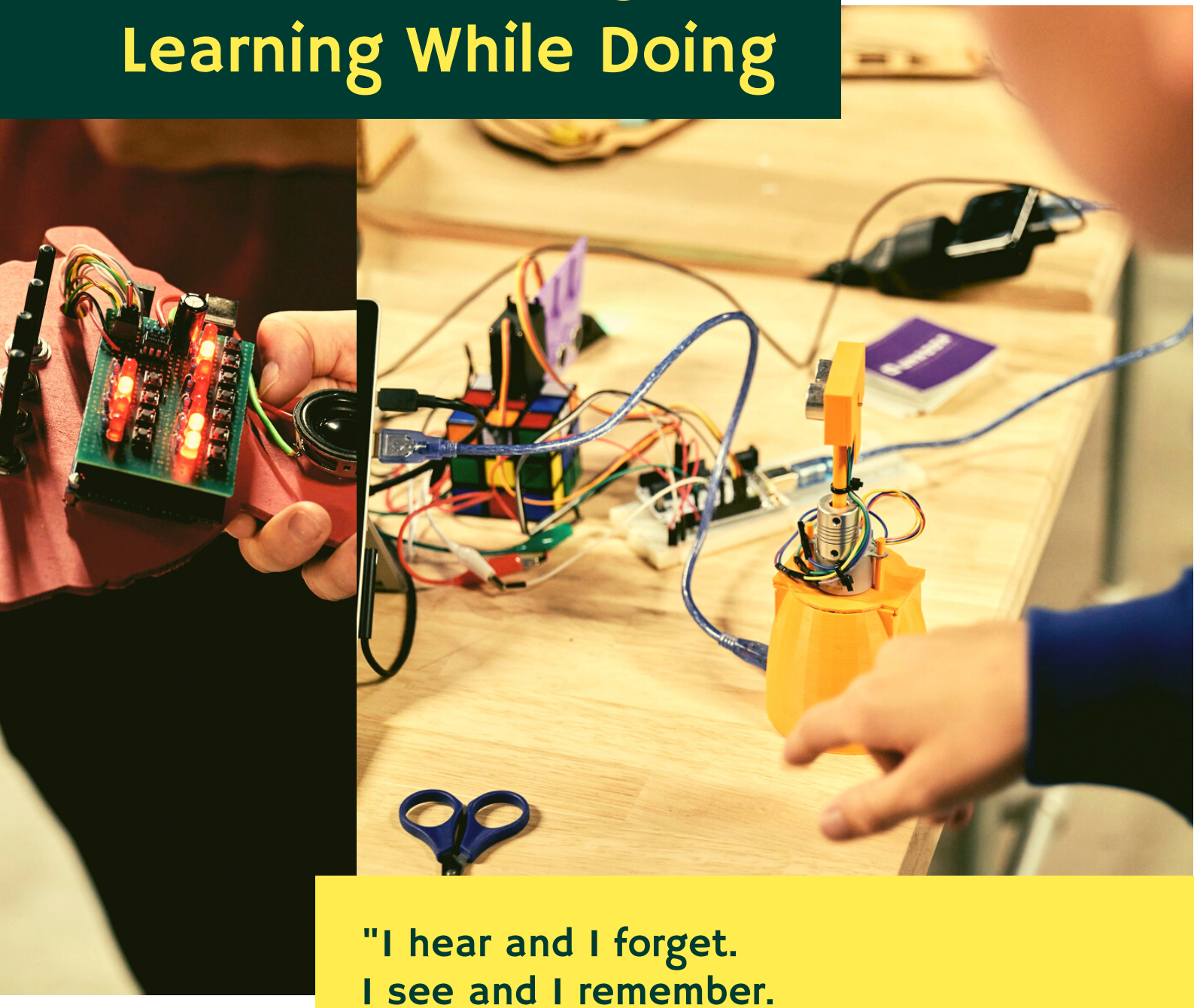
Make something!
Learning While Doing



"I hear and I forget.
I see and I remember.
I do and I understand." [Confucius]

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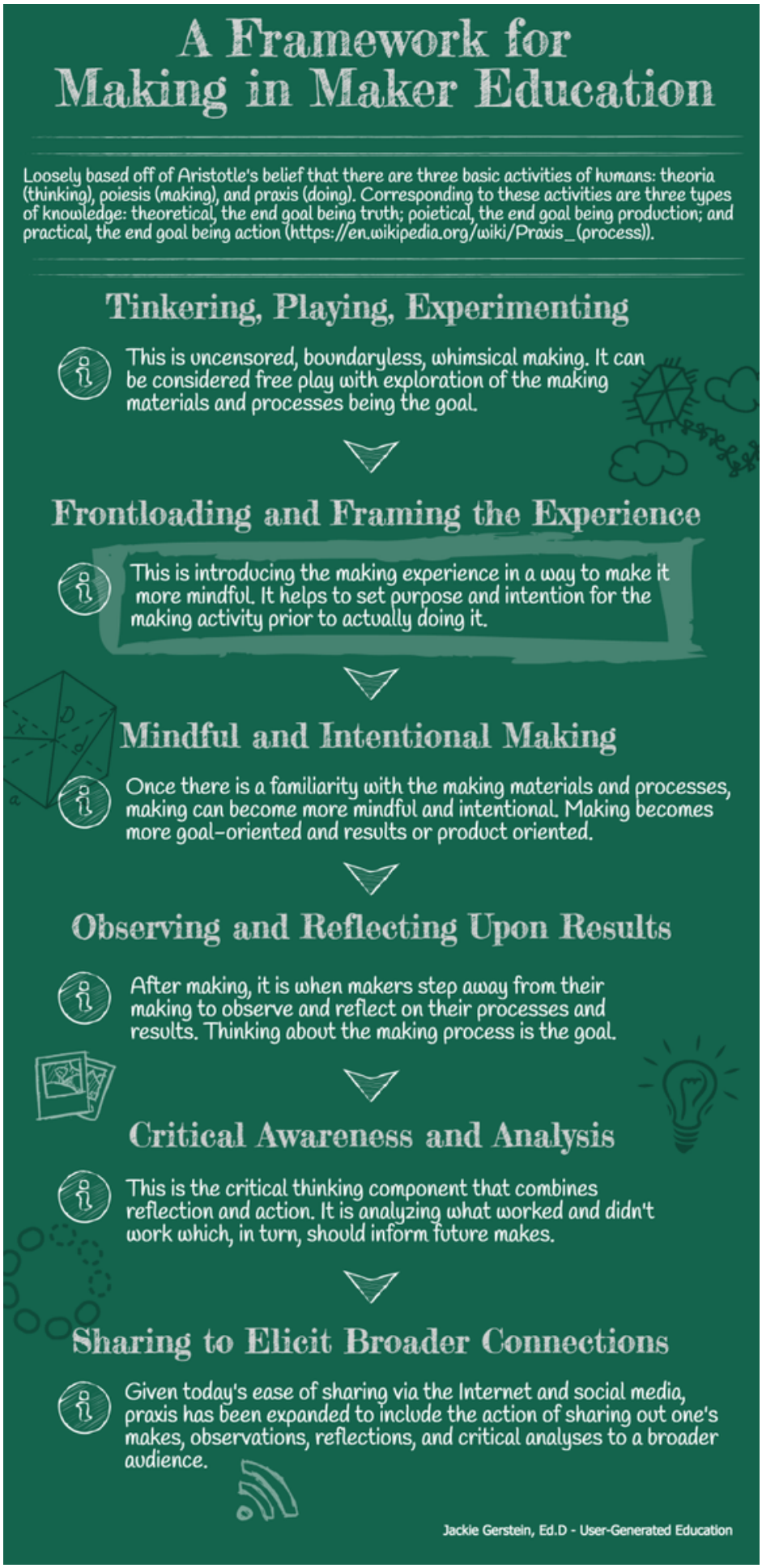
Foreword

Maker education is a way to promote problem-solving skills, collaboration, creativity, and critical thinking via making. It is a plus that the wide range of tools and high tech machines now available via fablabs and makerspaces make the learning experience more fun and appealing to all that are intrigued by design and digital technologies.

As a maker, a scientist and a STE(A)M trainer I believe that it is useful to reflect on a general framework that would help in integrating making in the traditional learning systems. This paper presents some general thoughts about maker education as they can be found in the literature.
This is not an original work but more a list of facts that I've been using with success throughout the past 12 years.

As a giveaway, I would like to mention the nice poster on the next page, made by Jackie Gerstein, where some fundamental elements to create a framework for making in education are summarized

dr. Maria-Cristina Ciocci


A Framework for Making in Maker Education
Loosely based off of Aristotle's belief that there are three basic activities of humans: theoria (thinking), poiesis (making), and praxis (doing). Corresponding to these activities are three types of knowledge: theoretical, the end goal being truth; poietical, the end goal being production; and practical, the end goal being action (https://en.wikipedia.org/wiki/Praxis_(process)).
Tinkering, Playing, Experimenting
This is uncensored, boundaryless, whimsical making. It can be considered free play with exploration of the making materials and processes being the goal.
Frontloading and Framing the Experience
This is introducing the making experience in a way to make it more mindful. It helps to set purpose and intention for the making activity prior to actually doing it.
Mindful and Intentional Making
Once there is a familiarity with the making materials and processes, making can become more mindful and intentional. Making becomes more goal-oriented and results or product oriented.
Observing and Reflecting Upon Results
After making, it is when makers step away from their making to observe and reflect on their processes and results. Thinking about the making process is the goal.
Critical Awareness and Analysis
This is the critical thinking component that combines reflection and action. It is analyzing what worked and didn't work which, in turn, should inform future makes.
Sharing to Elicit Broader Connections
Given today's ease of sharing via the Internet and social media, praxis has been expanded to include the action of sharing out one's makes, observations, reflections, and critical analyses to a broader audience.
Jackie Gerstein, Ed.D - User-Generated Education

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Introduction

Conceiving an idea is fundamental to any learning process. What makes it valuable in an educational setting is to be able to transform it into a tangible form which could be grasped by everybody involved. Makerspaces play a crucial role not only in transforming ideas to a tangible form but also supporting young people in learning about values, civility, good attitudes, competences and skills, especially around education for coexistence and personal development.

Maker education comes from the maker movement. The maker movement is a culture of do-it-yourself (DIY) individuals who among others want to make themselves more aware of the environment around them. They are known to be tinkers, inventors and innovators. They enjoy taking old technology and repurposing it until it is something new. Makers like to hack into the world around them and improve the design through collaborative efforts.

An educational making activity is one that brings together creative and innovative processes with an educational perspective, emphasizing practical learning during the process, and includes technology in all or some part of the process. These activities are substantial for promoting cooperation, respect for one another, teamwork, inclusion, promotion of creativity, learning by doing and innovation.

A major aspect in such activities is failure! There is no learning without failure and the iterative character of prototyping teaches the concepts of testing, tweaking, revising, improving in a natural way. The goal of iteration is to get closer to the answer, solution, or discovery with each repetition. The concept and the solution eventually converge, such as in a math process, because you progress toward your desired result each time you iterate or tweak the product. Students learn to work as a team, to face a problem, to propose solutions, to fail and to retry until they succeed. This type of pedagogy enables communication, collaboration, distributed learning, crossing boundaries and flexible teaching practices to grow.

Maker learning is not just about a subject or a physical space in an institution; it is a way of thinking: hands-on, design-centered and encouraging learning in both formal and informal environments. The skills acquired from design and fabrication have real-world applications in engineering, art, design, science, computer science and math. In addition to these skills, the culture of a makerspace itself can help students become independent learners driven by curiosity and intrinsic motivation.

Typologies of Educational Activities - I

There are different types of maker activities that teachers/trainers can integrate in the curriculum. It is wise to introduce the term tinkering and think of making activities as opportunities to train the tinkerer who is present in each of us.
The tinkerer is someone who experiments with materials and ideas to fully understand their capacities, and who further iterates on their learning to find better solutions to current problems.
The availability of digital fabrication tools next to the more traditional tools such as scissors and paper opens a box of endless possibilities for the tinkerer and gives new ways to experience processes of exploration and invention seeding potential for innovation.

The most often encountered can be classified under specific typologies which we list here.

Make-and-Takes: Make-and-take projects help students get excited for STEAM learning and give them something tangible to take home with them. These kinds of low tech activities use affordable supplies (cardboard, paper, tape, etc.) so that students can keep their finished projects.

Free-Form Making: These are unstructured activities where students can work on projects that they're passionate about. Free-form making allows students to stretch their creative boundaries without constraints.

Design Challenges: These types of activities are a great way for students to use a variety of technologies within a design process to identify and solve problems. Design challenges can include making catapults or creating devices for shooting rubber bands.

Portfolio Projects: Incorporate time throughout the year for students to work on long-term maker projects that they can then present at the end of the year and work on their presentation skills.

Cited from https://www.wgu.edu/blog/what-is-maker-education-movement2111.html#close

Hackathons

A Hackathon is any event in which people get together to engineer solutions to real-life problems, possibly involving technology. Hackathons generally have parallel tracks for educational workshops and/or conferences.

Essentially, during a hackathon, young people can be invited to work in groups (from 2 up to 5 people) on a project of their choice. Usually hackathons last for a whole day (from morning to evening). You can just walk in, figure out what is happening and get involved. Everyone has the opportunity to play, build and learn. And you can leave whenever you want.

Maker Faires

A maker faire is an event somewhat along the lines of a science fair. Thus, visitors move around different stations which each introduce a new concept, typically related to maker culture, digital DIY or classic DIY. Users can choose which station they want to visit and dig further into it by engaging with the presenter.

Most important difference of maker faires from traditional sciences fairs is the greater scale of interaction between the user and the presenter. Stations at the maker faires might be about skill sharing, while some others could encourage the users to engage with hands-on activities which increases information retention, works both sides of the brain, improves attentiveness and helps to explore new areas. It is required to be interactive.

Typologies of Educational Activities - II

Makerspace/Fablab: Ephemeral Places

Ephemeral places can refer to a facility/set of equipment or to a scenario in which a public space (can be any place) is temporarily turned into a makerspace-like environment.

Transforming a classroom, a civic center or any other public space into a makerspace for a short period of time can serve to gather young people together and help them to experience maker education.
At an ephemeral makerspace, users are invited to drop in to experiment with cnc machines, computer aided design and other tech-related activities. The objectives of such spaces are typically to give participants a taste of what sort of activities/projects are possible to undertake at a fablab or makerspace.

Themes of Educational Making Activities - I

The role of technology has a preponderant weight, however without connecting to the real world, everyday activities and day to day problems can seem daunting and frustrating. It is necessary to link more technical activities to creative practices, for which the STEAM methodology calls Arts, and what for us is a way of thinking outside of the world which surrounds us. It is important to choose a problem and think about how to address it. This will motivate participants to construct ideas and develop knowledge.

Computer Aided Design

Computer aided design tools which can be covered by an educator in a makerspace environment, include: open source and free graphic design softwares such as inkscape (2D design tool), online 3D modeling softwares such as tinkercad, and offline 3D modeling softwares such as for example Fusion 360. Open source platforms for electronics and physical computing are essential, Arduino and Raspberry Pi based systems play a major role.

Electronic Prototyping

This topic provides an introduction to coding, in which young makers can be invited to explore a number of existing tools for electronic prototyping. Primary learning outcomes can start with circuitry and electronics, with challenges around building simple electric circuits.

Coding

Young people can become acquainted with computer programming as well as with the computational way of thinking. An introduction to coding enables learners to explore visual/block coding softwares such as Blockly4Arduino, Scratch for Arduino, or mBlock. Not less important to mention Python and all its possibilities.

Themes of Educational Making Activities - II

Digital Fabrication Techniques

Through digital fabrication techniques, young makers can explore practices such as 3D printing, vinyl cutting and laser cutting. Through hands-on experiences of these topics, learners shall be able to understand what digital fabrication is and what are its advantages over traditional fabrication methods.

Robotics

This topic provides an introduction to coding, in which young makers can be invited to explore a number of existing tools for electronic prototyping. Primary learning outcomes can start with circuitry and electronics, with challenges around building simple electric circuits.

Creative Activities

Technology has a huge transformative potential in terms of educational practices. However for this, implementation must be accompanied by accessible and well thought out teaching methods. Maker education, project based or problem based learning, is an approach to learning that centers students' interests and directs them to an awareness of design. The learners take a lead role in their learning process.

Other themes involved in an educational making activity:

- Cardboard construction
- Prototyping
- Woodworking
- Textiles and sewing

It is wise to introduce the term tinkering and think of educational making activities as opportunities to train the tinkerer who is present in each of us.
The **tinkerer** is someone who **experiments** with materials and ideas to fully understand their capacities, and who further **iterates** on their learning to find better solutions to current problems.

The availability of digital fabrication tools next to the more traditional tools such as scissors and paper opens a box of endless possibilities for the tinkerer and gives new ways to experience processes of exploration and invention seeding potential for innovation.

"There is only knowledge in the invention, in reinvention, in the restless research"
[Paulo Freire]

Evaluation of Educational Activites

As a teacher is often required to evaluate the learning of the students. There are different methods to evaluate the process during creative making activities. The schemes below can be useful when engaged in the feedback and evaluation process.

They are based on research of Professor Lars Lindström in 'Criteria for assessing student performances in the Visual Arts' – Stockholm Institute of Education, dept. of Viual Arts, Drama, Physical Education and Music.

Level	Competency			
	Problem solving	Creativity	Community	Coding
1	Able to identify a problem and break it down to components	Able to express creativity through aesthetic means (eg. decorate an object.	Able to work with others.	Able to use visual coding software to create basic programmes.
2	Able to identify a problem and dissect it into components . Able to brainstorm possible ideas for solving it.	Able to customize outputs that come from recipe-like making activities.	Able to engage and share with the digital making community.	Able to use visual coding software to create more complex programmes. Able to complete small tasks and challenges using visual coding software.

3	Able to identify a problem and break it down. Able to brainstorm possible solutions. Being able to work with other to identify what may be the most appropriate solutions.	Able to use items, objects and materials in novel ways to make a simple project more interesting or personal.	Able to support others and work together with those around them. Able to provide help and assistance when those around them need it and allow others to help and support them.	Able to use visual coding for more complex tasks, that can be integrated with a project or a physical item. Able to understand lines of code written in more complex language such as C language (used with Arduino)
4	Able to identify a problem, brainstorm ideas for a solution and imagine a strategy that would be able to test different ideas. Be able to complete the testing and the implementation with support from those around them.	Able to connect projects to their own personal interests and experiences. Using tools and materials to create imaginative and personal outputs.	Able to collaborate and work well together with other makers on larger, more complex projects. Be able to share and discuss ideas and methods to others around them in the Makerspace.	Able to assemble lines of code to create a computer program that is able to fulfill a simple task.
5	Able to identify a problem, break it down into necessary components and to identify where solutions need to be found. To be able to idependently brainstorm ideas and solution before testing and implementing them in a real life scenario.	Able to create and imagine their own projects, which use a mixture of elements and skills which have been learnt from previous projects or even outside of the Makerspace, helping them to create something original.	Able to support and teach other new skills or help them to solve new challenges. Be able to explain more complex ideas in a clear and understandable manner. Be able to share projects and methodologies clearly on online maker platforms	Able to create and implement more complex computer programmes, and able to integrate these into a project for an output which is more advanced and interactable.

Guidelines for Evaluation

Assessment in making activities should be ongoing and should include opportunities for student reflection, self-assessment, and peer assessment. Students should be provided with means to facilitate ongoing exchange of ideas.

The following model proposes guidelines for assessment of learning, and suggests a wide variety of assessment tools and strategies.

Inquiry / Process	Issue selection and generation of guiding questions, inquiry planning, engagement in dialogue, ongoing learning log, peer and self assessment	25%
Inquiry /Product	Written, oral, and/or other creative multi-media communication of inquiry results	25%
Critical Understanding	Understanding of issues and key concepts; evidence of critical thinking; competencies of STE(A)M literacy (and/or citizenship) *[this can be adapted according to type and context of the project]*	25%
Making	Planning of project, implementation, communication, and evaluation of results	25%

Examples of assessment tasks

	Suggested tasks
Inquiry / Process	• Annotated bibliography • Reflection or response journal • Synthesis or reflection question response • Analysis of diverse perspectives • Analysis and interpretation of data • Discussion, position statement • Interviews • Selection of sources • Pre- and post-inquiry reflection
Inquiry /Product	• Oral defense of a position statement • Persuasive speech • Case study • Visual or multimedia creation/ presentation • Musical or dramatic production/ presentation • Simulation, role-play • News report or editorial writing • Cartoon creation • Position paper • Debate
Critical Understanding	• Mind map, concept map, graphic organizer, or flow chart • Issue analysis • Take-home exam, prepared question exam, written or oral test, quiz, ... • Bibliographical study/comparison • Audiovisual, photographic, musical, dramatic analysis/comparison • Hypothesis statement • ...
Making	• Organization & facilitation • Project work plan • Project proposal • Self- and peer assessment of project plan and results • Evaluation of project

Keys for a successful making

Mindset

Be visionary

- I envision a better world
- I imagine things that don't yet exist
- I believe that it is my place to turn ideas into reality

Be determined

- I persevere until I achieve my goal
- I recognize setbacks as opportunities to learn
- I know that innovation and mastery require effort

Be courageous

- I freely share my creative thoughts
- I stretch myself to try new things
- I embrace challenges

Be reflective

- I take time to think about what is and isn't working in my design
- I think about how my work impacts other people and the world
- I seek feedback to improve myself and my work

Be collaborative

- I vallue the unique perspectives of others
- I build on the ideas of others
- I use my strengths to support the work of others

Knowledge

Concepts and facts

The big ideas, principles and facts relevant to their work

Skills and techniques

How to use the materials, tools and technology that allow them to effectively create, test and share their ideas

Historical context

The contributions of relevant movements, artists, scientists, designers and other experts who came before them

Audience and environment

The needs and circumstances of their users and the physical context in which their work will be received.

Examples of Guiding Questions for Exploring an Issue when you are about to start on a project

A big advantage of maker education is that it allows bridging theoretical learning to the experiential by providing opportunities to engage in practical community-based projects. Students move from awareness to critical thinking and active engagement. Experiencing success in a maker project will make a difference in the student lives and possibly their closest friends and families.

The inquiring phase in a project is fundamental in leading to well defined goals and solutions/designs ideas.

We list a few sample questions that can help to guide student inquiry and may be adapted to respond to student needs, interests, and new or emerging issues of global significance.

> *Inquiry is a complex process that grows out of constructivist pedagogy. It begins with the selection of a topic and the design of powerful questions that guide students as they select resources, gather and interpret information, build relevant knowledge and understanding, and share their findings and conclusions.*

Significance and Scope

1. Why does this issue matter? To whom?
2. Who/what is affected by the issue? Who benefits? Who is harmed?
3. When/where/how did this issue begin?

Evidence

1. Have I used a variety of sources in my research, including primary sources?
2. How reliable are my sources?
3. How do the media treat this issue?

Perspective

1. How do perspectives differ on this issue (e.g., environmental, economic, political, social...)?
2. Which perspectives are most defensible and why? Whose voices are not heard?
3. What role do media play creating/ perpetuating this issue?

Connections

1. How has this issue changed over time? What might be future concerns?
2. How is this issue connected to environmental, social, or economic concerns?
3. Is this issue part of a larger trend or problem?
4. How does this issue affect the environment? Economy? Society? Quality of life?
5. Why does this issue continue to be a problem and for whom?

Reflection

1. How do you feel about the issue now that you know more about it?
2. How might this issue have been prevented? What could have been done differently?
3. What questions do you still have?

Action

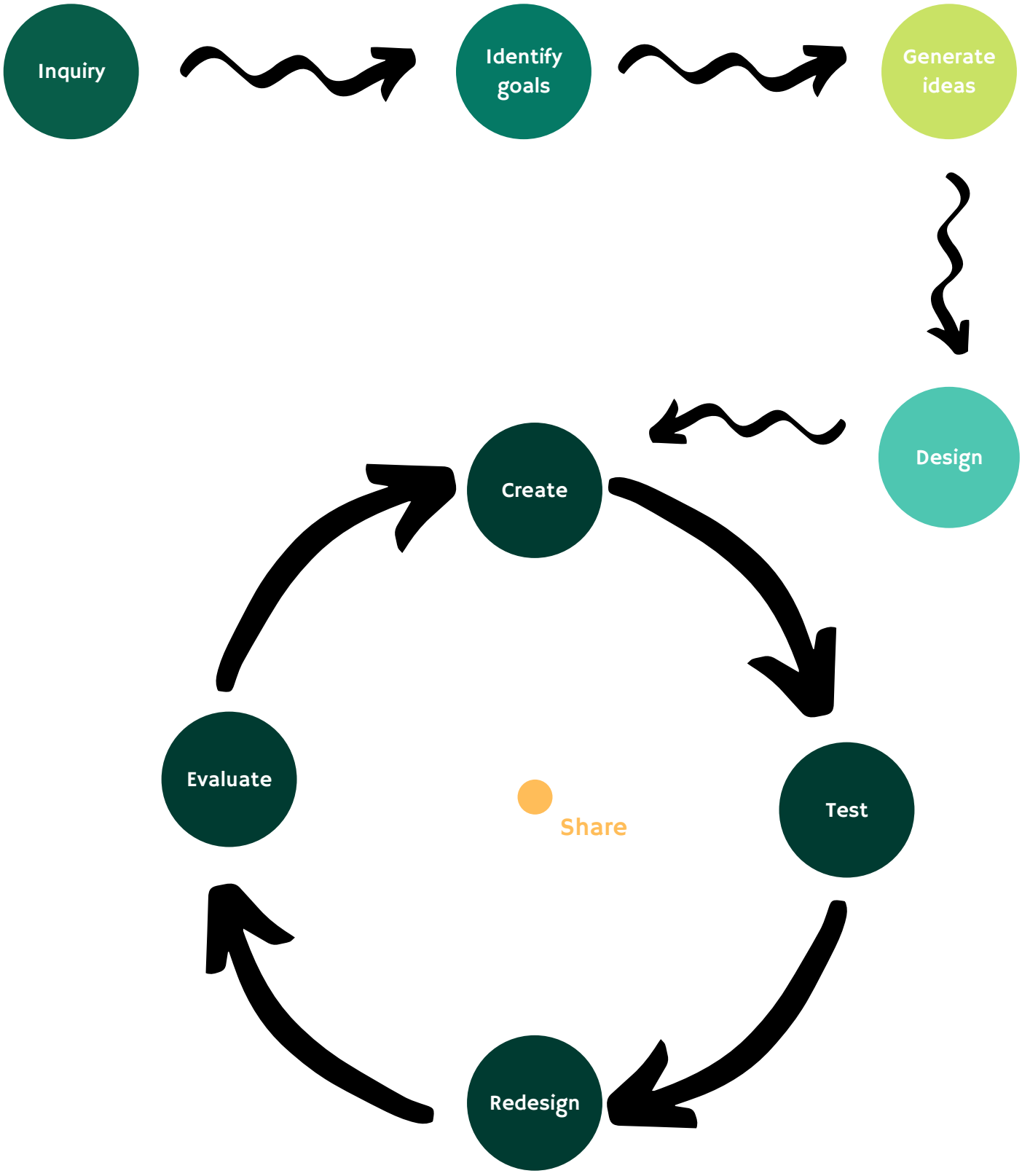
1. Who needs to do what? What can and should we do?
2. What are the challenges/barriers/risks to action?
3. What do I have to offer? How can I take action?
4. How can I get others involved?

Guiding Questions for mindful making

1. What resources do I have and need?
2. What will inspire me to give my time and effort to a project?
3. What do I know?
4. What will make me happy?
5. Can I let myself make a mistake?
6. Who is my audience?
7. How will my creation affect other people?
8. What kind of maker am I?

All these questions are summarized in a beautiful poster, made by Kate Holloway. If you want to download it, just scan the QR code.

Process


Inquiry
Identify goals
Generate ideas
Design
Create
Test
Redesign
Evaluate
Share

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