Developing Tinkering activities with a focus on sustainability

TINK@School

Co-funded by the Erasmus+ Programme of the European Union

A guide for developing Tinkering activities with a focus on sustainability

Methodological approach and instruments for defining the Tinkering toolkit (A3.1)

1. Preface

The Tink@school project is designed to address the needs of audiences coming from both the formal and the non-formal education sector. The ultimate target group are students - in particular, kids aged 8 to 12 years old - who will benefit from the application of the project activities. The project envisages to use tinkering as an engaging experiential method to unlock student's creativity and support teachers and schools in their efforts to design and apply meaningful interventions on sustainability and climate change topics, with the specific intention of generating a behavioural impact both at school and at home.

Tinkering is a learning approach that is gaining popularity in museums and schools in Europe. Previous projects have shown that Tinkering is a valuable methodology to work with adults with low science capital, in schools and informal education. Tink@school sees opportunities in using the tinkering methodology for Sustainability Education (SE or ESD).

With this document we hope to contribute to this movement. This guide focuses on supporting teachers and educators that want to learn more about developing tinkering activities for guiding their students towards more sustainable attitudes. We explain the tinkering methodology, the possible links and opportunities of tinkering for sustainability and how to develop such educational activities. We intend to create a useful instrument for developing the tinkering activities.

2. The Tinkering methodology

Tinkering is a learning approach; it is about creating physical things using a diverse range of tools and materials. It is learner centred; it is about their ideas and goals. The outcomes are diverse: the combination of activity design, materials and facilitation creates an engaging entertaining learning experience.

Tinkering is thinking with your hands and learning by doing

It has a playful nature, the learner is encouraged to play around with materials and tools. The learner is invited to work from their own experience, interests and personal motivation. Moments of frustration are challenges for the learner. The Tinkering methodology can help develop 21st century skills such as problem-solving, creativity, cooperation, critical thinking, confidence and resilience. (Bevan, Gutwill et al. 2015)

Activity

In Tinkering activities learners combine different subjects such as physics, maths, art, engineering and technology in an integrated way. Tinkering activities vary in style and content, but there are some common core features:

- Something physical is created using tools and materials.
- The atmosphere should be playful, innovative, creative and inclusive.
- Learners have the possibility to follow their interests and can therefore pursue their own path of learning.

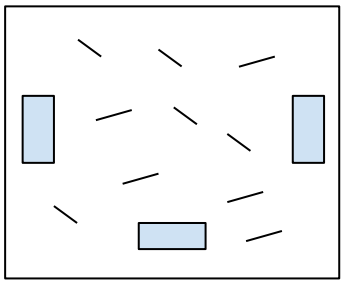
- Outcomes are highly variable and sometimes unexpected.
- Although tinkering activities begin with a task or a challenge, they are designed so that learners can add in or set their own goals. Therefore, they can progress through the activity in a way that is interesting and personally meaningful to them.
- The learner works on the activity by trying things out. They might start by improvising but through a process of iterative design, they can move from improvising to planning, designing, testing, redesigning and refining.
- There is a variety of materials that can be mixed and merged in multiple ways and will often be used in unforeseen ways.

On the next pages we provided two examples of tinkering activities to give an impression how tinkering works.

Tinkering activity: Marble Run
One of the most classic Tinkering activities is the marble run. Participants are invited to create a marble run on a peg board.

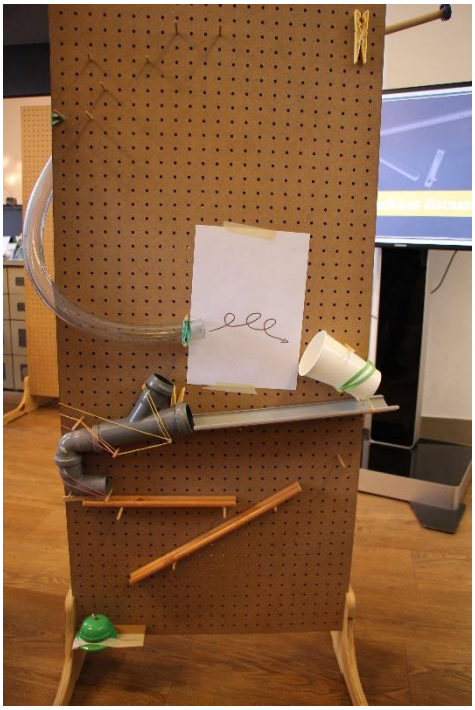
Prompt: You can start this activity with different prompts depending on the learners. You can ask them to make a marble run that uses sound or invite the participants to make a run where the marble has to go as slowly as possible.

The activity: Learners work on the marble run. During the activity they create their own goals, they may want to use a specific object or material, or they may want to use both sides of the board, make the marble go uphill or create a lift and so on.



Layout of the room: Place the groups scattered around the room. Place 3-4 material tables on different sides of the room. This encourages the learners to walk around the room and get inspired by solutions or material use of the other groups while passing by. It also encourages talking between the learners about their projects. .

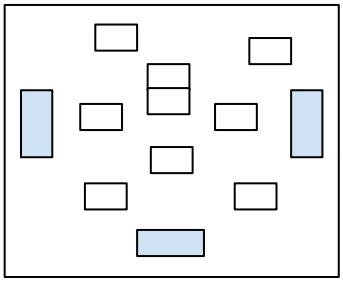
Materials: Place similar materials on the tables. For example: gutter like materials on table one (tubes, pvc pipes, toilet paper rolls), construction materials and tools on the other table (tape, cotter pins, scissors, glue, string, etc) and miscellaneous materials on the other (cups, packaging material, old toys, instruments)



Tinkering activity: Scribbling machine
A scribbling machine is a construction that moves in unusual ways. By using markers they leave a path.

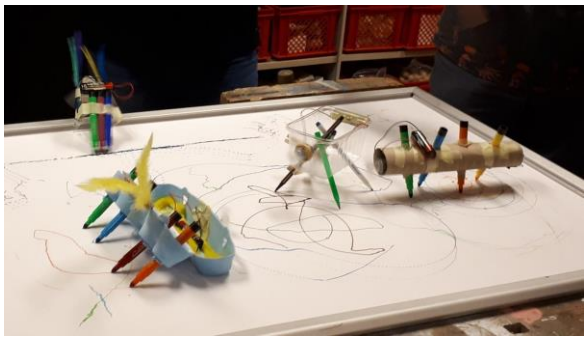
Prompt: You can start this activity with different prompts depending on the learners. For example make a machine that moves in a circle, or make a machine that moves irregularly.

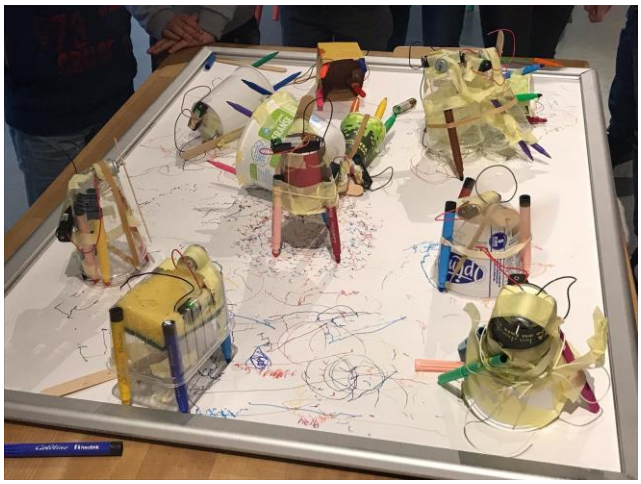
The activity: Learners are working on the scribbling machine. During the activity the participants create their own goals. For example, wanting to use multiple colours, create a specific pattern or use a specific material.



Layout of the room: Place the groups scattered around the room. Place 3 material tables on different sides of the room. Create a place where they can test out their scribbling machine. Preferably a table covered with paper with an edge so the machines won't fall off. This encourages the learners to walk around the room and get inspired by solutions or material use of the other groups while passing by.

Materials: Place similar materials on the tables. For example: Battery pack, wires etc on one table, construction materials and tools on the other table (tape, cotter pins, scissors, glue, string, etc) and miscellaneous materials on the other (cups, packaging material, old toys, instruments).





For more examples see:
www.exploratorium.edu/tinkering/projects
www.museoscienza.it/tinkering-eu/download/tinkering-total.pdf
www.nemosciencemuseum.nl/media/filer_public/97/b4/97b46c85-e28d-42bc-8c37-9e292fa9ea6d/tinkering_addressing_the_adults_tinkering_activity_plans_-_io2.pdf
www.tinkeringschool.eu/wp-content/uploads/2023/03/Marble-Machine-tinkering_WS.mp4
www.tinkeringschool.eu/wp-content/uploads/2023/03/Scribing_Machine_tinkering_WS.mp4

Facilitation

Facilitation of a Tinkering activity is an important part of a valuable experience. Below you find some tips for facilitation (Harris, Winterbottom, et al 2016).

- Pose questions instead of giving answers.
- Create a supportive and inspiring environment.
- Help participants/learners when/if experience frustration and failure
- Encourage learner-negotiated goals and pursuit of personal interests.
- Encourage collaboration with others.

In appendix 1 you can find the Facilitation field guide of the Tinkering Studio of the Exploratorium (part of the Tinkering Training with all the partners).

Frustration

Frustration is a common experience during tinkering activities. With the open character of tinkering activities, participants have ample space to experiment with different materials and designs, trying out various possibilities. But some designs are flawed, and sometimes the materials used prove not suitable for the task, and so the participants run into trouble. And since the work is their own, they cannot turn to a teacher or a facilitator to ask for a solution. They have to find the solution themselves. This may lead to frustration, especially when repeated “improvements” of the design or material selection do not solve the problem.

Getting stuck and overcoming the frustration of getting stuck is an important part of the tinkering experience. Frustration is part of the process; it is part of trying out new things only to find out that they do not work. But that can teach the participants much about the task they are trying to solve and the materials available, but also about themselves, their partners and the value of cooperation.

Although the facilitator will not directly come up with a solution, they must try to make sure that the frustration does not lead to the participants giving up. They can intervene by making suggestions, whether directly concerning the task at hand or simply suggesting the participants look at other teams and what they have done. The aim of the intervention is not to avoid frustration but to help the participants to respond constructively to it and overcome it. Some tips to help the participants to navigate the frustration:

- Read the room well, walk around, try to keep an eye on each group. Ask questions so that you know the goals of the group and what they are working on.
- Be authentic and refer to things you have heard or have seen. In general specific comments like “I saw you were struggling with ……, and know you made it work’ work better than generic comments like ‘How beautiful’. Learners feel more seen and addressed to the more specific and authentic the facilitator is.
- Encourage the groups to make something they really want to make, so they take ownership of the project and there is less chance of people not liking the assignment.
- Do not intervene too quickly; you can acknowledge that they have a hard time, but give the participants a chance to solve the problem on their own.
- Help participants to come up with a solution for example: put a material on the table that you think might help or point out a solution from another group.

- When discussing the assignment afterwards, emphasise what went well rather than the final result. Compliment the groups that may not have a final product but who showed great perseverance and ingenuity in trying to solve the problem. Explain to the group that these are important skills in life and that if they had more time they would have probably solved it.

Environment

Part of a valuable Tinkering experience is the set-up of the room and the organisation and presentation of the available materials. By setting up multiple material tables in different parts of the room, participants are encouraged to walk through the space. By doing so, they can get inspired by the work of others and little talks between the participants can happen. The diversity of materials and colours is another important component.

Collaboration

The activity is open and the outcome is not very well defined which leaves much room for those working on the activity to collaborate with each other, both on the way they approach the activity, what materials they use and how they see the outcome.

We distinguish between *cooperation* and *collaboration*. When people cooperate they work together for mutual benefit, but the benefit - the valued outcome of the activity - need not be shared nor is it part of the shared activity to define the beneficial outcome. Collaboration, on the other hand, is manifested when people work together to create something new where they outcome of shared activity is not predefined.

Tinkering activities call for collaboration rather than cooperation, since part of the activity is to define the desired outcome - or decide when the activity has produced something that all partners agree is the desired outcome. Thinkering, therefore, is not about assisting each other working on a specific task but truly coming together to work jointly on the task.

Letting participants work together in pairs or small groups can be a way to stimulate talking and expressing ideas; both on a knowledge based level as on a personal level. When working together learners are more inclined to express what they see happening and by formulating what they see, they are also thinking about and formulating explanations. For example 'Now the marble runs faster, we changed the surface from wood to paper, apparently the paper has less friction'. But also if they want to use a specific item or material: "I like music so let's use this, it makes a nice sound'.
Some activities however work better when done individually. The reason can be practical, the project is too small to work with more than one person. For example Paper Circuits (https://www.exploratorium.edu/tinkering/projects/paper-circuits). And for activities in which the learners can express a personal story it can also have an added value to let them work individually. It is also possible that learners don't want to work together.

For schools: the teachers know the pupils and have a good idea about the dynamics in the group. For a museum or other educational setting, forcing learners to work together if they do not want to, doesn't lead to a safe and playful environment.

Learning

The Tinkering Studio at the Exploratorium in San Francisco are the pioneers in Tinkering. Based on observations of hundreds of people taking part in Tinkering activities, they have developed a framework which describes the sorts of learning that Tinkering experiences develop (figure 1). This can be a useful guide to help identify moments of engagement, learning and skill acquisition when watching or trying out Tinkering. It can also be used with students after a Tinkering experience to help them reflect on their learning.

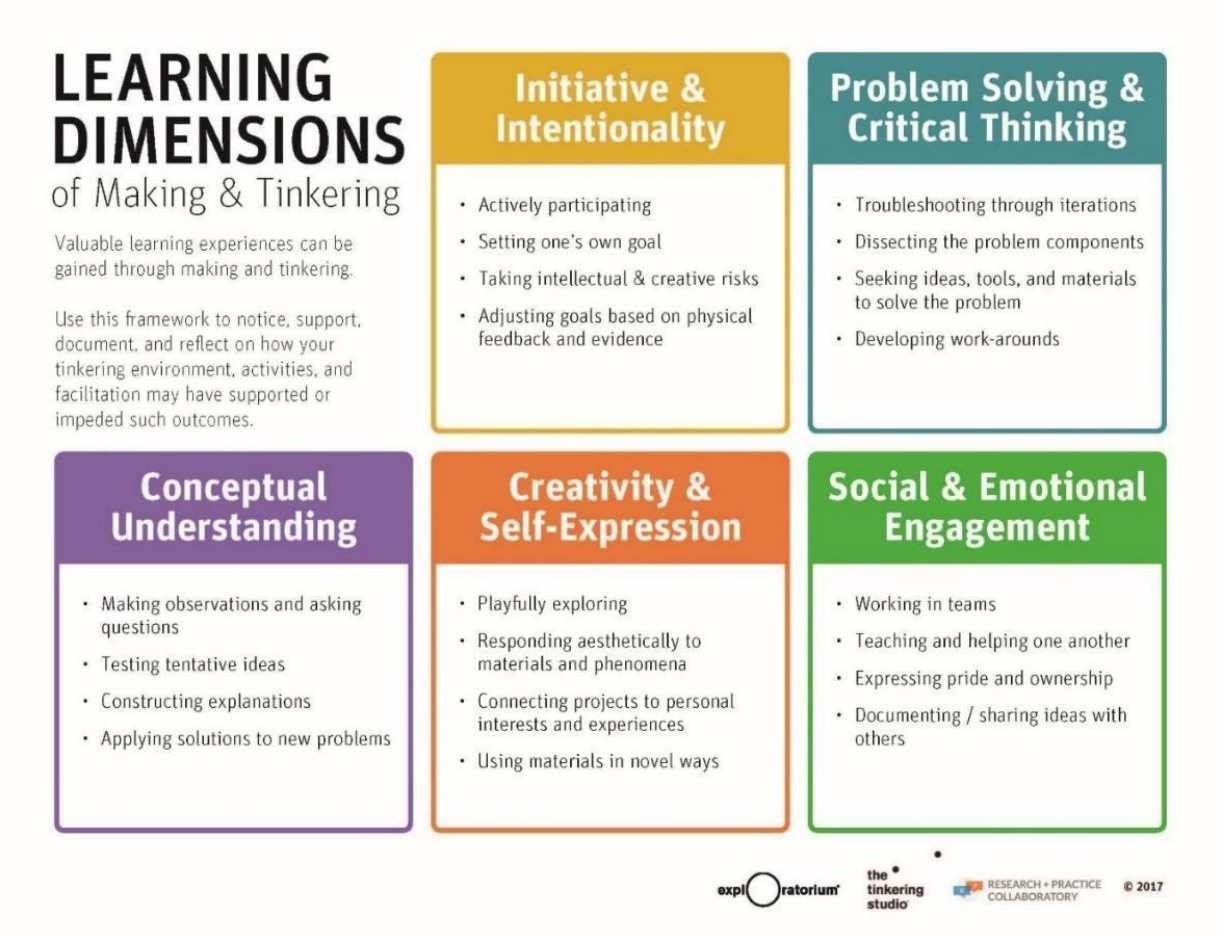


Figure 1: Different dimensions of learning that the tinkering experiences develop (from the Tinkering Studio at the Exploratorium in San Francisco).

Tinkering and other methodologies

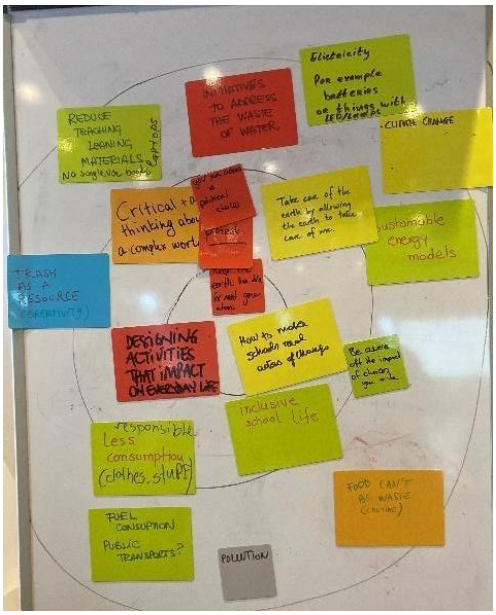
There is a range of hands-on STEM teaching/learning approaches that are used in formal and informal learning settings. A difference between Tinkering and these teaching approaches is that although characteristics of inquiry-based learning and learning by design can be part of the Tinkering methodology, but they are never the goal. Some participants might investigate a natural phenomenon within a tinkering activity, but that is their own goal, interest and learning path. It is not a goal of the specific tinkering activity.

- **Inquiry-based learning**. Inquiry-based learning challenges students to explore and find out how the world works. By asking questions, experimenting and reflecting on what they have done, they will get answers. The didactics of inquiry-based learning are based on the method of scientific research. Students go through an inquiry cycle in 5-7 steps, such as: explore, question, hypothesis, experiment, results, conclusion, learning more/follow up/revise. In this methodology the focus is on scientific skills like observing, critical thinking, formulating a (scientific) question that can be investigated, formulating a hypothesis, analysing the results, making conclusions, etc. While doing activities and experiments the students will deepen their understanding about STEM phenomena like light, gravity or air pressure, depending on the topic of the lessons and activities.
- **Learning by design**. Learning by design is about coming up with solutions or designing products. The activity starts with a problem or a wish. The learners are guided through a design cycle (the steps differ between different organisations). But they come down to four basic steps: design - make - test - improve. Within these steps the learners come up with a design, make it and test and then improve it. The open assignment offers space for the solutions and ideas of all students. There are more ways to come up with a solution within the criteria and restraints.
- **Making**. Within the maker community, 'making' is typically characterised by people coming together to use, share, manipulate and innovate tools, materials, ideas and methods. Within the setting of a school this is used as a teaching method to make something with materials and tools: the aim is making something. Often in a cook-book style. The focus is more about getting to know the characteristics of the used materials and tools and about concretely giving shape and life to something for themselves that can be taken home.

3. The Tinkering methodology and sustainability

The focus of Tink@school is “Environment and fight against climate change”. Tink@school wants to address this through engaging educators and learners directly with various issues of environmental and climate concern in a collaborative setting (using the Tinkering methodology) where key competences, such as critical thinking and communication competences, will be developed while students get trained in science literacy, gain knowledge of natural sciences and develop technical and artistic skills (STEAM approach) through real-life problem solving.

Through direct engagement with issues that arise in learners’ own daily lives, the project encourages changes in both behaviour and preferences, consumption habits, and lifestyles. The issues of environmental and climate challenges are rooted in condition within the realm of the natural sciences. To translate these challenges into aspects of everyday life requires considerable knowledge and understanding of natural sciences, including mathematics. Learners' scientific knowledge and technical skills will be developed through analysing and then responding to these challenges.



In the brainstorm during the Kick-off meeting the team established the following as being the three most important takes on sustainability for the project:

- Keep the earth liveable for next generations.
- Make schools real actors of change.
- Designing activities that have an impact on everyday life.

Whole School Approach for sustainability

Schools adopting this approach connect what students learn (curriculum) with what is practised by the school (management, procurement), while linking to the community. It is an approach that seeks to take learning outside of the classroom walls by engaging students in school decisions and real-life sustainability experiences and challenges (e.g. students undertake a project to improve the school waste management, reduce food-waste or to ‘green’ their transport to the school.) Sustainability is not an add-on, but is at the heart of the Whole School, while the school space itself ‘demonstrates’ how living sustainability can be. The process of becoming a ‘Whole School’ involves continuous cyclical processes of improvements and self-reflections with the entire school community.

Tink@school and sustainability

As explained in chapter 2, the value of tinkering for education can be found on different levels. Tinkering activities lead the learner to develop their own questions and challenges, discuss ideas, recognize and articulate problems that they face along the way, look for solutions, evaluate progress, hypothesis, test and retest in a learning journey which can have multiple outcomes and unexpected results. (Harris, Winterbottom, Xanthoudaki, 2020, p.28)

When learners gain more experience in Tinkering they will get more used to this way of thinking and working and will be able to apply it in other fields as well. They will develop what we like to call: a Tinkering disposition. A mindset that allows you to 'tinker' in different situations; in the kitchen when you are preparing a meal, when playing or finding a solution for a construction problem in your home. It means that you come up with creative solutions and use materials in ways you might not have thought of before. Afterall, Education for Sustainability is about cultivating mindsets, attitudes and behaviours to deal with complex and global issues but through concrete, applicable, transformative local actions.

According to climate experts, there is not one solution to climate change. It requires solutions in different areas, creative angles and out of the box thinkers. Tinkering can help students develop these skills. Besides developing these skills, tinkering can be used in a more concrete way to teach students about sustainability and climate change. In this project we will develop activities in three different areas:

1. Tinkering solutions to problems.
2. Tinkering with recycled materials.
3. Tinkering to create a change.

Tinkering solutions

Tinkering might not be the first didactic that comes to mind when thinking of problem solving/ finding solutions. Inquiry-based learning and design thinking might seem more logical. But tinkering can also be used for coming up with solutions. Not only because some great inventions were the result of accidental discoveries, think of penicillin and Play-doh. But also because Tinkering changes the way you face a problem: learners often start out by looking at one solution for a particular problem, while with Tinkering they approach a problem by playing, researching and building with materials. Solutions come forth from this process not from a thorough thought or research process. Because tinkering is more open, it can lead to more creative solutions and to an out-of-the-box use of materials.

Examples of activities can be: create a sorting machine for trash, make something that moves without batteries or electricity.

Re-use & Re-duce

Another area in which we can raise students' awareness is about the re-use of materials and the reduction of waste. This can be done with tinkering activities concerning the amount of waste we produce, overconsumption lifestyles and recycling of materials and resources. One way to do this is to create tinkering activities that only use recycled materials. For example by having students collect their own trash (clean plastics or cardboard packaging) and make an artwork with it or create a marble run with these materials.

Another way to achieve this is by designing tinkering activities in which the students come up with new ways to reuse/repair waste material or find new ways of using a material (repurpose). For example, try to find a way to reuse plastic bags or old clothes, or create a new toy from trash. These types of activities let students revalue materials.

> Tip: See appendix 2 for tips on places to find sustainable materials to use for tinkering.

Tinkering for change

The last type are activities that invite the students to be agents of change. It can be fun and inviting ways to motivate changes in others. They create something in the Tinkering activity that conveys a message about sustainability or climate change. For example they can conduct a little research about what can be changed around the school, and tinker something that invites people to make this change; a fun way to encourage other students to separate waste, or to use less water. Another is having students collect plastic trash in the park or on the beach for a week and then create a balancing piece of art from this saved trash. This artwork can be left on the beach or be exposed in school/museum to make people aware of the amount of litter in nature.

4. Developing Tinkering activities

Step 1: Tinker!

In order to develop tinkering activities it is important that you gained some experience as a tinkerer. This can be obtained by doing and/or supervising activities.

Step 2: Read Tinkering a practitioners guide

In *Tinkering: A practitioner's guide for developing and implementing tinkering activities* some guidance is given for developing activities. Read chapter 2 of the guide: Developing and implementing Tinkering.

Step 3: Start developing

Use the *Planning Framework* in appendix 3 to start developing the activity. Keep an open mind, the developing process is similar to a tinkering activity, it can change along the way.

Step 4: Check Tinkering value's

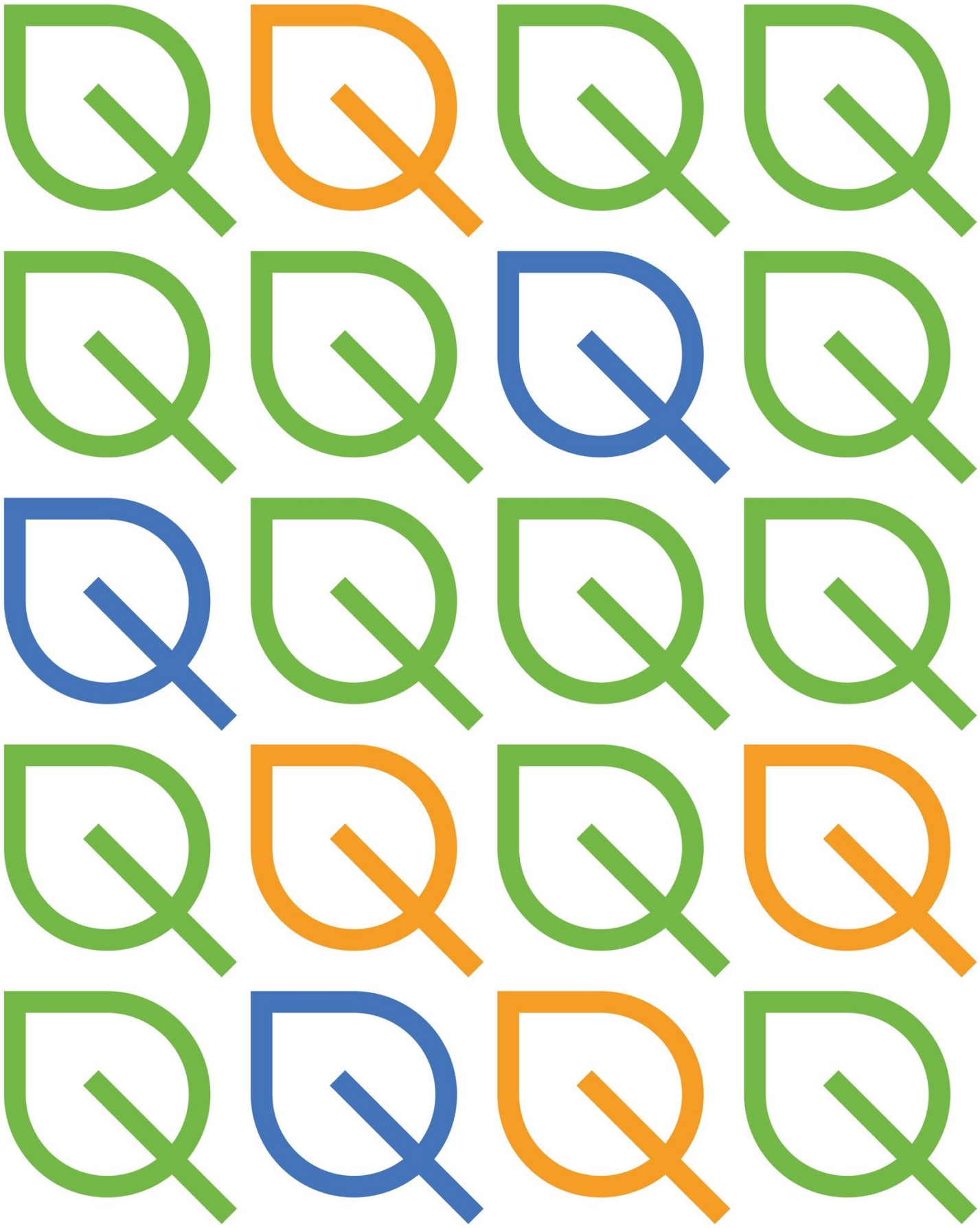
When developing a tinker activity think about the following points:

1. Keep the values of the tinkering methodology in mind (see chapter 2), check if you think it meets the requirements to be a tinkering activity
2. Create an activity in which the experience is physical, personal, immersive and creative.
3. Think about different prompts as the starting point of the activity.
4. Select materials that are inspiring and can be used in multiple ways. Make sure there is a variety of materials.
5. Think about the layout of the room, does it invite creativity, collaboration and being inspired by the work of other groups?
6. Test and retest the activity by yourself and with colleagues before you test with the target audience.
7. Is the activity open ended? If the activity feels more like a design assignment, go back to the start and make the prompt more open.
8. Test the activity with the target audience.

Step 5: Train educators and keep tinkering on the activity

Training educators is important. A facilitator in NEMO told us: "The Tinkering training is one of the most useful training I had so far, I don't only use it for the tinkering activities. I learned so much about how to guide and interact with people during their learning process that I use it every day when I guide people on the exhibition floor".

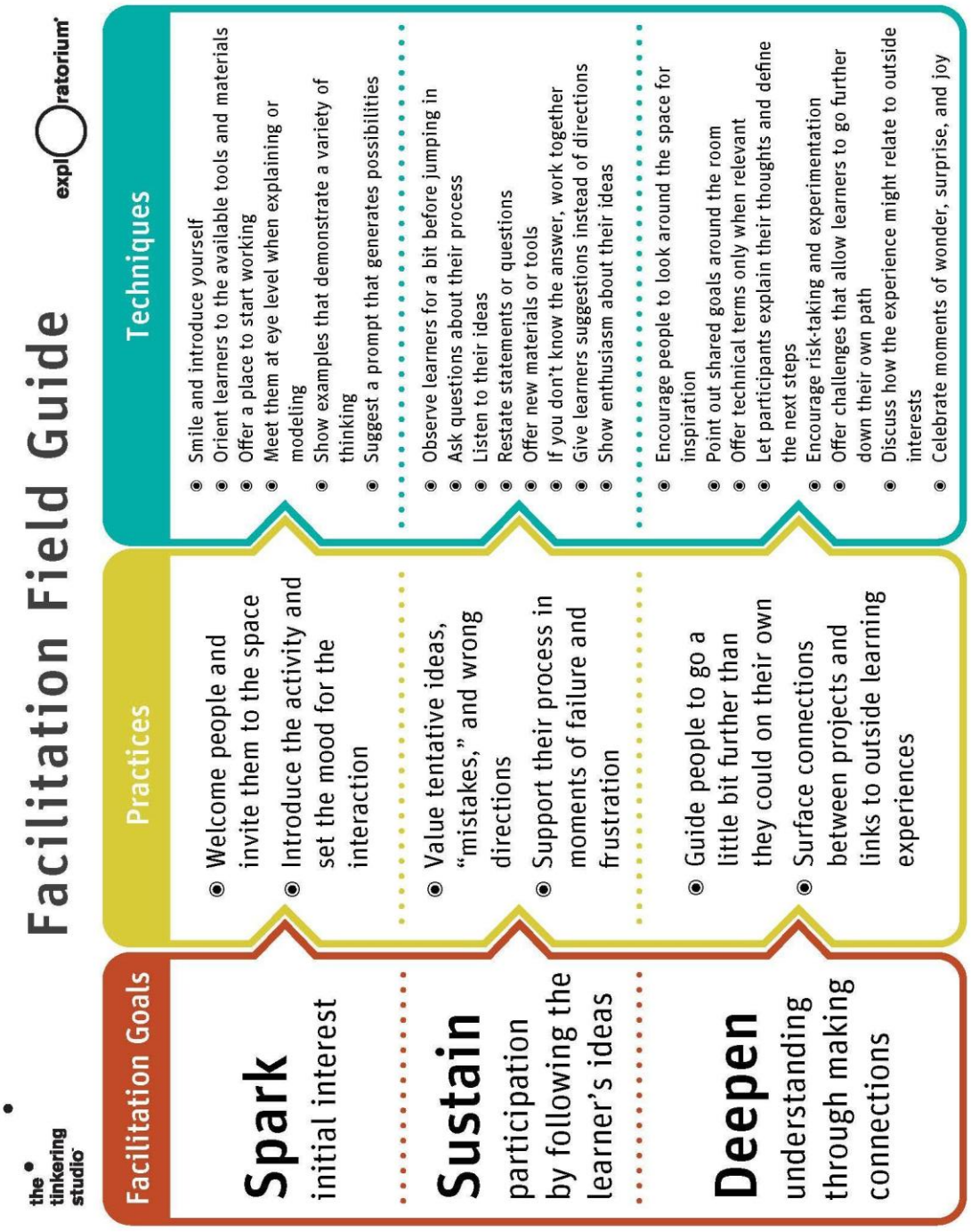
Have fun with the activity and keep tinkering to make it better!



Appendices

Appendix 1 - Facilitation Field guide

Figure 1
Learning



Dimensions by Tinkering Studio of the Exploratorium
https://www.exploratorium.edu/sites/default/files/files/Learning%20Dimensions%20of%20Making%20and%20Tinkering.pdf

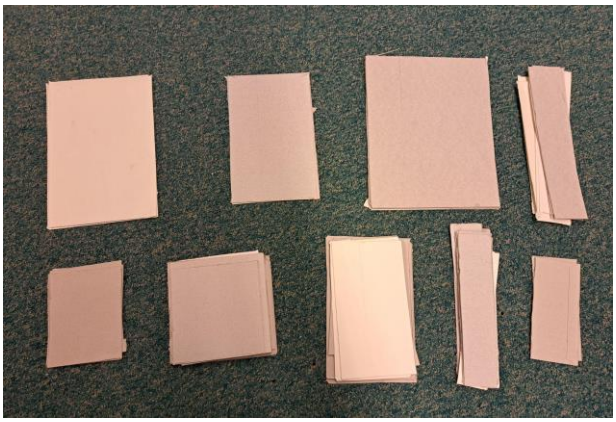
Appendix 2 - Sustainable Tinkering Materials

Examples of materials to collect:

- Old toys
- Old clothes
- Yarn or string
- Tote bags
- Waste:
    - Paper
    - Toilet paper rolls
    - Egg boxes
    - Cardboard packaging
    - Plastic packaging
    - Plastic bags
    - Cans
    - Fruit nets
    - Cardboard boxes
    - Toy packaging
    - Bubble wrap
    - Plastic bottles
    - Magazines
    - Caps, lids, and corks
- Collect materials from nature:
    - Leaves, flowers, stones, shells, feathers, sand, pine cones, straw, wood, etc.

Tip: Make the materials more attractive to use by cutting them the same size and display them according to colour or size. See examples for cardboard materials below:

Cardboard materials sorted by size and shape



Recycled cardboard boxes cut into shapes.

Paper circles from recycled cardboard

Places to pick up materials

- Packaging form stores
    - Luxury furniture stores use really nice packaging
- Waste from makerspaces
- Waste from factories
- Waste from building sites
    - Foam
    - Plastic
    - Wood
    - Pipes
    - Styrofoam
- Scrap Yards
    - Seatbelts
    - Fabric
    - Buttons
    - Wires
- Second hand stores
    - Ask if they have certain products that are not bought often that you can take of them (stuffed animals, glassware etc)
- Local recycle stations

Basic tools and materials

- Materials
  - Paperclips (different sizes)
  - Cotter pins
  - Elastic bands (different sizes)
  - Markers
  - Glue (hot glue gun can be handy but might need more supervision)
  - Masking tape
- Tools
  - Scissors
  - Hammer with nails
  - Screws with screwdriver
  - Saw
  - Box cutter
  - Awl
  - Gimlet

Tip use a compartment toolbox to create a set of basic Tinkering materials:

Appendix 3 - Planning framework to guide the development of Tinkering activities

Descriptors	Indicators
Create an experience that is physical, personal, immersive, creative, sensorial and manual in nature	Identify a theme or scientific phenomenon that you want the learner to explore.
	Challenge the learner to incorporate unusual and enticing tools or materials or to use familiar tools and materials in a novel way.
	Select materials and tools that are enticing, evocative, inspiring, exciting – they should be inviting and spark people's curiosity and interest (Petrich & Wilkinson, 2013)
	Spend time generating ideas, testing and trailing: Play around with the sorts of materials and tools that you think will work to help refine your activity idea. Ask a group of critical friends (e.g. museum colleagues) to test your activity and provide feedback to help you refine it further. Pilot your activity with the audience that you will be using it with and redevelop and refine based on their feedback.
Make sure that your activity involves generative, iterative design	Watch visitors engage with your prototype activity to see if they try something over and over and/or to work in an iterative, improvisational way. Keep that in mind as you adjust materials, table placement, examples, etc.
	Design your activity so that the learner will ponder, puzzle, build, test, plan, re-design, tweak and refine.
	Provide a choice of materials and tools and make sure that this is a genuine choice. The learner should not be 'led' to a specific goal or solution based on the materials that you provide.
Requesting or offering help in solving problems	Set long-term goals, not challenges: rather than posing challenges to solve, propose long-term goals that are broad enough to give everyone freedom to work on something that interests them personally, but specific enough to foster a sense of shared experience among participants (Rusk, Resnick, Berg, & Pezalla-Granlund, 2007)
	Make sure that any long-term goal (or starting point) can be broken down into smaller short-term goals by the participant - learners should be able to negotiate their own goals and to pursue and express their individual interests so that they engage in activities that are personally meaningful to them
	Provide opportunities for different levels of challenge and therefore allow for highly variable and often unexpected outcomes.
	Carefully plan introductory instructions-they should help people to get started but should not close down creative ideas for emerging projects and ideas. Test different approaches out when you pilot your activity.
	Make sure that facilitators understand that their role is to support but not to instruct

Create an atmosphere of play, innovation and creativity	Create 'Tinkering' atmosphere through the manner and conduct of the facilitators as well the physical presentation of the space
	Show sample projects that illustrate the wide diversity of what is possible to provoke people to think divergently. (Resnick & Rosenbaum, 2013)
	Keep past examples on display for inspiration. (Resnick & Rosenbaum, 2013).
Arrange your space to optimise interaction and collaboration	Tinker with space: consider how you might rearrange or relocate, to open new possibilities for exploration and collaboration. For example, how can the arrangement of tables and screens help people see each other's work? How can the arrangement of materials encourage clever and unexpected combinations? (Resnick & Rosenbaum, 2013).
	Create working areas that will enable people to view each other's projects as they develop
	Place materials for collection in a location where people can congregate together.
	Display example projects/objects to inspire.
	Encourage people to view each other's work by placing materials and tools in a position that requires them to move around the room

References

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Colophon

This publication is a product of Tink@school (2022-1-IS01-KA220-SCH-000087083), which was funded with support from the Erasmus+ Programme of the European Union. This publication solely reflects the views of the authors, and the Commission cannot be held responsible for any use that may be made of the information contained therein.

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