oneself	Learners are part of the studio network; everyone's actions affect everyone else. Projects are designed to serve the studio and community at large..
Anxiety inhibits learning	The studio is a playful, exploratory, self-directed space designed to be a supportive, facilitated, mixed-age environment.

Conclusions

We know that creativity and innovation are going to be key skills for our children to have in the future. We also know that our formal education system is lagging in providing the learning and the learning environment that will not just support but stimulate creativity and innovation.

We know that play is important because it allows people to grow and develop socially, intellectually and physically. Through play, children learn to make friends, conquer fears, problem solve independently and learn agency, the ability to have influence on your world. Through exploration and discoveries children experience surprise and wonder and awe. When they find the optimal balance of challenge to their skill level they reach a 'Flow' state where doing becomes its own reward.

We know that making something is an exercise in understanding it better. Through the process of taking an idea and tuning into something tangible that lives in the real world, learners are trying out these ideas – prototyping. Once this idea is brought to life physically, it can be considered better than if it was just described, drawn, or rendered – by the learner that created it or anybody else that so desires. This process of idea representation is the impetus for collaboration – asking for and receiving feedback, integrating that feedback along with emergent learning that comes from making, and sharing the iterative process with others.

We know that children need to develop perseverance and the ability to problem solve and think critically. These are skills that are developed through project-based learning, exploring and investigating things of interest, creating one's own understanding, trying things out, failing, and trying again by taking a fresh perspective or adding new knowledge.

We know supportive parents will help them to develop these skills by providing them with appropriate opportunities and encouraging them to read, to get outside and explore, and to follow their passions. Those passions can evolve into one's purpose with the guidance and example of caring mentors who have grown their own purpose from earlier passions.

We know strong collaborative skills are imperative to working in a group. One must take a leadership role or step back and be led, at times find compromise and show empathy, see varied perspectives and be understanding to other's needs, listen as well as talk, understand how a situation or experience will impact others, and relate all of that gathered information to the process of problem framing and ultimately finding a prospective solution.

We know that a cooperative rather than a competitive learning environment tends to bring out the best in us. Competition creates anxiety and anxiety makes learning difficult and can eventually lead to depression. By testing and ranking our children we are

teaching them to see their command of specific, dictated knowledge in comparison with their peers and collaboration as cheating. We unfairly label children that struggle to sit still in class and focus for extended periods of time with attention deficit hyperactivity disorder (ADHD). The system that we are asking them to follow does not speak to there natural instincts. Children don't want to sit and be told what to do. They want to move and explore with all their senses, to make their own discoveries, to form their own questions and strive to find answers to them, to follow their curiosity, and to reach the goals that they set for themselves through the process of exploration and discovery.

We know that we must take a holistic or systems perspective to properly understand and fix the issues inherent to the complex or 'wicked' problems that we face. We must change our focus from the parts to the whole, from objects to relationships, from quantity to quality, from structure to process, and from contents to patterns. Specialization has become standard in education and professionalism with the wealth of information available, but creativity and innovation typically come from crossing over domain boundaries. The key to new thinking and fresh perspectives is combining knowledge and experience from multiple disciplines.

We know through huge amounts of research and studies that have gathered compelling evidence and produced convincing results that indicate what we already know in our hearts and primordial minds. Our children need a place where they will be nurtured and supported in their development, growth, and learning, driven by their own curiosity,

hunger for understanding, search for answers, and biological need to make sense of the world they are to inherit. It is a safe place free from the coercive methods of our formal education system and rich with the tools and materials needed to discover that which they seek.

We know that our children need to make representations of what they understand so that understanding can evolve with each iterative version. The best environment for these explorations is one where they can get dirty and use all their senses; where they can take the ideas in their brains and exploit the already heavily connected pathway between the hands and the brain; where they can follow their passions about their interests and develop deep understanding, knowledge, first-hand experience, and further questions; where their curiosity can guide them in new ways, to new discoveries, by new means, using a multitude of materials and tools; where they can design and make things that are functional and add to their lives or other's; where they are supported by caring and extraordinary mentors and facilitators; where their natural instincts are honored and respected; and where they can get down to serious play.

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Appendix A - Case Studies and Researched Precedents

Examining a range of inspiring programs and products helps in choosing and designing a methodology that is most appropriate to the design-make framework. Many of the examples and case studies that were examined for this research are focused on teaching engineering or architecture students the practical application of their theory and concepts. Although one might think that an education in applied design like engineering and architecture would naturally have a practical hands-on component, this is seldom the case, though that seems to be changing. As we have discussed, connecting concept to fabrication has immense value with respect to conceptual understanding, knowledge retention, developing collaborative skills and improving communication and feedback between concept creators and fabricators. The following examples are considered according to how learning and collaboration are facilitated and what methods are employed.

STEM to STEAM

There has been in a push lately to focus on STEM – Science, Technology, Engineering, Math - subjects at schools and other complimentary learning environments. Innovation and economic prosperity are strongly associated with school graduates having skills and knowledge in these subjects. The Rhode Island School of Design is pushing the movement to include Art + Design, making it STEAM. They believe that Art + Design will transform the 21st century as technology transformed the last.[1] There is disagreement about whether typical STEM students lack the creativity that comes with art and design education or if adding art and design is even necessary to developing these students. By

including art and design, we value the creativity needed for innovative thinking and Nature as a fundamental inspiration for sound, human design. Studying drawing, sculpture, fashion, or music adds experience with imaginative work, following one's curiosity, fine motor skill development, decision-making skills, and perseverance. Art and design students learn mental visualization skills that are atypical techniques used in STEM subjects. Students in creative study have unique expectations as well, including accountability for tangible, made deliverables that will be critiqued, collaborative skills for group projects, seeing from multiple perspectives (conducive to learning empathy), and having the confidence to put their work on display for others to see and judge. There is concern that art and design will be presented and valued through the same pedagogical lens as other subjects, but the hands-on, exploratory, expressive, and emergent nature of the learning process is different.[2] Perhaps the value of art and design must be judged using a different perspective because how one learns is often more important than what one learns. We should look to Papert, Dewey, and Montessori for pedagogical reference rather than trying to fit art, design, and making into an inappropriate and limiting mold. This is a challenge to typical pedagogy and may not be acceptable in a system that is founded on different grounds. However, looking at some of the supporting statistics, students who study arts benefit at least within the formal education system.

> *"On average, students who study the arts for 4 years in high school score 98 points higher on the SATs compared to those who study the same for half a year or less" and that "Students who took up music appreciation scored 61 points higher on the verbal section and 42 points higher on the math section."*[3]

Perhaps the most significant opportunity STEAM has to offer learners is the nature of how one learns. Through hands-on, investigative, self-directed learning, STEAM students – and design-makers – find engagement with learning that is lacking in typical classroom studies. What could be better than learning science, technology, engineering, and math subjects through discovery and manipulation in real-world context using over arching concepts?

Sloyd

I first became aware of Educational Sloyd, or just Sloyd , while researching for this project. Doug Stowe is a woodworker and teacher in Arkansas who writes a blog called Wisdom of the Hands. He is an eloquent and insightful writer and teaches at Clear Spring School in Eureka Springs, Arkansas. The school is unique in that it promotes "a lifelong love of learning through a hands on and hearts engaged educational environment".[4] Sloyd came out of the Naas System of manual training, created in Sweden by Otto Salamon and reads like a manual for exceptional development of young people. It is a system of education founded on many of the same principles and methods I am combining and describing here. Sloyd endeavors to teach self-reliance, independence, habits of order, exactness, attention, industry, and perseverance to overcome difficulties through a variety of woodworking projects that move from the simple to the complex and from concrete concepts to more abstract.[5] Salamon recognized that children should not have too much of one thing at a time, that they are happiest when their projects are done all by themselves, that those projects should be

'real' projects in that they serve their maker as something functional and that becomes the property of the learner. The teacher was to 'superintend' the learners and never do the work for his students, teaching them to trust and use their judgment because their projects are their responsibility not the teacher's. And, as facilitator, to create an environment that promotes true and not baseless interest in their projects, enjoyable and valuable for their own sake, not for any awards or other external recognition to be received.

When Sloyd can to America in the late 1800's, B.B. Hoffman set about writing *The Sloyd System of Woodworking* as a guide for teachers to set-up and run Educational Sloyd programs. He describes the value of Sloyd as:

> *"necessary, from a psychological point of view, to try to give the child the ability to express objects by means of delineation and construction, and thus to add to the power of mere verbal description…. It is more natural for the [child] to be able to draw a sphere, or to make one out of wood or clay, than to understand the geometrical definition of the sphere"*[6]

The value of Sloyd also lay in its organization as a system. Learners advanced their skill and understanding as they built upon their experience with previous projects. Educational Sloyd differed from other manual training because it wasn't vocation, but rather about mind, body and character development. Hoffman saw Sloyd as formal education – imparting knowledge and developing one's mind – and outlined three objectives.[7]

1. To give a general dexterity to the hand – to train the hand as the obedient servant of the brain.
2. To develop the mental faculties, and at the same time impart positive useful information.
3. To make it a means for intensifying intuitions, thereby giving a clearer insight into the nature of things.

Like Papert, Hoffman and Salamon saw a need for a practical, tangible side of learning to mirror and provide personal meaning to theory and the exercises of the brain. Hoffman understood the necessary duality of learning and the power of combining theory and practice. He wrote "Man is not only born to think, but also to do. He is a creative animal; he can and must embody his ideas in form."[8] Educational Sloyd strove to spark curiosity, deep interest and new ideas by combining elements of art and science through construction and illustration.

Doug Stowe makes a very astute observation about making artifacts in a short documentary made about him and his work.[9] While walking through the forest he explains that he sees similarities in trees and people in that they are both "a narrative form"; we both tell our stories through the form we take and how that form changes over time and with experience. In making things out of wood, we, as the maker, add to that narrative and change it by choosing how to present that which is the character and properties of the wood. We tell a story with our material choices, with the forms we create and in turn have our story changed by the experience of making. It is a conversation, an exchange of knowledge, that leaves both different from before they came together.

Brightworks

Brightworks is an alternative private school in the San Francisco area that believes learning happens everywhere.[10] They strive to bridge the gap between the learning that happens at home, school and in the world. Learning is accomplished by a very impressive method in which learners move through three 'arcs' per school year. Each arc has a topic that works best when it functions as a seed rather than an umbrella. For example, arc topics have been photograph, mirror and air. Each arc (Figure 30) begins with a phase of Exploration in which questions like what is it? or why is it important? are explored. The next phase is Expression. Students create anything from a structure or art object to an experiment, a research project, or a performance. The final phase, Exposition, requires students explain their work to their community and themselves through written and oral presentations, question sessions, and demonstrations. This three-stage process of investigation leading to understanding is very inspiring because it

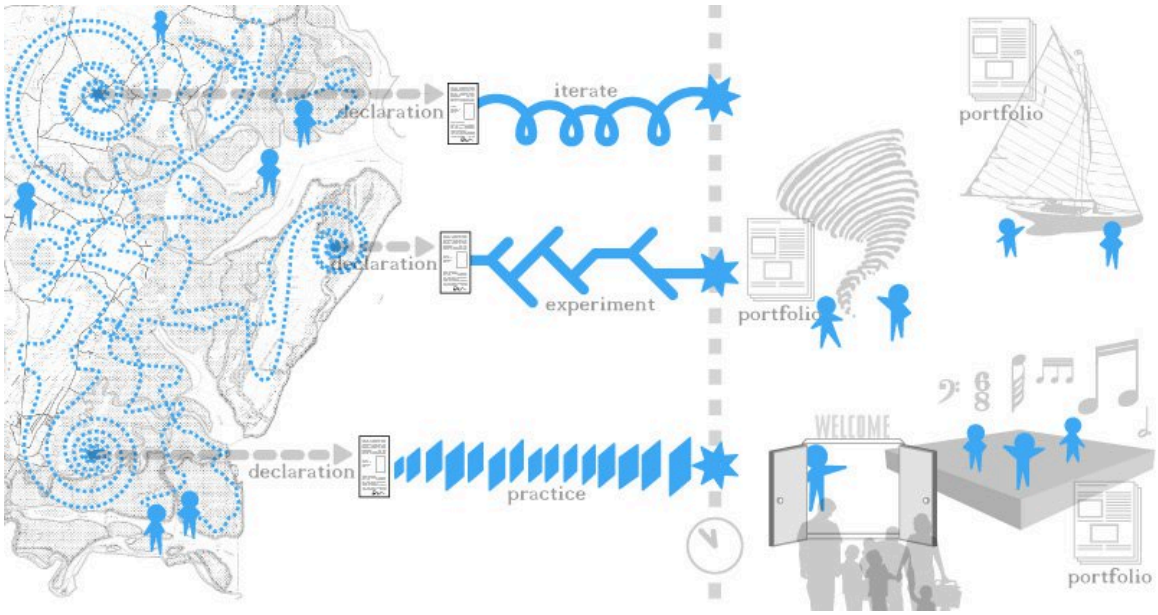

Figure 30. Brightworks Arc (http://sfbrightworks.org/wp-content/uploads/2012/08/arc.jpg)

allows learners to follow their own curiosity and interests. Learning happens in a self-directed, multidisciplinary way where learners are co-creating with the school facilitators that they call "Collaborators". Children are organized into Bands, made up of 7-10 students with at least a 3-year age span among them. Collaborators embody enthusiasm and curiosity as travel together with their band members on a learning journey of self-discovery, exploration, fun, and adventure.

Beam Camp

Beam Camp provides an outdoor, camp setting where campers learn "creative problem-solving through working with their hands and actively working with others."[11] Beam Guides make a life and living from pursuits that require invention, design, planning and production. They are artists, architects, engineers, craftspeople, teachers, designers, chefs, and musicians. Beam Camp uses 7 words to inform all their activities: invent, guide, balance, link, sustain, delight, and reflect. Throughout the summer campers build a unique installation designed by a different "distinguished artist, architect or general big thinker" every summer. This Project Master leads the campers and staff through the process of creating the project.

Real Architecture Workshop (RAW)

Real Architecture Workshop (RAW) is a collection of intensive design/build workshops presenting meaningful design challenges rooted in a rich, local, natural and cultural context.[12] Paul Neseth's mission is to change the way young architects think about their

work and the world. Like Craig Morrison of the Oasis Skateboard Factory, uses product-based learning to facilitate learning around process and methodology, but also how to value one's work and create products that are professional and subject to the usual demands of the real world. With real clients and real sites, built environments are mindfully designed and built for specific human needs. Students experience an intense process of learning and doing that engages their body, mind and spirit. Not unlike Samual Mockbee, the founder of Auburn State's Rural Studio, Neseth believes that architects have the responsibility to make positive change through an education rich in experiential learning and accessible to all people. Social responsibility and cultural impact are big topics for Neseth, as they are for Morrison, and have inspired similar structural elements for the design-make framework. The ability to actually build things is regarded as a significant increase to an architect's value to employees and clients. There is a significant systems perspective that informs their process. Through immersive on-site designing and building, students experience firsthand the impact of their decisions and are challenged to create architecture that is efficient, creative and sustainable. All design is ecological design. The following excerpt from the RAW blog illustrates the intensively collaborative nature of living on the work site.

> *"It's amazing how a group of people work together when they eat/sleep/design and build all with such close proximity. There's not just a building getting built here. I also do so love being able to design on the fly, walking 50' to the site to confirm dimensions, test out the best feeling for a ceiling, and where the best views need to be captured and framed. All architecture should be built this way – living, breathing, and sleeping on the site."*[13]

When another student is asked about his experience working and living in the outdoors, he describes a change in his thinking in which the project is considered 'in totality'. The elements of that totality included water conservation, solar power and local building materials harvested from the property. This new systems view contributed to his perceived sense of place and appropriateness in the landscape.

The real value of design/build workshops, like design-make exercises, comes from the integrated experience. Learning through a hands-on experience or about systems thinking or the value of collaboration or design thinking concepts and practices or how to best take a concept to fabrication, individually is not particularly unique or powerful. However, learning about all these elements together and exploring the connections and synergies that emerge as the experience progresses is a very unique and powerful experience. Because a design-make project like this is quite a journey to embark upon, the process of participating in the program will be recorded and documented and shared. Reflection and journal keeping are integral parts of how active learners foster awareness of the process they are following and the impact that process is having on them.

Howtoons

Howtoon's mission is to provide engaging content that teaches 8-15 year-olds how to build things, combining instructions with storytelling.[14] Their graphic books are based in science and engineering education and use art and imagination to inspire creativity. This

small group of an artist, an engineer, and a toy maker are engaging children and teens in designing and making through compelling stories and fun, accessible functional projects. Instructions for the projects are integrated into the story and can be made using things typically found around the house or available locally. The instructions are the beginning, but readers are encouraged to take their builds to the next level through exploration and using creative problem solving. Howtoons inspires good values in their readers like recycling, getting outside, collaborating, and having fun. Topics covered include cooking, building, music, being active, using tools, and playing at being a kid. The creators of Howtoons want to inspire readers to explore their world and understand it better, overcome their fears of the unknown, see failure as part of the journey to success, and playfully investigate how things work through homemade projects like

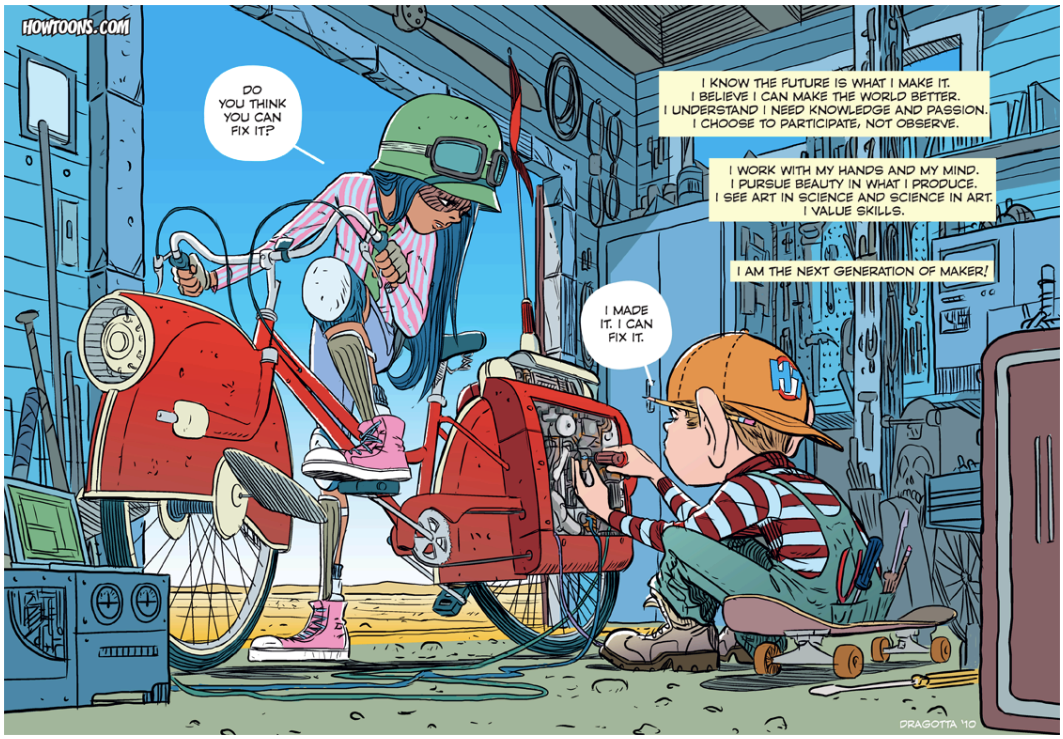

Figure 31. Howtoons - Next Generation of Maker
(http://www.howtoons.com/wp-content/uploads/2010/06/makeit.png)

bottle rockets, marshmallow shooters, simple but clever flying machines, robotics, music makers, and more. The combination of being able to use a lot of household or recycled items for the building projects and incorporating the instructions in a compelling story make Howtoons a very engaging, fun, creative, and inspiring way to get kids to explore and gain understanding about science and engineering. Their books are a great addition to any design-maker's library.

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[1] The Rhode Island School of Design. (2015). STEM to STEAM. Retrieved from http://stemtosteam.org/

[2] Rudzitis, T. (2015, Mar. 1). *STEAM, STEM, and Making.* [Web log post]. Retrieved from http://fablearn.stanford.edu/fellows/blog/steam-stem-and-making

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[7] Hoffman 19-21.

[8] Hoffman 20.

[9] Gentry. G. (2014). *Doug Stowe - Wisdom of the Hands by Gabe Gentry*. Retrieved from https://www.youtube.com/watch?v=L_lVlywDNo8

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[11] Beam Camp. (2015). *Beam camp. For making and collaboration*. Retrieved May 22, 2014 from http://www.beamcamp.com

[12] Real Architecture Workshop. (2015). Retrieved May 22, 2015 from http://www.rawdesignbuild.com

[13] Real Architecture Workshop. (2011, April 5). *Trust. Teamwork. A shared experience.* [Web post log]. Retrieved from http://rawdesignbuild.com/trust-teamwork-a-shared-experience/

[14] Dragotta, N., Griffith, S., Dragotta, I., Bonsen, J. (2015). *Howtoons: The worlds greatest d.i.y. comic website*. Retrieved from http://www.howtoons.com

Appendix B - Perspective on ADHD

Approximately 12% of Canadian school children aged 7-14 are diagnosed with ADHD, 59% of those diagnosed are taking medication as a treatment, and just seven years before, significantly less of those diagnosed were medicated at 43%.[1,2] Typical medication for ADHD is a stimulant, amphetamines, whose side effects include loss of appetite, listlessness, stomach pain, sleep disruption and many more. Spontaneity is immediately reduced, children report feeling 'weird' and parents have described their kids as "not as playful, funny, or happy".[3] Diagnosis and subsequent drug treatment occur because children have trouble sitting still in school for extended periods of time, more specifically, trouble concentrating, paying attention, staying organized, and remembering details. More accurately, they were restless being forced to do something boring, tedious and repetitive.

From another perspective, people with ADHD are often better at focusing than others in situations where there is personal meaning to an activity and they are deeply engaged.[4] The area in their brains that is difficult to suppress is actually the same area that is conducive to flow and engagement in complex activities like music. Higher than average creative thinking and accomplishment is more likely in people with characteristics typically associated with ADHD than those without those characteristics.[5] Furthermore, an extensive review of literature from 1961-2003 helped create a list of 22 recurring personality traits in creative people. Positive traits like independent, comfortable with risk, curious, funny, artistic, and energetic are also associated with those diagnosed with

ADHD.[6] In consideration of these findings, it appears that children labeled as ADHD may be guilty of not conforming to the coercive educational model in which they must survive, but command often exceptional qualities that will be advantageous to them as professionals in their near future. Not surprisingly, ADHD-labeled children should thrive in PBL approaches, where engagement is high, there is an authentic and relevant context that allows for deep personal meaning, and learners are actively involved in generating and developing the driving question.

What are the implications if these kinds of minds are stifled and 'dumbed-down' through the use of psychoactive drugs during formative developmental stages? Here is another example of how creativity is being systematically 'schooled' out of our children.

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[1] Gazaille 1.
[2] Gray 56.
[3] Gray 13.
[4] Kaufman, S. B. (2014, Oct. 21). The creative gifts of ADHD. Scientific American. [Web log post]. Retrieved from http://blogs.scientificamerican.com/beautiful-minds/the-creative-gifts-of-adhd/
[5] Walla, A. (2014, Nov. 25). *The Creative Gifts Of ADHD: Disorder Or Gift? Real Or Fictitious?* Collective Evolution. Retrieved from http://www.collective-evolution.com/2014/11/25/the-creative-gifts-of-adhd-disorder-or-gift-real-or-fictitious/
[6] Walla 1.

Appendix C - Maker Space

Because designing and making is a physical act, where one creates tangible versions of ideas that exist in the world, it is critical that the space in which they are made supports that process. Learners need gifted facilitators and the intrinsic qualities for design-making like motivation and curiosity, but they also need the tools, materials and space in which to explore and express their intentions. David Kelley of IDEO speaks about the necessary modularity of learning space in *Make Space*.

> *"Space is something to think of as an instrument for innovation and collaboration. It's not an initial, given condition, something that should be accepted as is."*[1]

At times learners will work in groups, taking advantage of the stimulating, energetic, and sharing nature of collaboration. Often, however, they will be in search of something personal, investigating something perplexing and unknown individually, hopefully attaining a flow state and disappearing into deep focus and concentration. Both kinds of discovery must be available in the design-make studio. The space should provide equal opportunity for facilitators and assistants to support each group and redirect them in the exploration. The mentor-apprentice relationship is very important to maintaining drive and direction throughout the design-make process. Space must be flexible, able to move easily between group and individual, neat and clean, organized and chaotic, quiet and boisterous, divided and open.

When the opportunity presents itself, it is best to have the users design and build the space they will use. Personal investment of time, physical effort, and thinking in a project creates a feeling of ownership that is otherwise absent. Though learners might not be able design and build the overall space, mobile and modular walls, furniture, workbenches, and machines provide opportunities for group bonding, personalizing space, and maximizing functionality. The goal is to create a space that can be easily adjusted and reorganized according to group size, stage of exploration, and the specific space requirements at that time.

Space for making should support interdisciplinary explorations involving a range of tools, materials, and other supplies. Learners should feel inspired by the space. Materials and tools should be easily accessible, but also visible to provoke their use and influence on ideation and method of execution. Everything should be labeled and parts made visible by using transparent containers, drawers or other storage. Learners need to move efficiently between stages of investigation, especially when prototyping. Representations of ideas need to be explored quickly and either elaborated and refined or discarded for better suited versions. The design-make environment should cultivate a love of learning and enthusiasm for building knowledge and understanding. Every effort should be made to grow learner's confidence by encouraging questioning and subsequent inquiry in a collaborative atmosphere.

[1] Doorley & Witthoft 5.

Appendix D - Making Maker Makers

Finding people with the right training, skills, attitude, and approach to facilitate design-make explorations is a challenge. Robert Frost described his perspective on guiding learning when he said, "I am not a teacher, but an awakener." While Albert Einstein explained, "I never teach my pupils. I only attempt to provide the conditions in which they can learn." Past training and experience can be both helpful and a hindrance; teaching is not an appropriate style of facilitation, but typically those with desire to support learning are teachers. A way to overcome that difficulty is to grow one's own facilitators. In *Creating Innovators* Wagner describes two teacher-training programs that support learning based on similar principles to designing and making.[1] High Tech High (HTH) is a network of innovative independent high schools in San Diego that has developed their own comprehensive teacher-training program. Upper Valley Educators Institute (UVEI) has been providing alternative teacher certification for over 45 years. Both programs share a similar training philosophy that emphasizes development of a student-teacher relationship based on collaboration and co-creation; obliges trainees to show knowledge through portfolios, projects, and exhibitions of mastery; requires trainees to spend most of their time with teacher mentors in a school setting; use of video to assist trainee assessment and skill development; promotes teacher-teacher collaborative skills; creates interdisciplinary courses; develops essential skills and perspectives for innovation and actively engaging learners in pursuing their passions. For example, at HTH trainees must complete an "action research" project, a study of a particular learning problem that was identified in the classroom context. UVEI requires

teachers to demonstrate mastery of 10 essential competencies through oral presentations and within an e-portfolio. Both programs are competency-based, meaning one must demonstrate proficiency for certification.

Finland has established an innovative and very effective educational system.[2] What is unique to their system is that they have defined a standard for excellent teaching and developed a thinking-based curriculum[3]. Finish teachers are also required to work collaboratively and are given time at school to do so, allowing them to constantly improve and receive feedback on their lessons. The key here is to apply the same principles and methods to facilitation and creating facilitators as is applied to designing and making – deep questioning and inquiry; self-directed, passion-driven learning; playfulness; integrative, multi-sensory, project-based exploration; trial and error with iteration and comfort with failure; mentorship and collaboration; and followed by reflection and feedback with reference to context. Because the type of leadership necessary to promote this supportive but not instructive type of learning, it is best to grow new facilitators through a system of apprenticeship. Experienced facilitators can guide new facilitators along their own journey by role modeling appropriate behaviors, perspectives and actions.

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[1] Wagner 191-195.
[2] Hancock, L. (2011, Sept.). *Why are Finland's schools successful?* Smithsonian Magazine. Retrieved from http://www.smithsonianmag.com/innovation/why-are-finlands-schools-successful-49859555/?all).&no-ist
[3] Sirota, D. (2011, July 18). How Finland became an education leader. Salon. Retrieved from http://www.salon.com/2011/07/18/tony_wagner_finland/

Appendix E - Next Steps

Business Model Generation

The next step with this framework is to create a business plan to guide its application. Using the Business Model Canvas I plan to map out the implementation of the program described here. With this document and the canvas, I can approach lending institutions to seek funding and support. An abridged, more visual version of this MRP will be used to inform potential learners or their parents or guardians and spark interest and excitement for this unique program.

Virtual Guides

Not everyone will be able to come to the studio to learn and play. It is exciting to imagine multiple studios available to serve people in their communities and creating a studio framework that would support establishing studios wherever they are needed. But as a way to reach less accessible people, I imagine creating virtual guides that prompt and encourage the design-make system of inquiry. Learners follow a combination of a visual guide that inspires over-arching topic exploration and a system of inquiry and investigation with stepping away to ideate, research, explore, question, design, or make something, depending on their progression. Through the use of posing questions and asking learners to come up with their own questions and ideas, the guide will promote independent designing and making. Learners will benefit from online groups of other independent designer-makers by obtaining and providing support, feedback and even collaborating virtually with this community. The guides will be used as idea generating

templates that promote a process rather than specific things to do or instructions to follow. Learners will apply their own interests and ideas to a system of inquiry, design and making.

Project Nesting

Nesting projects within each other is an original way to create dependent interaction between groups towards a shared goal, using ecosystems as a model. Project nesting involves small groups of learners working towards a specific objective that is a piece of a larger whole. That whole, however, is then a piece of a larger whole that nests the first group of connected projects within its project system. So there is a kind of ecosystem of designing and making. Each level of the project includes exchanging group members so, as the project moves along, each group benefits from the experience of learners in other groups and different combinations of people. The learning that took place in one group travels to the next through the sharing of group members, systematically redistributing people with new and varied interpretations and perspectives. The ability of experienced design-makers to anticipate needs and tap available resources makes them very valuable members. In this way we are helping to nurture an ecosystem of inquiry that is specific to the designer-maker mentality of exploration and ideation.

Studio Market

As an extension of the studio, a market will be created to provide services to people in the local community. Community members can tap the power of the design-make

process through a system of connecting needs with projects. Instead of learners bringing their solutions and interventions to the community, the community can bring their problems to learners. This relationship would promote connecting children and other learners with providing services to their local community, mixed-age interactions, and teaching their skills – like knowledge of and comfort with technology – to people in need. The opportunity to connect young with old around service, utility, and support is an effective way to manage our aging population. Through the application of design-making and networks of community services from a central creation hub, young learners will help older, more dependent community members with their problems, challenges, and needs while learning to value, market, and sell they products and services.

Mobile Lab

By creating a mobile, travelling design-make lab, this type of learning framework is made available to a wider range of leaners and the program is brought to them. The mobile lab will be a trailer that can be pulled behind an appropriate vehicle and parked in any location. Power for the lab will be provided by an alternative energy source like solar and wind, providing complete independence from outside sources. This self-contained lab will model the type of thinking the design-make framework promotes and will make its integrated energy system visible to learners. The mobile lab also offers an opportunity to market, share, and make visible the purposeful, designed communal input that the design-make studio strives to achieve.

If I could relate all the positive and helpful pieces that can spin-off of this kind of endeavor it would not be true to its nature. By putting it in motion, this program will grow and flourish, leading to many positive iterations and an associated supporting ecosystem. Because the principals and values are grounded in such inquiry-based philosophy, it is by design resilient and searching without seeking control or ownership. Rather utility, function, and betterment in a local context are valued by seeking optimal thinking and doing through designing and making.

Videos

How do we learn?
Design/Make/Play - NYSCI
https://vimeo.com/62218638

Challenges with the current formal education model
XQ: Rethink
https://www.youtube.com/watch?v=JGBkqkorwxw

Learning happens everywhere, all the time.
Howtoons.com
https://www.youtube.com/watch?v=_pVBJKgVZXQ
30 years of collaboration towards empowering children to be creative thinkers, LEGO Foundation
https://vimeo.com/143858250

Promoting creativity
Drive: The surprising truth about what motivates us
https://www.youtube.com/watch?v=u6XAPnuFjJc&feature=youtu.be
Cultures of Creativity, nurturing creative mindsets, LEGO Foundation
https://vimeo.com/105388899

Play
Tim Brown – Tales of Creativity and Play
http://www.ted.com/talks/tim_brown_on_creativity_and_play?language=en

Flow
What is Flow?
https://vimeo.com/121105961
Flow, the secret to happiness
https://www.ted.com/talks/mihaly_csikszentmihalyi_on_flow

Lifelong Kindergarten
Ken Robinson – Do Schools Kill Creativity?
http://www.ted.com/talks/ken_robinson_says_schools_kill_creativity?language=en

Innovation
Tony Wagner – "What matters most is what you can do with what you know", LEGO Foundation
https://vimeo.com/91830309
Arvind Gupta – Turning Trash into Toys for Learning
http://www.ted.com/talks/arvind_gupta_turning_trash_into_toys_for_learning

Design Competence
The Innovator
https://vimeo.com/59379393

Ecological Design
Through The Lens with Rob Machado - Taka's Treehouse
https://vimeo.com/69138889

Design Thinking
Design & Thinking trailer
https://vimeo.com/41075888

Design-Based Learning
XQ Canvas
https://www.youtube.com/watch?v=gPczNgUpK8g

Making is part of thinking
Caine's Arcade
https://www.youtube.com/watch?v=faIFNkdq96U&feature=youtu.be

Maker Movement
MAKER Trailer
https://vimeo.com/98296767

Problem-solving skills
Power of Making
https://vimeo.com/29842222

Agency and Empowerment
Agency by Design: Empowering Young People to Shape their Worlds
https://vimeo.com/136525046

Connecting and Sharing
Through The Lens with Rob Machado – Jay Nelson
https://vimeo.com/65100156

Perseverance - Fail early, fail often
THE GAP by Ira Glass
https://vimeo.com/85040589

Biomimicry
Theo Jansen :: Kinetic Sculptures
https://vimeo.com/48572867

Permaculture, Sustainability, Resilience
Reuben Margolin
http://www.ted.com/talks/reuben_margolin_sculpting_waves_in_wood_and_time?language=en

Product-based Learning
Learning the Physics of Skateboarding Engages Kids in Science
https://www.youtube.com/watch?v=6bu_9sI7QTI&feature=youtu.be

Design-Make Framework
Studio/Designing/Making
https://vimeo.com/55094310

Conclusions
Futrue of Learning, LEGO Foundation
https://vimeo.com/72336539
The Ox – Blue Ox School
https://vimeo.com/78788086

STEM to STEAM
Lasers, Fire, Robots: The Best of STEAM Carnival 2014
https://www.youtube.com/watch?v=GH8A8touKrw&feature=youtu.be&list=PLvzOwE5lWqhQ6oGndUhK5wV5MjT5htJMl

Sloyd
Sätergläntan Institute of Crafts
https://vimeo.com/132375731
Doug Stowe - Wisdom of the Hands by Gabe Gentry
https://www.youtube.com/watch?v=L_lVlywDNo8

Perspective on ADHD
[ADD]vantage
https://vimeo.com/32950273

Maker Spaces
Making Design Lab
https://vimeo.com/99190296

Case Studies
If You Build It - Trailer
https://vimeo.com/79902240
Hello Wood 2014 - Play with Balance
https://vimeo.com/103134681