Supporting Science, Technology, Engineering, Arts and Math

STEAM

Learning

A Guidebook for Educators

Prepared by: Peter Wardrip
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Supporting Science, Technology, Engineering, Arts and Math (STEAM) Learning: A Guidebook for Educators

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Introduction

This guidebook has been developed by an international team of educators and researchers to assist educators in Palestine in designing and facilitating Science, Technology, Engineering, Art and Math (STEAM) learning experiences. It is also meant to serve as a resource for other educators and educational leaders who wish to intentionally design STEAM-based learning experiences with their own learners.

This manual in part of the A.M. Qattan Foundation's ongoing efforts to address the growing importance of STEAM education in Palestine. It recognizes that STEAM is a complex and debated topic, with various interpretations and approaches taken by teachers and institutions in different contexts. To ensure a comprehensive understanding of STEAM, the team responsible for this manual drew upon their extensive expertise in the field and developed their own definition of STEAM, using the process through which this manual was developed as an example. The wider scholarly discourse surrounding STEAM includes the argument that it is often dominated by normative Western knowledge, thereby disregarding the valuable local wisdom and expertise accumulated within the (Palestinian) community. With this consideration, the manual aims to inspire educators to create STEAM scenarios that address social issues while incorporating local wisdom. By doing this, the manual contributes to the ongoing discussion about the type of STEAM education that is most relevant and beneficial to Palestine, and represents a crucial step towards fostering collaboration and collective efforts in STEAM education.

The process of developing this manual and the work itself is a continuation of the Foundation's comprehensive Science Education program since its inception. The Foundation launched the Science Studio project, which placed emphasis on STEAM education from a design and making perspective. Through this initiative, STEAM exhibits were designed to enable children to interact with various natural phenomena while highlighting local and global socio-scientific issues. Accompanying these exhibitions were STEAM 'tinkering activities' for children and their families. Building on these achievements, the Foundation responded to the growing movement of STEAM education in Palestine by expanding its science education program to engage teachers in a professional development program on STEAM, as well as children in a Non-Formal Education program focused on STEAM. Additionally, the Foundation established a FabLab at its Cultural Building in Ramallah to serve as a central hub for STEAM clubs and activities established in schools. We hope that these initiatives will promote a collaborative and interdisciplinary approach to STEAM education and foster a network of educators and students dedicated to exploring and embracing the potential of STEAM.

Nader Wahbeh

About the Team

Dr. Nader Wahbeh

is the Senior Manager in the Education Unit at the A.M. Qattan Foundation. He earned his PhD in Science Education from the University of Illinois at Urbana Champaign in the US, and his MA and BSc in Chemistry from Birzeit University, Palestine. His focus is in-service professional development, nature of science, curriculum design and evaluation, information technology, science and early childhood.

Dr. Peter Wardrip

is an Assistant Professor of STEAM Education at the University of Wisconsin – Madison in the US. He earned his PhD in Learning Sciences and Policy from the University of Pittsburgh in the US. His research focuses on informal/formal learning collaborations, professional learning for educators, formative assessment and making as a learning process.

Peter Kirschmann

is a designer, educator, and maker interested in creating opportunities for learners to tinker, design, and create personalized and socially meaningful projects. He currently works at the University of Wisconsin School of Education as a learning designer. He holds an MA in Technology, Innovation, and Education.

Wiam Alali

is an experienced and passionate IT school teacher with love for teaching and empowering others. She acts as a facilitator of learning experiences where students share their own passions and curiosities.

Eissa Alzabat

holds a BSc in Mechatronics Engineering and an educational qualification diploma. He is responsible for the Fab Lab Club in the Child Creativity Unit in Gaza for the A.M. Qattan Foundation. His work focuses with children, adolescents, teachers, and educators in the field of learning and teaching science and training in modern education techniques in the field of critical thinking, problem solving, project learning and interactive STEAM techniques.

Tariq Abu Mariam

holds a BSc in Mechatronics Engineering in addition to a diploma in educational rehabilitation. He has seven years of practical experience in the field of creative work with children by designing and implementing a range of interventions to develop their skills. He is the administrator of the Technology & Design Club in the Child Creativity Unit in Gaza for the A.M. Qattan Foundation.

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holds a BSc in Electrical and Telecommunication Engineering from Birzeit University. She is an IT and computer teacher at Farkha Basic School for Girls and Dayr Istya Secondary School for Girls in Salfit. She is also a STEAM Education Trainer. Her favourite quotation is, ‘Life begins at the end of the comfort zone’.

Awfa Mustfa Ali Bsharat

is a teacher at Hisham Bin Abdul Malik Secondary School for Boys in Jericho. He holds a BSc in Mathematics from An-Najah National University, Faculty of Science and an MA in Mathematics Teaching Methods. He is a trainer in the field of STEAM at An-Najah National University in the preparation and training of teachers in Nablus and Salfit summer schools for STEAM Palestine at An-Najah National University for the year 2019 and 2020.

Asif Al-Khazendar

holder a bachelor degree in Computer and Software Engineering, the coordinator of the Audiovisual Arts Club at the Qattan Cultural Center in Gaza, and STEM trainer since 2016. He participated in creating educational content based on the integrated STEAM approach for the primary stage, and conducted many trainings for teachers, parents and children, and university students.

Alaa Yousef Fannoun

is a technology teacher at Umm Al-Shuhada Basic School for Boys. She studied at Al-Quds Open University and completed an MA in Teaching Methods of Mathematics. Her hope in life is to acquire the skills and education methodology that will transform education from the traditional way currently being practised in schools and to education that makes students excited and eager to learn and acquire new techniques and knowledge.

Maysa Abdel Mohdy Al Mohtaseb

holds a degree in Computer Systems Engineering. She has been a technology teacher at Taffouh Secondary School for Girls since 2013.

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Iyad Ahmed Nabtiti

is a technology teacher at Ibrahim Abu Dayyah Secondary School for Boys with fifteen years’ experience and hold a bachelor degree in information systems. He believes in the entrepreneurial teacher mindset and dedicates his time and effort to try to be a genuine success story in the field. He believes in critical thinking and teamwork. His conviction that one day our dreams will come true is his inspiration to move forward with this road map.

Samah Ouda

has been a physics and science teacher at the American International School in Gaza for fourteen years. She is proud of being part of this amazing and hard work. She credits it for changing her vision of teaching science and physics, helped her in planning relevant activities. She hopes it will be part of the syllabus in all schools to give students in Palestine an educational system that supports creativity and encourages creative people.

Yasmin Sandouka

holds a bachelor’s degree in Biology with a minor in Psychology. She is a science teacher and instructor at the Arabian Academy for Modern Education. She is interested in sustainability, TOT, educational strategies, and business. She is interested in opportunities that have an effect on community awareness and building new pedagogical methodologies and techniques for STEAM.

Eman Atallah Shatat

is a science teacher for the fourth and sixth primary stage in Khan Yunis Joint Elementary School. She loves teaching science in modern ways and is always looking for strategies that make science interesting.

About the Manual

The manual communicates STEAM Learning Principles that can serve as empirical markers for designing, facilitating and assessing STEAM learning experiences, and aids in the process of developing one's own STEAM learning principles. The learning experiences that we develop for our learners are based on what we think is important for our learners to know, do and feel. These principles were developed in partnership with a group of Palestinian educators to capture what they valued for learning and engagement in STEAM learning experiences. While frameworks such as this can be important for suggesting key elements of learning experiences, they do not need to be used 'off the shelf'. Rather, this framework, and others like it, serve as starting points for identifying what we value for learning and engagement in our own settings and what constitutes evidence of engagement in what we value.

This manual provides a description of professional learning experiences that educators can engage in with their colleagues. As STEAM naturally brings together different content areas and domains, it also joins different vocabularies, approaches to learning and ways of knowing. The professional learning experiences within this guidebook can help to bring educators together to develop STEAM projects for their students and, in so doing, develop a common language and approach to ambitious teaching and learning.

This presentation is an ongoing approach to learning that draws upon multiple disciplines. The professional learning experiences presented here can be repeated: even with the same educators participating, new creative possibilities will be discovered through these design activities.

Finally, the STEAM Learning Principles are an aspiration. As we point out in the following, innovative projects will be developed that do not adhere to all of the principles. However, like most principles, they serve to push us in the direction of providing ambitious learning experiences for our students as well as points of reflection about how we might improve on our own intentions in the future.

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STEAM Education Overview

STEAM education is an approach to teaching and learning that seeks to integrate Science, Technology, Engineering, Arts and Math. While many schools keep content areas separated, STEAM acknowledges what many of us experience in the real world: that is, learning often happens in a way that integrates or draws on multiple disciplines (Braund and Reiss, 2019). For example, when we learn to cook a new dish for dinner, we might engage in mathematics when dealing with proportions of ingredients. Or we might engage with science in working with chemical changes that happen to the food when it is cooked or in the very act of experimenting ingredients, for example, the chemical changes that occur when we bake bread. We might even use technology tools that are distributed across the kitchen, such as a tablet with recipe instructions or a video demonstrating how a dish is prepared, or appliances for baking and smaller tools that help us combine the ingredients in the dish we are preparing. Over time, we might engage in an engineering process of refining the recipe based on feedback we receive from those tasting what we cook. We might even engage with art in the presentation of the food on the plate or the table.

As we highlight in the principles that were developed for this manual, preparing a new dish offers opportunities for engagement that go beyond the STEAM content. There are also opportunities to be curious and tinker, such as adding more sugar to a cake recipe because you are fond of sweeter cakes. Cooking may create opportunities for teamwork, especially if you are preparing a meal with several dishes. Learning to cook a new dish may even create opportunities for critical thinking as you consider why the cake you have made does not look the same as the one in the video you have been using for guidance.

Learning to cook a new dish in the kitchen is just one example, but serves to highlight a larger point. Much of our learning in the real world does not make distinctions between subject areas. While the acronym STEAM presents a straightforward general vision of how these disciplines fit together in learning experiences, they can present challenges and opportunities. In a literature review of STEAM education, researchers identified a lack of clarity of how STEAM subjects are combined and implemented (Perignat and Katz-Buonincontro, 2019). What is important to acknowledge is that STEAM learning experiences seek to create real world learning experiences that combine these content areas. What we will highlight with the STEAM Learning Principles is that the context for authentic learning also creates opportunities for learners to work together, solve problems, and explore their curiosity.

STEAM Learning Frameworks

In designing and facilitating STEAM learning experiences, as in any learning experience, it is important to acknowledge the goals and intentions of that learning experience. To characterize STEAM learning, other professionals have developed frameworks to identify and characterize the kinds of learning and engagement happening during STEAM learning experiences. For some, these frameworks can serve as important guideposts for design and assessment in the STEAM learning experiences.

Below, we show two frameworks that can be useful for STEAM educators. The first (**Table 1**) is a framework of epistemic practices of the arts and sciences. Epistemic practices are what practitioners do when they encounter, create or use knowledge in their work lives. In a learning context, epistemic practices can be ways to think about what learners need to know to carry out authentic work. Bevan et al. (2020; p. 27) identify STEAM practices at the intersection of such practices in STEM with the Arts. For educators' purposes, they might use this table to design a STEAM learning experience. For instance, educators might design opportunities for learners to engage in exploratory practices like noticing, questioning and producing tentative representations. Similarly, educators might design assessments or assessment tools, like rubrics, to monitor the extent to which learners are engaged in these practices.

Table 1 A framework for epistemic practices of the arts and sciences (Bevan et al. 2020)

STEM practices	Epistemic intersections	Arts practices
Investigative practices	**Exploratory practices**	**Technical & critical practices**
• Asking questions/ defining problems • Planning and carrying out investigations • Using mathematical • and computational thinking	• Noticing and questioning • Exploring materiality • Defining the problem space/ deconstructing components • Producing tentative representations	• Looking closely • Deconstructing the parts of the text (at a literal level) and the meaning behind the text
Sense-making practices	**Meaning-making practices**	**Creative practices**
• Developing and using models • Analyzing and interpreting data • Constructing • explanations/ designing solutions	• Principled iterations/ revisions (responding to feedback) • Considering multiple approaches • Engaging multiple modalities • Finding relevance • Adopting a critical stance	• Applying artistic principles to augment meaning • Designing interrelations within and across multiple sign systems • Referencing or combining existing works and ideas

Critiquing practices	Critiquing practices	Ethical practices
• Arguing from evidence/ peer review • Evaluating and communicating findings	• Sharing results • Hacking the ideas of others • Engaging in critical reviews • Cultivating dissent • Holding commitments to standards of the field	• Negotiating what constitutes a "good" project • Given a particular artistic goal, evaluating how successfully this goal has been met

As another example framework, Quigley et al. (2017) developed a STEAM teaching model (**Table 2**). This framework offers dimensions related to the instructional content and the learning context. Related to each of those dimensions, criteria are provided to more clearly articulate examples of each dimension. For example, as teachers design and enact assessment practices in their teaching, the criteria suggest that those assessment practices include elements such as regular feedback, authentic alignment to the real-world project context and opportunities for student reflection. While the Bevan et al. framework is focused on what the learners will be doing during STEAM learning, the Quigley et al. framework is focused on what teachers do to create the conditions for STEAM learning. In general, teaching and learning frameworks are tools to focus our attention and thinking on certain elements of practice. Both of these can be used separately, or together, to guide the planning and reflection for STEAM learning experiences.

Table 2 Overview of STEAM Teaching Model (Quigley et al. 2017)

Domains	Dimensions	Brief Definition	Criteria
Instructional content	Problem-based delivery	This dimension captures the ways in which teachers deliver materials from multiple disciplines in real-world problem-based ways— including concepts, methods, and approaches— and how they support the learning objectives	• Problem-focused instruction • Content purpose • Standards alignment • Discipline consideration
	Discipline integration	This dimension captures the ways in which teacher present material from multiple disciplines or content areas (science, technology, engineering, arts, and math) in clear and connected ways.	• Content connection • Instructional strategies • Synthesis across the disciplines
	Problem- solving skills	This dimension captures the ways in which teachers foster developing the underlying skills that are needed for effective problem solving.	• Cognitive skills • Interactional skills • Creative skills
Learning context	Instructional approaches	This dimension captures the ways in which teachers structure the classroom environment, tasks, and resources to facilitate deep learning.	• Inquiry rich • Multiple domains • Technology integration
	Assessment practices	This dimension captures the iterative process of refining instruction and evaluating learning in a real-world context using multiple forms of data.	• Authentic alignment • Regular feedback • Data driven adjustments • Student reflection
	Equitable participation	This dimension captures the ways in which the classroom facilitates access and engagement in learning for all students, with specific attention to abilities and resources.	• Task relevance • Diversity appreciation • Responsiveness • Student choice

Acknowledging the importance of these frameworks as a point of reference to build upon, we embarked on developing our own framework for STEAM learning, which we briefly articulate in the next section. Later in the manual, we provide a description of our process. We encourage educators to use these aforementioned frameworks, as well as our framework and other frameworks that they come across as starting points as they characterize STEAM learning in their context.

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Our STEAM Learning Framework

As a project team, we sought to develop our own framework while acknowledging the many frameworks available and building on previous work of educators who identify what they value for learning and engagement (for example, Wardrip et al., 2017 and Wardrip and Brahms, 2016). In developing our own framework, we first defined STEAM learning for our own work and clarified the kinds of learning and engagement relevant to the Palestinian context. Through this process we developed a common language and vocabulary for STEAM learning and engagement.

For readers of this manual, the STEAM Learning Principles can be useful in a few ways. First, these principles can serve to guide the design and assessment of STEAM learning in your own setting. Second, the principles can be used as a tool to reflect on the extent to which learners in your own setting are engaged in these behaviours, the extent to which educators are facilitators and/or the ways in which the curriculum supports engagement in the principles. Finally, the STEAM Learning Principles can serve as a starting point for the development of your own framework. We noticed that there were similarities between our principles and other frameworks in the field. Later in this guidebook, we describe the iterative process we used to develop the STEAM Learning Principles.

STEAM Learning Principles

Teacher

Teacher as Facilitator: guiding student inquiry, dialogue, and thinking.

Student

Collaboration and Teamwork: Learners have opportunities to work together. It is a 'group-worthy' task.

Critical Thinking: Learners have the opportunity to analyse and evaluate evidence to form a judgment.

Curiosity and Tinkering: Learners have opportunities to explore materials, ideas, and phenomena in new and novel ways.

Curriculum

Relation of STEAM + Social Issues: The activity connects content learning to things important to the learner's real life.

Hands-on and/or Project Based: Learners actively construct a project and their own understanding through the activity.

Student-centred: Learners have the opportunity to choose the content and methods of their learning.

Interdisciplinary (Integrated): The activity brings together STEM content with social studies, art, or language arts in deep and meaningful ways.

STEAM Learning Case Studies

We provide two concrete examples of STEAM learning projects that were designed and implemented by members of our core team of teachers. These cases are not intended to be put forth as examples (although we think they are great), but they do provide a more specific example of what we mean by the STEAM Learning Principles listed above.

Case 1: Conductive Play Dough

The content goal of this project is to introduce electricity basics to fourth-grade students using conductive and insulating play dough. Before starting this activity, students are divided into groups to explicitly create opportunities for the students to work together or in teams. The project is broken into five activities.

First Activity: Making the play dough and mixing the colours

The teacher starts by providing the groups with the recipe (squishycircuits.com/pages/dough-recipes) and the work guidelines. The students start making the play dough under the supervision of the teacher. The teacher plays the role of facilitator while the groups of students work. In addition, the teacher connects what the students are doing with some mathematical concepts they have recently worked on, such as measurements and fractions, including adding fractions. When the students finish making the play dough, they can create different colours by making mixtures of the three primary colours (yellow, blue and red). This reinforces art content for the student. The teacher attracts the students' attention to the learning goal by asking, 'What is the difference between the two kinds of play dough we have just made?' This question can encourage the students' curiosity and their further investigations in the coming sessions.

Second Activity: Building the circuit

The main goal of the second activity is to learn about open and closed circuits and the components of a simple circuit. The teacher starts by providing the groups with the needed materials. After giving the students guidelines about the materials, the students build their simple circuits using the conductive play dough. The teacher raises the challenge by adding more LEDs and electrical components to the circuit.

At this point, students use the trial and error approach to test their assumptions. The teacher continues their role as facilitator, not giving explicit answers, but encouraging exploration and calling attention to other students as resources for questions. This space gives the students the freedom to explore the materials and build their own ideas. The intention is to appropriately challenge students to gradually push what they know and can do with circuits.

Third activity: Insulating and conductive materials

For the third activity, the groups of students are provided conductive play dough and LED lights as well as objects of different materials (wood, metal, leather, paper, etc). The students are asked to build an open circuit using the conductive play dough and use the different objects they have to close it and test if it works or not. The teacher introduces the words 'conductive' and 'insulating.' The students classify the materials into these two groups. The teacher may conduct an experiment with both salty and sugary solutions and their respective electric behaviour to help students explain the conductivity of the dough. When the students classify their materials, if they reach contradicting results, the teacher may facilitate a debate during which the students can support their claims using the scientific evidence from their work. This activity reinforces the students' critical thinking by letting them build their conclusions based on scientific evidence. The students have the opportunity to explore, examine and classify the materials by themselves.

Fourth activity: Building the 3D logo of the team

Before assigning the final mission, the teacher builds the teams' identities by asking the teams to work together on a 3D logo that reflects the goals, achievements, findings or beliefs of each team. Again, this specifically addresses and reinforces the experience of collaboration for the students. The 3D logo is to be built using the conductive and insulating play dough and any electric components they choose (LEDs, buzzers, motors, etc.). The students can play with form, colour, and shape in an artful way. Finally, the students have the chance to present their work in front of their classmates. This addresses the principle of communication as the students present what they made, how they made it and what it means.

Fifth Activity: Raise awareness about using electricity safely

The focus of the last activity is for students to find out how to use electricity safely. To do this, they may search the internet, read or ask experts. Once they have gathered information and guidance for using electricity safely, the students' task is to start an awareness campaign in the school. Each team decides who will be their target audience and how they will spread awareness about safety. Some examples of what some students have done include performing a play, designing a brochure, making a drawing, singing a song, or making a presentation.

Case 2: AI Technology to Solve Problems

The setting for this example is a student technology club in Gaza, where students are learning about Artificial Intelligence (AI). In the club, the students think about how to use AI Technology to solve problems in their life. As a group, these students worked together to identify the best solution to optimize a SMART GARAGE through AI. Specifically, they sought to implement an intelligent system to open the garage door automatically through a camera that detects the license plate and type of the car.

The project was implemented by student members of the technology club, through the following activities:

First, the students were divided into teams to purposefully create chances for the students to collaborate together. Within the groups, the students brainstormed problems that they noticed in their lives and in their community that could yield opportunities for finding solutions. Having the students themselves identify the problems ensured that the learning activity was student-centred. Once the problem was identified, the students divided their team's responsibilities and tested out their ideas for solving the problem. The role of facilitator is to support the children to assume responsibilities in their groups and to provide feedback to the children on how they are collaborating together. The students also maintain a file to monitor the progress of the implementation process of their project.

With the students involved in the project, the teacher as facilitator helps and guides the children through the process of implementation. They can also assist students in their methods of research, and their learning through exploration. Ultimately, the project seeks to keep the children at the centre of the work. The problem to be addressed in the project is what the children have identified and the children develop their own ways to address the problem of opening the garage door.

4

STEAM Learning Processes

This section provides a set of activities and processes for building, understanding and practicing a set of STEAM Learning Principles. They are intended for a community of educators working in person and can be sequenced or scaled to be used over the course of a few hours or a few days. They are divided into two categories:

Make, Share, Reflect Activities

Constructionist learning philosopher Seymour Papert said, "You can't think about thinking without thinking about something." The Make, Share, Reflect activities provide a structure for educators to think about STEAM learning and their own practice. As such, the activities included in this section are not intended to be facilitated as written with young learners (although they can be), but rather they provide a context for professional learning and building an understanding of the STEAM Learning Principles. As the words indicate, each activity will provide educators with an opportunity to make something, share what they made and then reflect on what they have made.

These activities provide an opportunity for learners to make a learning artefact independently or with others (a comic, bridge, model, etc.) and share it with the larger group. Learners are then prompted to reflect on how the STEAM Learning Principles are represented or demonstrated in the activity and ideate modifications to better integrate the principles. For example, in one of the activities participants were given a design challenge to construct a bridge out of simple materials that would span across two tables and hold weight. After constructing and sharing their bridges with the group, the teachers engaged in reflection using the provided STEAM Learning Principles evaluation form (see page 32). The activity provided strong evidence of some of the principles but did not generate evidence of the full list such as Relation of STEM+Social Issues. During the ideation time, teachers brainstormed ways that the activity might be contextualized within a local issue to better align with that principle.

When engaging in these activities in your own professional learning setting, you can use the provided STEAM rubric or use your own set of learning principles.

STEAM Design Activities

The STEAM Design activities are a set of scaffolds and activities that can be used by educators to plan STEAM Learning Activities, either individual lessons or full units. The tools align with the STEAM Learning Principles (including the rubric) but could be used with a variety of STEAM learning or project-based learning frameworks.

This section includes the Learning Activity Planner, which is a scaffold-like tool that can be used to plan STEAM Learning Activities ranging from a drop-in or one-day experience or a multiweek unit plan. This tool is crucial because, much like STEAM (and similarly Maker) education, it provides both a tool that teachers can use to plan future activities but also a context in which teachers can explore and better understand the STEAM Learning Principles.

The original implementation of these activities took place in August 2022 at the A.M. Qattan Foundation Cultural Centre, and were facilitated with the STEAM core team of educators.

STEAM Learning Principles Evaluation Form (also called: Single Point Rubric)

Activity:

Evidence of Criteria	STEAM Learning Principles Criteria	Opportunities for Improvement
	The Facilitator	
	Teacher as Facilitator: guiding student inquiry, dialogue, and thinking.	
	The Learner	
	Collaboration and Teamwork: Learners have opportunities to work together. It is a 'group-worthy' task.	
	Critical Thinking: Learners have the opportunity to analyse and evaluate evidence to form a judgment.	
	Curiosity and Tinkering: Learners have opportunities to explore materials, ideas, and phenomena in new and novel ways.	
	The Curriculum	
	Relation of STEM + Social Issues: The activity connects content learning to issues important to the learner's real life.	
	Hands-on and/or project-based: Learners actively construct a project and develop their own understanding through the activity.	
	Student-centred: Learners have the opportunity to choose the content and methods of their learning.	
	Interdisciplinary (integrated): The activity brings together STEM content with social studies, art, or language arts in deep and meaningful ways.	

Make, Share, Reflect: Sister Images

In Sister Images participants create a 4-frame autobiographical comic based on evocative learning experiences from their past. It is called Sister Images because the comic consists of two drawings that are related or connected to each other. This version is adapted from an activity created by Lynda Barry.

Overview

Time	40–50 minutes
Group Size	Flexible. Small groups of 4 to 5 for larger workshops.
Slides	MSR: Sister Images*.
Purpose(s)	• Team building and getting to know other workshop participants. • Elicit participants' prior experiences of powerful, curiosity-driven, interdisciplinary learning.
Supplies	• Blank paper • Pens or pencils • Timer • Background music (optional, to play while drawing)

Timeline

Time	Activity
5 min	**Introduce Activity and 'Noodle Arms' Drawing Technique** *Slide 2:* Lynda Barry is a comic artist and professor of Interdisciplinary Creativity at University of Wisconsin – Madison. In 2019, she received a MacArthur Genius Grant and has authored several books on her method and pedagogy. She talks about how everyone is an artist and creative when they are young and that her comic making activities attempt to encourage people to get back to the creativity they experienced as a child. This activity is adapted from one in her 2019 book *Making Comics*. *Slides 3-5:* She encourages students to use a technique introduced by cartoonist and comics scholar Ivan Brunetti. • Start with a large head and connected body. • Add 'Noodle Arms'. • Then fill in details, with things like eyebrows adding a lot of emotion. This technique is more expressive than using stick figures.

* https://docs.google.com/presentation/d/1qW5te1VSZYIcA2BBHxqYgZvYMex8grzwHPjTMv14bL8/edit#slide=id.g1462b58069e_0_45

20 min	**Make | Sister Images** *Slide 6:* Start by drawing four empty frames on a blank sheet of paper. This will be our comic. *Slide 7:* In the first frame, draw a powerful, curiosity-driven learning experience that you had as a child. Draw your whole body and face. If you get stuck, keep your pen moving. You have 5 minutes. *Slide 8:* In the second frame write about what is happening using the first person and present tense. You have 3 minutes. *Slide 9:* Look at your drawing in the first frame. Draw something you have done in the last month that reminds you of that image. It could be, for example, thematically linked or linked to the physical position that your body is in. Again, draw your whole body and face. If you get stuck, keep your pen moving. You have 5 minutes. *Slide 10:* In the fourth frame, again write about what is happening in the drawing in the first person, present tense. You have 3 minutes. *Slide 11:* Finally, label each picture with the season and approximate year.
10-15 min	**Share | Sister Images** *Slide 12:* Depending on the size of the group and amount of time available, share your comics in small groups or as a whole group.
5-10 min	**Reflect | Sister Images** *Slide 13:* Were there themes or commonalities that emerged from your stories? Themes you can call out or elevate: ● Driven by learner interest ● Joyful, fun, exciting ● Interdisciplinary ● Connection to community or family

Sources and Additional Resources

Adapted from 'Sister Images' activity in: Lynda Barry, Making Comics, Drawn & Quarterly, 2019.

Make, Share, Reflect: Bridge Building

Bridge building, a common activity in STEM or engineering classrooms, is used as an opportunity to explore the STEAM Learning Principles. Participants work in small groups to construct bridges based on given criteria.

This activity offers a context to discuss the presence or absence of the STEAM Learning Principles as well as how you can redesign an experience to better incorporate the principles.

Overview

Time	75–90 minutes
Group Size	Flexible. Participants work in small groups of 3 to 5.
Slides	MSR | Bridge Building*.
Purpose(s)	Participants build an understanding of the STEAM Learning Principles. Participants discuss opportunities to modify existing activities to better incorporate STEAM Learning Principles.
Supplies	Materials can be based on what is available in a given context, but should include structural materials as well as adhesives/connecting materials. This might include: ● Cardboard ● Popsicle sticks ● Pipe cleaners ● Fabric scraps ● Other recyclable materials ● Hot glue guns ● Duct tape ● Masking tape You will also need a space to test the bridges and reflect on the activity: ● Two tables, or other flat surfaces, spaced approximately 50 cm apart. ● Weights (heavy books, rocks, etc.) ● STEAM Learning Principles rubric (1 copy per participant)

* https://docs.google.com/presentation/d/1NSFWiaxduLli9XkROYwEP9sj1DK9SoXUQikZUWy-_os/edit#slide=id.g13815d5bf65_0_0

Timeline

Time	Activity
5 min	**Introduce Activity** *Slide 1:* We will now engage in a common engineering challenge. The purpose of engaging in this activity together is to provide a context to further explore our STEAM Learning Principles. *Slides 2:* Your task is to work in teams to create a bridge that spans these two tables and holds as much weight as possible. You will have 30 minutes to construct the bridge. You may test your designs using the tables and weights.
30 min	**Make | Bridge Building** Facilitators may circulate to offer feedback to the groups as they build, reminding teams to test their designs. The facilitator also can simply observe the groups in action.
10-15 min	**Share | Bridge Building** Give each group the opportunity to place their bridge across the span and slowly add weights. You may formally measure the amount of weight that each structure holds or simply let this be a presentation for the rest of the group. Timing will depend on the number of small groups who are participating.
30-45 min	**Reflect | Bridge Building** *Slide 3:* Individually, spend 5-10 minutes with the STEAM Learning Principles Rubric first identifying specific evidence of each principle that you can see in the design, facilitation, and implementation of the activity. Then focus on the right side, what opportunities for improvement are there? (If you have less time, ask participants to focus on the one or two principles they see the most and least evidence of in the activity.) *Slide 4:* With a partner or small group, compare your rubrics. Discuss 3-4 modifications you might make to the activity based on your observations. *Slide 5:* As a whole group, what patterns have emerged from the conversations? Was there anything surprising? What new understandings (or questions) do you have about any specific of the STEAM Learning Principles.

Make, Share, Reflect | Monument Design

Monument Design engages participants in an interdisciplinary (engineering, design, humanities, mathematics) hands-on making project. Participants work in teams to design and prototype a monument to commemorate a historic person, event, or idea.

It is an opportunity to explore the STEAM Learning Principles. The activity offers a context to discuss the presence or absence of the STEAM Learning Principles, and is designed to include more evidence of the principles than the previous Bridge Building activity.

Overview

Time	120 minutes
Group Size	Flexible. Participants work in small groups of 3 to 5.
Slides	MSR | Monument Design*.
Purpose(s)	• Participants build an understanding of the STEAM Learning Principles. • Participants discuss opportunities to modify existing activities to improve incorporation of STEAM Learning Principles.
Supplies	Materials can be based on what is available in a given context, but should include structural materials and crafting materials. This might include: • Cardboard • Popsicle sticks • Pipe cleaners • Fabric scraps • Googly eyes • Clay • Other recyclable materials • Hot glue guns • Duct tape • Masking tape It can be helpful to provide bases that monument prototypes can be built upon and rubrics that reflect on the activity: • Larger pieces of cardboard • STEAM Learning Principles rubric (1 copy per participant)

* https://docs.google.com/presentation/d/1AuwAXDvIEwyDdSdVBwZgL6CHOZ0y1gXACGBcZViiqFM/edit#slide=id.g13815d5bf65_0_4

Timeline

Time	Activity
10 minutes	**Introduce Activity** *Slide 1:* We will now engage in a hands-on activity. The purpose of engaging in this activity together is to provide a context to further explore our STEAM Learning Principles. *Slides 2:* Your task will be to design a monument that commemorates a notable person, event, or idea. Monuments can take many forms. *Slide 3:* Desmond Tutu Memorial Arch | Capetown, South Africa. The arch consists of 14 intertwined strands of bent wood, representing the 14 chapters of the South African constitution. Together the arching wooden elements inscribe a globe, celebrating Archbishop Tutu›s role as a unifying figure for the international peace movement. *Slide 4:* Leila Miqdadi Al-Qattan Library | Ramallah, Palestine. Library commemorating Leila Miqdadi, one of the pioneering women in charitable and social work in Palestine and the Arab World. The library is at the A. M. Qattan Foundation. *Slide 5:* Memorial to Those Who Saved the World | Chernobyl, Ukraine. A monument in Chernobyl, Ukraine, to the firefighters who died putting out the fire at the Chernobyl Nuclear Power Plant in 1986 after the catastrophic nuclear accident. *Slide 6:* Victims of Lynching Memorial | Birmingham, USA. Memorial of African Americans killed by acts of racial terror in the United States. Each jar is filled with soil from the site of a lynching or murder, and labeled with the name and location of the individual who was killed. The memorial is part of the Equal Justice Initiative Legacy Museum. *Slide 7:* Taj Mahal | Agra, India. An Islamic ivory-white marble mausoleum constructed by the Mughal emperor Shah Jahan (r. 1628–1658) to house the tomb of his wife, Mumtaz Mahal. Construction began in 1632 and continued for years. *Slide 8:* Full group: What monuments are in your city or neighbourhood? What do they represent?

60 min	**Make | Monument Design** *Slide 9:* Your team is offered a unique opportunity to design and create a tribute to a historic figure, event, or idea. You get to choose whom to honour, how to honour them, and what to create. The tribute monument – which can take the shape of a poem, monument, statue, museum, anything – must: ● Be on public display ● Be able to withstand outdoor elements (rain, wind, varying temperatures, etc.) ● Designed and secured in a way that thwarts theft. Take 20 minutes with your team to first discuss and design, then 40 minutes to build a physical model of your monument.
10-15 min	**Share | Monument Design** *Slide 10:* Let each group share what they made, answering the following questions. ● What did you make? ● Where would it be? ● How is it weather and theft proof? Timing will depend on the number of small groups who are participating.
30-45 minutes	**Reflect | Monument Design** *Slide 11:* Individually, spend 5 to10 minutes with the STEAM Learning Principles rubric, first identifying specific evidence of each principle that you can see in the design, facilitation, and implementation of the activity. Then focus on the right side, what opportunities for improvement are there? (If you have less time, ask participants to focus on the 1 or 2 principles they see the most and least evidence of in the activity.) *Slide 12:* With a partner or small group, compare your rubrics. Discuss 3 or 4 modifications you might make to the activity based on your observations. *Slide 13:* As a whole group, what patterns have emerged from the conversations? Was there anything surprising? What new understandings (or questions) do you have about any specific of the STEAM Learning Principles?

Sources and Additional Resources

Adapted from: 'Eighth Graders Design Monuments to Historic Figures' by Heather Allen Pang. Pang-Monument.pdf*

* https://drive.google.com/file/d/1MdarTO8H8m0GWt6FWrFghsafN9F-tBL3/view

Make, Share, Reflect | Thinking Routines

Thinking routines are structures that help focus student thinking and specifically develop core capacities. In this activity, participants try out the thinking routine “Parts, Purposes, and Complexities” and discuss the affordances of using the practice.

Overview

Time	75–120 minutes
Group Size	Flexible. Participants work in small groups of 3 to 5.
Slides	MSR | Thinking Routines* (We used flowers instead of pens.).
Purpose(s)	• Participants build an understanding of how thinking routines provide an opportunity for students to build key skills that support STEAM learning. • Participants discuss how they might integrate thinking routines into their existing practice.
Supplies	• Flowers, one stem per 1 to 3 participants • Tools for taking apart (sharp knives, tweezers, etc.) • Tools to look closely (digital microscope, hand lens, etc.) • Large sheets of paper • Tape or glue • Markers • STEAM Learning Principles rubric (1 copy per participant)

* https://docs.google.com/presentation/d/1MfZ6wrc5uBSmRUi04RUCidtmCpW5xHV59ZASagQu06A/edit#slide=id.g1382277aebf_0_89

Timeline

Time	Activity
5 minutes	**Introduce Activity** *Slide 2:* Thinking routines are structures that help focus student thinking and specifically develop core capacities. In this activity, we will try the thinking routine ‘Parts, Purposes, and Complexities’ and discuss the affordances of using this practice. *Slide 3:* ‘Parts, Purposes, and Complexities’ guides inquiry to understand systems, and how pieces of a system work together to create a whole. *Slide 4:* In this example, students took apart different ballpoint pens and made inferences about how the parts work together to create something that allows a user to write. *Slide 5:* Thinking Routines fit into a larger framework created by the Agency by Design team at the Harvard Graduate School of Education. This thinking routine provides an opportunity for students to slow down and look closely at a system. This close exploration allows students to explore the complexity and inner workings of a system. This exploration can lead to students finding opportunities to change, modify, redesign the system. These systems can be the technology tools such as a pen, the functioning of your school’s cafeteria, or larger city or nationwide systems. *Slide 6:* Today we will be taking apart flowers to explore the biological system. You will carefully take apart the flower and make observations about all of the small pieces present. Lay the parts onto your large sheet of paper, label each (technical language is not important here), describe its purpose, and using arrows or shapes to explore how the pieces work together to form a system.
30 minutes	**Make | Parts, Purposes, and Complexities** Facilitators may ask participants questions that encourage them to slow down, look more closely, and explore the complexities of the system.
10-15 minutes	**Share | Parts, Purposes, and Complexities** Hang papers on the wall (if possible) or clear off tables and display the papers on top. Allow time for a gallery walk for participants to explore the different ways that the task was approached.

30-45 minutes	**Reflect | Parts, Purposes, and Complexities** *Slide 7:* Individually, spend 5 to 10 minutes with the STEAM Learning Principles rubric, first identifying specific evidence of each principle that you can see in the design, facilitation, and implementation of the activity. Then focus on the right side, what opportunities for improvement are there? (If you have less time, ask participants to focus on the 1 or 2 principles they see the most and least evidence of in the activity.) *Slide 8:* With a partner or small group, compare your rubrics. Discuss how you might integrate thinking routines into a larger activity to support students. *Slide 9:* As a whole group, what patterns have emerged from the conversations? Was there anything surprising? What new understandings (or questions) do you have about any specific of the STEAM Learning Principles.

Sources and Additional Resources:
Agency by Design: Thinking Routines + Tools + Practices*

* https://pz.harvard.edu/search/resources?f%5B0%5D=sm_field_resource_type%3ATool

Make, Share, Reflect | Technology Playground

Participants are given demonstrations of a variety of different technology tools available for integration into STEAM classrooms. They have the opportunity to explore tools of interest, and then reflect on how they might use these tools to support the STEAM Learning Principles.

Tools and technologies can vary depending on what is available and the experience and comfort of the facilitator. The facilitator does not have to be an expert with the tools; they just need to know enough to do a basic introduction and participants can explore using web resources to go deeper.

Overview

Time	75–90 minutes
Group Size	Flexible, depending on the number of stations and technologies.
Slides	N/A
Purpose(s)	• Participants are introduced to a variety of materials and tools available that can be integrated into STEAM activities. • Participants consider the affordances of different tools and strategies that can be used to enhance STEAM learning.
Supplies	Tools can vary based on what is available. Below are some suggestions but others can be used as well. Software: • Scratch (https://scratch.mit.edu/) • PictoBlox (https://thestempedia.com/product/pictoblox/) • Teachable Machine (https://teachablemachine.withgoogle.com/) Hardware: • MaKey MaKey (https://makeymakey.com/) • MicroBit (https://microbit.org/) • Raspberry Pi (https://www.raspberrypi.org/) • Arduino (https://www.arduino.cc/) • Robotics Kits • Basic Circuitry Materials (LEDs, batteries, breadboards, switches, etc.) Materials to reflect on tools: • STEAM Learning Principles rubric (1 copy per participant)

Timeline

Time	Activity
5 minutes	**Introduce Activity** The purpose of the activity is to be introduced to a range of different educational technologies and explore the different affordances of each. The goal is not to become an expert on any individual software or tool. Spend about 5 minutes demonstrating each of the selected tools, showing an example of what is possible or what a participant might explore.
30–45 minutes	**Make | Technology Playground** Give participants the opportunity to tinker and explore with the different tools. Participants may choose to go deep and work on a project with a single tool for the given amount of time or to try multiple tools.
10–15 minutes	**Share | Technology Playground** Give time for each participant or small group to share back to the whole group (or in smaller groups, depending on the number of participants) answers to the following questions: ● What did you make or do? ● What is one thing that you noticed? ● What is one thing that left you wondering?
30–45 minutes	**Reflect | Technology Playground** Using the STEAM Learning Principles rubric, have individuals or small groups pick one of the available technology tools. Identify 2 or 3 of the principles which the tool would make most possible and 1 or 2 which the tool may not support as well. As a whole group, what patterns have emerged from the conversations? Was there anything surprising? What new understandings (or questions) do you have about any specific of the STEAM Learning Principles.

Sources and Additional Resources:

‘Designing for Tinkerability’ by Eric Rosenbaum and Mitchel Resnick, from Design, Make, Play. 2013.https://web.media.mit.edu/~mres/papers/designing-for-tinkerability.pdf

STEAM Design | Learning Activity Planner

Spark	Driving Problem or Question
A real world inspiration that drives the project. This could be based on a hobby or interest as a teacher, a student interest, a current event, or another source.	*What problem or question is driving your lesson? It should enable students to engage in ongoing inquiry and exploration through your project.*

Product	Exhibition / Audience
What the students make to show their learning or understanding. This can be very open-ended (a general solution to a design problem) or more specific to target a learning goal (a letter to a government official to encourage writing and literacy skills).	*Who will see the product and how? This may be as part of a bigger student showcase at a school or community event, or could be a very specific group.*

Learning Targets / Goals	
Discipline, specific skills, understandings, and dispositions.	*Non-disciplinary skills (21c skills, future ready skills) informed by your vision of student success.*

Pause: Now is a good time to test your activity in two ways

1. Check your activity based on the STEAM Framework.
   a. Which elements are present in how you are thinking about your activity?
   b. What iterations or redesigns are needed to better meet these design principles?
2. Make a prototype of the project you would expect learners to make.
   a. As you are working, are you focused on the driving question and learning targets?
   b. If not, how might you iterate or redesign the activity to support the learner?

Project Timeline

- How will you introduce this project to the learners?
- When are there opportunities for learners to give and receive feedback from mentors and peers?
- How will they share what they have made?

Timing	Activity / Action

What ways are there to adapt and extend this project to meet the needs, interests, and abilities of your particular learning community? What opportunities are there for each of the following:

Student Centred
How does this project build upon the perspectives and interests of the learners? How can they bring those perspectives and interests into their projects?

Project Scaffolds	Project Extension
What tools, techniques, or protocols might you use to support learners as they engage in this project?	*What opportunities are there for learners to go beyond the project as you have designed it, to take their learning deeper?*

STEAM Design | Spark Walk

A Spark is the real world inspiration that drives a STEAM project or lesson. This could be based on a hobby or interest as a teacher, a student interest, a current event, or another source.

This design scaffold encourages teacher-designers to look closely around them to practice noticing and identifying sparks.

Overview

Time	60 minutes
Group Size	Flexible
Slides	N/A
Purpose(s)	• Understand that sparks can come from anywhere, and that grounding lessons and projects in the world around us increases engagement and motivation. • Practice looking for sparks in the immediate environment.
Supplies	• Paper to document • Camera / phone (optional)

Timeline

Time	Activity
5 minutes	**Introduce Activity** Introduce the idea of a spark, the real world inspiration that drives a STEAM project or lesson. This could be based on a hobby or interest as a teacher, a student interest, a current event, or another source. These sparks are then tied to a driving question or content theme to build out a lesson. Give some examples from your experience or context. For instance: ● After seeing traditional embroidery at a craft market, you develop a STEAM lesson for your geometry class on patterns, shapes, and design. ● After talking to a student about family they have abroad, you work with students on a digital mapping project about immigration and diaspora around the world. Sparks can be anywhere. In this activity, participants will walk around the immediate area (building, school, neighbourhood) and identify potential sparks for projects. They can capture these sparks by writing them down or taking a picture with their phone. Examples: ● Seeing innovative shades blocking the sun outside the building's window, you may ask: What are ways that architecture and design can be used to make buildings more comfortable and energy efficient? ● Seeing a coffee spill on the floor, you may ask: How might we mix/make our own paints, inks, dyes to make art from materials around the house? ● Seeing an olive tree in a large planter on wheels, you may ask: How can we make it easier and more accessible for people to grow their own food even when they don't have a lot of space?
20 minutes	**Spark Walk** Individually or in teams, participants take a walk around and identify 2 or 3 sparks in the environment.
10–15 minutes	**Share** Give each individual or small group the chance to share 1 or 2 of the sparks they identified along with the question or idea for a project based on the spark.
10 minutes	**Reflect** In journals, spend time reflecting on the question: ● What is a personal interest or experience I have had that I could develop into a STEAM project? ● What is an interest or passion that my students have shared with me that I could develop into a STEAM project?

STEAM Design | Red, Yellow, Green Feedback Protocol

Use this protocol to give feedback on whole STEAM units, project prototypes, or adapt to use with students while they are working on their own STEAM projects. This protocol was adapted from the Creative Computing Curriculum from the Harvard Graduate School of Education.

PARTS OF THE PROJECT THAT MIGHT BE HELPFUL TO THINK ABOUT:

- Connection between the SPARK and the PRODUCT
- Connection between the PRODUCT and the LEARNING GOALS
- Which STEAM Learning Principles are present? Which could be brought in more?

RED, YELLOW, GREEN: Add a detailed comment for each row after thoroughly thinking about the project and seeing any prototypes. The goal of the exercise is to help improve each other's projects and so provide constructive criticism in a manner that recognizes the designer's efforts.

[RED] What are 1 or 2 things that could be improved?	
[YELLOW] What are 1 or 2 things that are confusing or could be done differently?	
[GREEN] What are 1 or 2 things that work well or you really like about the project?	

5

Developing Our Framework

Our STEAM Learning Principles were developed over a series of virtual meetings and asynchronous work by a team of educators and researchers in the spring and summer of 2022. In this section, we will describe some of the activities and methods we used to develop our set of principles and better understand them. For each meeting, a longer agenda was planned but thoughtful discussions over Zoom (and across languages) takes time. This represents what actually happened in each of our one- to two-hour Zoom sessions. The purpose of this section is both to document the creation of this framework as well as provide inspiration for learning communities who may want to develop their own frameworks. This might be a helpful activity for other teachers and STEAM trainers that support teaching and learning.

Co-design Team

Research and Learning Design: The process and documentation was primarily facilitated by Dr. Peter Wardrip, Professor of STEAM Education at UW – Madison and Peter Kirschmann, a learning designer and educator. Wardrip and Kirschmann drew from their experience working with teachers, museums, and libraries to guide the process, create opportunities for educators to share their own best practices, and document and assemble the principles and manual.

A. M. Qattan Foundation Staff: Dr. Nader Wahbeh, Education Unit Director, provided an initial vision, assembled the overall team, and provided facilitation.

Teachers: Teachers on the team were recruited from a larger group of teachers already involved in "Creative child, Bright Future" at the Qattan Foundation which is co-funded by Drosos. The teachers joined from across the West Bank and Gaza and brought a deep knowledge of the local education context, their communities, and students.

Design Activities

Activity 1: Accessing Prior Knowledge of STEAM

The first activity took advantage of the co-design educators' prior experience with interdisciplinary and student-centred learning. Originally designed to take place in one hour-long meeting, the rich conversations took longer than anticipated, requiring two hour-long Zoom meetings.

Agenda:

- *Small Group Discussion about STEAM education*. In groups of 3 or 4, team members discussed a set of questions and took notes on a virtual whiteboard (for this project we used Google Jamboard) for ten minutes. The teachers' prior experience with interdisciplinary learning together led to productive and wide-ranging conversations. The conversations used the following prompts:

💭 **What is STEAM?**
✨ **What are elements of high quality STEAM learning experiences?**
👀 **What does it look like when a STEAM learning experience is going well?**

- *Large Group Report Back and Clustering of STEAM Elements*. Breakout rooms shared the virtual sticky notes they had generated. The group was given an opportunity to ask clarifying questions and provide additional context. The sticky notes were then clustered by emerging themes.

What is STEAM?

Employing scientific knowledge	Project based learning	Project based learning	Student centered learning	Celebration success	Exploration	Partnerships beyond the class-room(teachers, parents, com-munity, experts, etc...)
Art as a tool	Real educating and evaluating	The elements: learner, educator, challenge, curriculum	Creative environment	project based learning	Teacher as a part of the team (class)	Problem solving
Applied science	Inquiry	Cooperation	Merging students with different interests	Integration	Removing limitations of classroom and replacing with wonder	Positive attitudes toward learning
Appreciate science and technogogly	Critical thinking	Art and science hobbies	Considering the different learning identities of the students	Trial and error	Curriculum integration	Guiding students inquiries, dialogs and thinking
Sharing, collaborating	Away from theory	Investing students abilities	Team work	Self intiated learning	Helping to plan	Integration of many fields
Wider perspective of science	Fun	Hands-on activities	Team WorkProjects	Problem solving	Teacher as a facilitator	Problem solving
Educational approach where many topics (science, Technology, engineering, math and Art) are being studied collaporatively	Critical thinking	Motivation	Challenges	Exploration and play	Collaporation	Design thinking

Clustered virtual sticky notes generated by the core team.

Meeting 2: Naming and Collaging the Clusters

Agenda:

- *Small Group Naming of STEAM Element Clusters*. Before the meeting, the facilitators finished grouping all of the available virtual sticky notes and gave each of the clusters a label using an emoji. Emojis were intentionally used, rather than giving each cluster a name such as 'teamwork' so that each cluster had a shorthand way to identify it without giving it meaning. For example, 'The apple group has four ideas in it.' This left room for the teachers to make their own meaning of the virtual sticky notes. In small groups, teachers were prompted to give a name to each of the clusters that could be an answer to the question "What is a principle, or quality of good STEAM learning?" The purpose of this activity was to build consensus among the group about what good STEAM learning could look like. All team members had contributed to the initial set of sticky notes based on their experiences. Naming the clusters in small groups helped move us from individual to (small group) collective ideas.
- *Large Group Sharing*. We then needed to move from small group consensus to a full group understanding of the STEAM Learning Principles we had identified. Each of the groups shared the names that they gave to each of the clusters and provided a rationale. During this time, we started talking about the principles in clusters (having to do with the facilitator, the learner, and the curriculum itself) which has remained an organizing principle of the STEAM Learning Framework.
- *Synthesis of Names*. At this point in the meeting, we ran out of time to continue the process of collectively bringing all of the individual groups› ideas together. Ideally, we would have done this as a collective, but our time constraint kept us from doing this. After the meeting, the facilitators went through and, as much as possible, used the language from the small groups to come up with an overall draft of our STEAM Learning Principles.

What is STEAM?

Considering the different learning identities of the students

Selfintiated learning

Investing students abilities

Student centered learning

Celebration success

Motivation

Activity

Positive attitudestoward learning

Thinkin roles

Critical thinking

Real educating and evaluating

Critical thinking

Ingegration of many fileds

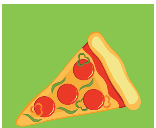
Integration

Art and science hobbies

Curriculum integration

Wider perspective of science

Away from theory



Employing scientific knowledge

Appreciate science and technology

Applied science

Art as tool

Creative environment

Exploration

Fun

Exploration and play

Removing limitations of classroom and replacing with wonder

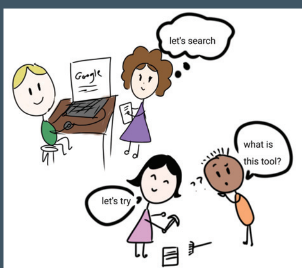
Names generated by small groups for different clusters.

Meeting 3: Activity Storyboarding

The first two meetings used the teachers' experience, along with some sharing of existing definitions of STEAM learning, to generate a draft set of principles. We then wanted to move from the abstract to the concrete, to start to share and understand what these principles look like in action. Between the meetings, teachers were asked to create a storyboard representing a STEAM learning experience. Storyboards allow the creator to explore not just what the teacher is doing, as may be the case in a traditional lesson plan, but also what the students are doing, how they are interacting, and what they are thinking.

- *Homework:* Create a STEAM Storyboard. Using a template, teachers created a storyboard of a STEAM-based learning experience. They drew from either experiences they had designed and facilitated in the past or created a new one based on the collective STEAM principles. Storyboards represented the activity at three points in time and highlighted how the learners were engaging with the activity.

Name: Learning about Agricultural technology for 5th grade students/ Wiam Alali



SCENE 1:First and second week:
- Kids learn about the roles of a farmer/ agricultural engineer
- read about making a Compost
- They search and discover the real tools
- Mantle of the Expert (Drama/ art)
- Meet a farmer or an engineer
- <u>Kids learn to ask questions</u>

SCENE 2:Third week:
- Collect items from nature and use them to make an artwork
- (Small model of a field)
- Learn how to plan the field (Math and measurements)
- <u>Kids work in a team</u>

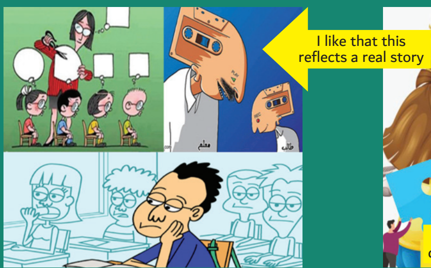
SCENE 3: fourth week:
- Final project
- Making a compost
- Learn how to take care of the school's garden
- <u>Kids learn sustainability and commitment</u>
- <u>Kids learn within a real context</u>

Storyboard created in a shared Jamboard.

- *Pair Share and Annotation of Storyboards:* In pairs, teachers shared the storyboards they created with each other. As one teacher shared, the other teacher was encouraged to ask the following probing questions to further explore the activities:
    - What are the learners doing in each of the storyboard frames?
    - What are the learners thinking in each of the storyboard frames?
    - What are the learners feeling in each of the storyboard frames?
    - What are the learners saying in each of the storyboard frames?

As they listened, the second teacher was also asked to annotate the storyboard, calling out three moments within the storyboard that felt particularly important, and guided the attention of the full group as we continued to discuss and make meaning of the storyboards. Ultimately, the storyboard creates an opportunity to make some ideas concrete and shareable, and thus, something for colleagues to talk about.

Name: Iyad Nabtiti - 11th grade (Programming)



SCENE 1:
The student is bored with the traditional style and molding

SCENE 2:
Break the ice, changing mindset

SCENE 3:
interactive , creative student and after graduation he has a startup in programming filde (success story)

Storyboard with yellow arrows annotating key moments or features.

- *Full Group Gallery Walk and Discussion:* Teachers were given the opportunity to explore all of the storyboards that had been created and annotated, keeping an eye on similarities and differences between how the storyboards represented the STEAM Learning Principles. We then shared our observations in a full group discussion. Some of these new understandings included:
  - All projects started with a context and content, but encouraged the development of soft skills.
  - There were differences between projects that started as challenges versus prompts or topics, each leading to different outcomes.
  - The importance of connecting to students' prior knowledge and the expertise of the community and community members emerged as a theme.

Meeting 4: Getting More Concrete, Connecting to Experience

- Homework: STEAM Artefact. In the storyboards, teachers were asked to design based on their experience or to create a new activity which represented some of the key STEAM principles. Several of the teachers included images of students engaged in STEAM learning. For this meeting, teachers were asked to bring an artefact or artefacts from a STEAM project that represents some of the emerging STEAM principles. It could be a project that the teacher or a colleague had facilitated. Artefact was broadly defined as videos, lesson plans, student work, etc. that help to communicate the project.

- Small Group Looking at Learning Artefacts (LALA) Protocol: Protocols are ways to structure discussions among colleagues and learners. The structure may guide what topics should be addressed in the discussion, how much time participants should have within the discussion and / or the roles participants play in the discussion. (Protocol below.)

Looking at Learning Artefacts Protocol (LALA)

Protocols are ways to structure discussions among colleagues and learners. The structure may guide what topics should be addressed in the discussion, how much time participants should have within the discussion and / or the roles participants play in the discussion. Below, we describe the LALA protocol to share STEAM projects and how they align with the STEAM Learning Principles.

Overview

Time	30–60 minutes. Timing will depend on group size.
Group Size	Flexible. Work in groups of 3 or 4.
Slides	N/A
Purpose(s)	Structure close looking at student work to identify principles or themes.
Supplies	All participants will bring an artefact or artefacts from a STEAM project that they have facilitated. By artefacts, we mean photos, videos, student work, lesson plans, assessments, etc. Selected artefact(s) should show evidence of aligning with one of the STEAM Learning Principles. • Timer (phone timer works well) • Copy of STEAM Learning Principles

Timeline

Time	Activity
5 min	**Describe the artefacts** Each person will describe their STEAM learning activity through the artefact(s) that they have. Through this description, they will: • Describe the artefact. • Describe the context of the STEAM learning activity through the artefact. • Describe how the artefact shows evidence of aligning with one of the STEAM Learning Principles. Explain why you think that.
3 min	**Ask clarifying questions** The participants can ask each other clarifying questions. These clarifying questions should establish clear meaning in the words the speaker is using and the context that the STEAM learning project took place. A clarifying question can refer to something that the speaker specifically said (for example, 'When you said that the students were tasked with solving a community problem, what community were you referring to?') or something that the speaker did not address. (e.g. 'What ages were the learners you were working with?').

N/A	**Repeat** Repeat the DESCRIBE and ASK step for each artefact and participant.
10-15 min	**Discuss STEAM Learning Principles Connection** This is time for the participants to ask questions related to the STEAM learning principles. This might involve: ● What similarities do you see between the projects represented by the artefacts? ● What differences? ● What similarities do you notice in the artefacts? ● What differences? ● What do the artefacts say about you as an educator? ● What do the artefacts show about what you value about STEAM learning? ● What other artefacts might show alignment with the STEAM learning principles? ● What do the artefacts not show well or hide about the STEAM learning experience?
5 min	**Reflect** In closing, either still in your small group or with the whole group, reflect together about the process with artefacts. ● What was interesting or surprising in discussing the artefacts? ● What about the process helped you to see or learn new things about STEAM? ● What new perspectives did your colleague(s) provide? ● What questions about STEAM learning did the artefacts raise for you?

Meeting 5: Distilling Stories from Artefacts

As an additional way for the Core group to refine what STEAM learning looks like in practice, we used the STEAM Learning Principle rubric as a tool for reflection. The rubric allows us to look at evidence of learning (the artefact) through the lens of STEAM learning and consider the extent to which the artefact addresses (or not) the STEAM learning principles.

- STEAM Learning Principle Rubrics: Using a single point rubric[1] containing the STEAM Learning Principles, teachers looked closely at the artefacts that they shared in the previous meeting. The teachers were asked to look at the artefact, and the learning experience that it came from, and identify which of the STEAM Learning principles were already present or which principles the activity best exemplified. This would support the next step, developing STEAM Learning Case Studies which would be used to communicate the principles to other educators.
- Elevator Pitches: To begin the process of developing STEAM Learning Case Studies, teachers worked in pairs to develop "Elevator Pitches" about the artefacts and projects they brought to the meeting, using the notes taken on the STEAM Learning Principle Rubrics. The idea of an elevator pitch is that they would have just 60 seconds to communicate the most important elements of the project or artefact.

1 Information on Single Point Rubrics: https://www.cultofpedagogy.com/single-point-rubric/ where you can find a copy of the rubric we used in the previous section of this manual.

Meeting 6: STEAM Learning Cases

In meeting six, we wanted to share and celebrate the prior experience of the teachers in a holistic way. Our core group had already been enacting STEAM learning experiences on their own prior to joining our group and this was previously demonstrated through the sharing of artefacts. In this meeting, the core group was encouraged to describe a STEAM learning project as a case that would allow us to discuss each other's work. And by doing so, we can learn more about what STEAM learning looks like in practice.

- *Homework:* Draft a Case: Before our next meeting, teachers were asked to take the artefact, rubric, and elevator pitches from the previous meeting and draft the first version of a case study. They were given the following prompt:

> The goal is to provide a detailed description of a STEAM learning project. This does not have to be a "perfect" project or even your best project. However, your case will communicate to others what a STEAM learning project looks like and how your project aligned with some of the STEAM learning principles.
>
> - Your case can be in Arabic or English (or even a mix)
> - Your case should have 1 to 3 photographs (learning artefacts, like photos of students, student work, etc.)
> - Your case should be approximately 500 words. This means it should not be too long.
> - Your case should describe what you did, with whom, how the project aligned with certain STEAM learning principles and how/why.

The prompt was intentionally open-ended, with just a few criteria to meet, because we were interested to see what details or elements were included across the various cases.

- *Feedback on Cases:* In groups of three, teachers read each other's case studies in sequence. Once group members have read all case studies, they can discuss with two goals:
    - o First, ask each other questions about their case studies. The questions that readers ask can reveal what may be missing from the case.
    - o Second, collectively identify 2-3 elements of the cases that productively communicated a STEAM learning principle or the STEAM learning experience more broadly. This could be something that one person in the group incorporated into their case, or all of the people in the group, or even no one in the group. An example of an element might be including a caption for your photos. This was to help identify what a standardized case should look like for inclusion in training materials or this guide.
- *Sharing common elements:* In the large group, we shared the common elements which the group identified in the small groups. We made a list, and discussed which elements felt most helpful. After this meeting, teachers were asked to iterate their cases to include more of the elements.

Meeting 7: Feedback Session

When the process of identifying STEAM Learning Principles began, none of the core team knew exactly what form the principles would take or how we might get there. In a large part, the process was planned and facilitated by the Research and Learning Design team (Dr. Peter Wardrip and Peter Kirschmann), based on their previous work with STEAM education, consensus building processes, and value mapping. At this point in the process, the teachers requested a meeting to reflect on the process and provide feedback.

This session was largely spent zooming out to discuss the process we were engaged in. A process that involved zooming in on specific examples and artefacts, pulling back to identify principles, and then zooming back in to find greater clarity around these principles. In future iterations of this project, we would plan regular reflective process retrospectives to provide dedicated time and opportunity to reflect on the process.

Meeting 8-9: Planning for STEAM Learning

For the final two meetings together, our attention shifted from the Principles to planning and discussing the STEAM Learning workshop, which happened in person, in Ramallah and was documented in a previous section of this guide.

We tested an early version of the **STEAM Design | Learning Activity Planner** (p. 45), which was implemented during the workshop. We also practiced remixing existing curriculum, which informed the **Make, Share, Reflect** activities.

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Epilogue

This guide is intended to communicate to other educators how we have come to define STEAM learning in our context, as well as to articulate a process for those other educators to define STEAM learning for themselves. We have communicated the STEAM Learning Principles, which we produced from our perspective and which others can use as a starting point. We describe our approach and the activities that we have developed and tested for discussing, designing and reflecting on STEAM learning.

As we described at the beginning of this guide with an example from cooking, STEAM learning captures, in spirit, what authentic learning looks like in our everyday lives. We naturally learn and solve problems in our lives in an interdisciplinary way. Yet, it is our challenge as educators to adapt what is authentic outside of the classroom to fit within our constraints of time, curriculum, resources, etc. Thus, our overall process seeks to leverage the expertise of educators, who know their students, know their curriculum and collectively develop ways to design for STEAM. We have grounded this work in opportunities to make something, share or talk about what you have made and reflect on that process.

Seymour Papert once said, 'The role of the teacher is to create the conditions for invention rather than provide ready-made knowledge'. This is what we do with our students and this is also what we hope to do as we work with other teachers.

7

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MAKE, SHARE, REFLECT | Reflection Protocol