Perspectives on Imagination in STEM

Results of a Fieldwide Survey

Museum of Science, Boston

Why imagination?

"If we realize that imagination is not simply a capacity to form mental images, but a capacity to think in a particular way — that is, a way that involves our capacity to think of the possible rather than just the actual (Egan, 1990) — then its significant role in science education can be easily comprehended." (Hadzigeorgiou & Fotinos, 2007, p. 16)

"Imagination enables people to rise above their own circumstances, to dream new visions and to hold on to old ones. It fosters inventions and discoveries, facilitates simple improvements to people's lives and uplifts our spirits. Creating is not the exclusive domain of the rich, nor of the technologically superior, but of the imaginative." (Smith, 2012, p. 209)

"We are what we imagine. Our very existence consists in our imagination of ourselves. Our best destiny is to imagine, at least, completely, who and what, and that we are. The greatest tragedy that can befall us is to go unimagined." (N. Scott Momaday in Loft et al., 2014, p. 58)

Hadzigeorgiou, Y., & Fotinos, N. (2007). Imaginative Thinking and the Learning of Science. *Science Education Review*, *6*(1), 15-23.

Loft, S., Pechawis, A., 2Bears, J., Lewis, J. E., Foster, S., Hopkins, C., & L'Hirondelle, C. (2014). *Coded Territories: Tracing Indigenous Pathways in New Media Art* (S. Loft & K. swanson, Eds.). University of Calgary Press.

Smith, L. T. (2012). *Decolonizing Methodologies: Research and Indigenous Peoples* (2nd edition). Zed Books.

Perspectives on Imagination in STEM: Executive Summary

101 professionals representing various sectors related to STEM education shared perspectives on imagination and its relationship to STEM education and practice.

Professionals believe in the power of imagination in STEM.

Beliefs about imagination:

- Most believe imagination influences engagement and learning and is useful in different contexts.
- Most believe everyone imagines, but *how* and *how much* might vary.
- Some believe imagination should feel fun and playful, and not like work or effort.
- Some believe it can be difficult to prompt others to use their imagination.

Beliefs about imagination *and STEM*:

- Nearly all believe that STEM is imaginative.
- Most believe STEM can improve imagination.

Ideas about how imagination and STEM relate:

- Some describe imagination as part of the STEM process
- Some describe imagination is a STEM skill
- Some describe imagination is a STEM trait or capability

There is an appetite – and need – for more imagination-infused work.

Professionals held positive attitudes about engaging in imagination-infused work:
- **Curious** to learn more about perspectives on imagination in STEM
- **Comfortable** talking to colleagues about imagination's relationship with STEM
- **Interested** in beginning or continuing work that addressed imagination in some way.

But they reported gaps in knowledge and a range of questions:
- **Outcomes**: How does imagination impact learning?
- **Audiences**: How can we foster imagination among different audiences (e.g., adults and children)?
- **Buy-in**: How can we better communicate the value of imagination in STEM?
- **Inclusion**: How might more imaginative STEM education broaden participation in STEM?
- **Strategies**: What strategies effectively foster imagination in STEM?
- **Measurement**: How can we measure or identify imagination when it's happening?
- **Arts integration**: What role can the arts play in addressing imagination in STEM/STEAM?

Definitions of imagination vary, offering an expansive range of entry-points to the construct.

Imagination was defined as the...

Ability | Activity | Capacity | Faculty Foresight | Process

To engage in...

Conceptualizing | Creativity Embodying | Feeling Generating Novelty | Moral Thinking Navigating Inconsistency | Organizing Playing | Problem Solving Possibilities Thinking | Relating Self-identifying | Sensing | Socializing Understanding | Visualizing "What if?"-ing

In relation to...

The self or others What is present or absent Fictive or hypothetical situations The past or future

Overall, results suggest that professionals in STEM education (and adjacent) sectors collectively hold rich understandings of the role of imagination in STEM, but more work is needed to support professionals in developing and implementing imagination-infused efforts.

Introduction

What does imagination mean to STEM education professionals?

How does imagination relate to STEM learning and STEM practice?

How can we more intentionally attend to imagination in STEM education?

As part of a National Science Foundation conference grant (#DRL-1906899), the Museum of Science, Boston surveyed professionals from STEM education sectors to explore questions addressing the role of imagination in STEM learning and STEM practice. Preliminary survey results were initially used to inform the content of virtual convening events hosted by the Museum of Science, Boston (see our project page on informalscience.org).

This report summarizes full results from the survey, with the goal of describing the rich landscape of beliefs about and understandings of imagination in the context of STEM education.

Methods

Survey Methods

Participant Characteristics

Participant Demographics

Survey Methods

Invitations to complete an anonymous, online survey about professional perspectives on imagination in STEM were shared through several avenues:

Direct email invitations to professionals identified through the team's efforts to recruit for participation in the conference. Respondents who participated in the survey through this route were likely to be involved in imagination-infused work in some way.

"Snowball sampling" in which direct contacts and project advisors shared the survey link with their own contacts.

Invitations posted to **listservs and online forums** serving STEM education professionals, and general informal and formal education professionals (e.g., Association of Science & Technology Centers, Visitors Studies Association).
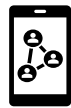
Invitations posted on relevant **social media platforms** (e.g., the Museum of Science's LinkedIn page, Twitter).

Responses were collected between June and September of 2021. This time spanned the summer during which the COVID-19 pandemic was still greatly impacting the world, including the museum and education sectors. This was also the time during which vaccinations had just become widely available to the general population. While availability of vaccines was a signal of hope, we also acknowledge that layoffs, furloughs, and financial strains felt by the field during this time likely influenced participation in this survey.

Participant Characteristics

101 professionals representing various sectors related to STEM education shared their perspectives.

Respondents reflected a range of professional backgrounds, with some identifying as coming from multiple backgrounds:

- **73%** were STEM education professionals (formal and informal educators or learning experience designers)

- **31%** were STEM education research or evaluation professionals

- **26%** were STEM professionals

- **8%** were other education or research professionals

We refer to respondents collectively as "the field," as this range of professional backgrounds reflects the interdisciplinary nature of STEM education sectors.

Participant Demographics

Participant demographic characteristics represented a range of backgrounds and identities, though the sample was predominantly comprised of white women with graduate degrees. While these characteristics might reflect the nature of the STEM education field, we want to acknowledge that homogeneity within certain participant demographics and lived experiences might limit the extent to which diverse perspectives will be reflected in the overall survey results.

Gender	n	%
Female	55	68%
Male	22	27%
Nonbinary	1	1%
Genderqueer	1	1%
Prefer not to say	2	2%

Age	n	%
18 to 24	3	4%
25 to 34	19	24%
35 to 44	27	34%
45 to 54	18	23%
55 to 64	7	9%
65 or older	5	6%

Race or Ethnicity	n	%
White or Caucasian	66	83%
Hispanic or Latinx	4	5%
Asian or Asian American	3	4%
American Indian or Alaskan Native	2	3%
Black or African American	2	3%
Prefer not to say	4	5%

Note: Participants could select more than one response.

Identify as LGBT+	n	%
No	74	75%
Yes	15	19%
Not sure or questioning	2	3%
Prefer not to say	3	4%

Residence	n	%
Suburban	37	46%
Urban	35	44%
Rural	8	10%

Highest Level of Education	n	%
Graduate Degree	57	70%
Some Graduate Work	10	12%
College Degree	11	14%
Other	2	2%
Prefer not to say	1	1%

Disability Status	n	%
No	70	88%
Yes	7	9%
Prefer not to say	3	4%

Results

Defining Imagination

Beliefs about Imagination Broadly

Beliefs about Imagination and STEM

Appetite for Imagination-Infused Work

Defining Imagination

The survey asked respondents to provide a definition of imagination that resonates with them, and it asked respondents to describe their understanding of the relationship between imagination and STEM.

Through a content analysis, the team unearthed common themes that definitions and descriptions of imagination might fall into. These categories are not firm, nor are they mutually exclusive. Rather, they represent an organizing framework to help illuminate the varied ways imagination can be defined.

Participant definitions often included at least one of three components:

Essence
- How do participants describe what imagination is?

Ways of Thinking
- What cognitive, physical, social, and emotional processes are involved?

Context
- Where, or towards what context, does imagination occur?

How does the field define imagination?

Respondents were asked to share their own definition of imagination. Our analysis of these definitions sought not to unearth the most-common responses, but to organize features of these definitions so readers might find more utility within this framing. The table here presents the high-level categories of the different elements that make up definitions of imagination.

This organizing tool invites users to trace their own connections between relevant elements, ultimately crafting definitions of imagination that are useful to their own work.

For example, imagination could be defined as:

The **ability** to engage in **possibilities thinking** relating to the **future**.

The **capacity** to **visualize** what is **not present to the senses**.

The **process** of **feeling** (e.g., **empathizing**) in **relation to others**.

Essence How imagination is characterized / what it is	Ways of Thinking Cognitive, physical, social, and emotional processes involved in imagination	Context Contexts towards which imagination is focused, or in which it emerges
Ability	Conceptualizing	Self and Social Contexts
Activity	Creativity	Within the self
Capacity	Embodying	In relation to others
Faculty of mind	Feeling	
Foresight	Generating Novelty	Contexts of Presence and Absence
Process	Moral Thinking	In reality
	Navigating Inconsistency	To the senses
	Organizing	Within experiences
	Playing	Related to what is known
	Problem Solving	
	Possibilities Thinking	Fictive or Hypothetical Contexts
	Relating	In relation to fictitious possibilities
	Self-identifying	Within narrative or storytelling
	Sensing	In play scenarios
	Socializing	
	Understanding	Temporal Contexts
	Visualizing	Relating to past or future
	"What if?"-ing	

*A worksheet version of this tool can be found on *

Beliefs about Imagination

Survey items addressing beliefs about imagination asked respondents to rate their agreement on a 7-point scale (completely disagree, mostly disagree, slightly disagree, no opinion, slightly agree, mostly agree, completely agree) to 14 statements. Statements were crafted based on the research team's preliminary literature review activities and discussions with project advisors, and were meant to address a broad range of possible beliefs and conceptions about imagination.

Survey items included:

1. Children use their imagination more than adults.

2. Children and adults imagine in different ways.

3. A person's imagination is always influencing how they engage in the world.

4. It's difficult to prompt someone else to use their imagination.

5. Some people are able to imagine, while others are not.

6. It is important for a person to engage their imagination when learning anything new.

7. Imagination is important to use in certain contexts, but it's not always useful.

8. Using your imagination should feel fun and playful, and not like work or effort.

9. Imagination is essential to STEM learning.

10. Imagination is necessary in STEM careers.

11. When engaging in a STEM practice, imagination is used every step of the way.

12. The idea that 'imagination is a STEM skill' is hard to take seriously.

13. STEM education can help learners improve their imagination.

14. It's important to communicate publicly that STEM is imaginative.

For brevity and clarity, the following pages report the total percent of respondents who agreed (the sum of those who completely, mostly, or slightly agreed) with each statement.

What does the field believe about imagination?

Most believe imagination influences engagement and learning and is useful in different contexts.

- **94%** agreed that "A person's imagination is always influencing how they engage in the world."
- **89%** agreed that "It is important for a person to engage their imagination when learning anything new."
- **35%** agreed that "Imagination is important in certain contexts, but it is not always useful."

Most believe that everyone imagines, but *how* and *how much* might vary.

- **87%** agreed that "Children and adults imagine in different ways."
- **87%** agreed that "Children use their imagination more than adults."
- **14%** agreed that "Some people are able to imagine, while others are not."

Some believe imagination should feel fun and playful, not like work or effort.

- **55%** agreed that "Using your imagination should feel fun and playful, and not like work or effort."

Some believe it can be difficult to prompt others to use their imagination.

- **33%** agreed that "It is difficult to prompt someone else to use their imagination."

What does the field believe about imagination *and STEM*?

Nearly all believe that STEM is imaginative.

- **96%** agreed that "Imagination is necessary in STEM careers."

- **95%** agreed that "Imagination is essential to STEM learning."

- **94%** agreed that "It's important to communicate publicly that STEM is imaginative."

- **69%** agreed that "When one engages in STEM practice, imagination is used every step of the way."

- Only **11%** agreed that "The idea that '*imagination is a STEM skill*' is hard to take seriously."

Most believe that STEM education can improve imagination.

- **89%** agreed that "STEM education can help learners improve their imagination."

In response to the question, "How would you describe the relationship between imagination and STEM?" respondents shared a range of ideas:

- **Imagination is part of the STEM process:** *Example quote:* "Imagination is fundamental to the learning processes that form the bedrock of STEM education."

- **Imagination is a STEM skill:** *Example quote:* "To solve big issues, to explore new territory of any field, you first have to be able to imagine that there is a solution, that there is something to find."

- **Imagination is a STEM trait or capability:** *Example quote:* "To be able to formulate questions and engage in either the scientific method or engineering process, you must be imaginative and be willing to think outside the box."

Appetite for Imagination-infused Work

A set of items on the survey addressed respondents' appetite for engaging in imagination-infused work. These survey items asked respondents to rate their attitudes, awareness, and behaviors related to imagination-infused work..

Items addressed the following:

1. Comfort talking with colleagues about imagination's relationship with STEM.

2. Knowledge of research on imagination's relationship with STEM.

3. Curiosity to learn about different perspectives on imagination's relationship with STEM.

4. Awareness of ways to foster and develop imagination in STEM.

5. Awareness of other people or projects that focus on imagination in STEM.

6. Interest in continuing or beginning projects that focus on imagination in STEM.

7. Plans to begin or continue projects that focus on imagination in STEM.

Your **comfort** talking with colleagues about imagination's relationship with STEM. (N = 87)
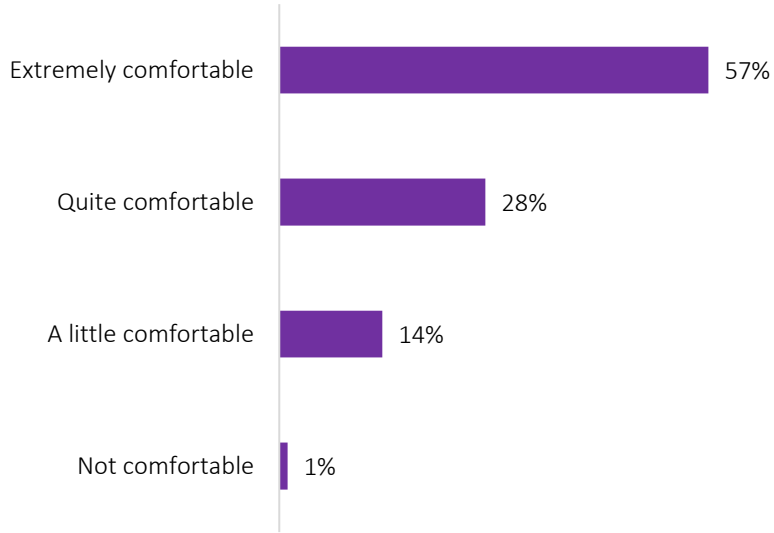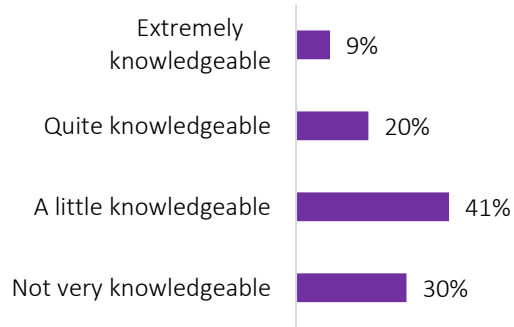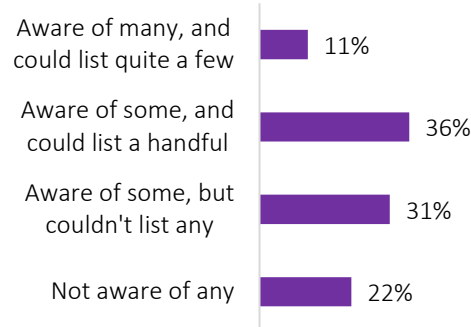
Extremely comfortable	57%
Quite comfortable	28%
A little comfortable	14%
Not comfortable	1%

Your **curiosity** to learn about different perspectives on imagination's relationship with STEM. (N = 87)

Extremely curious	57%
Quite curious	32%
A little curious	9%
Not very curious	1%
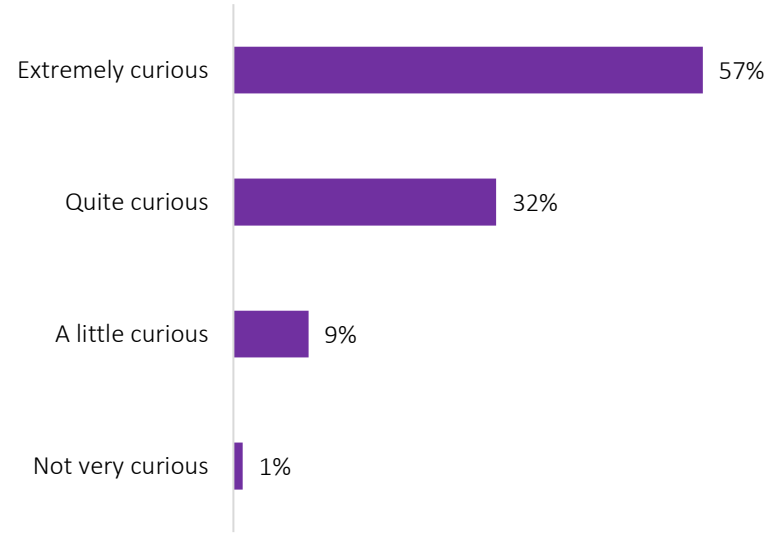
Respondents were highly comfortable with and curious about addressing imagination in STEM.

Your knowledge of **research** on imagination's relationship with STEM (N = 87)

Extremely knowledgeable	9%
Quite knowledgeable	20%
A little knowledgeable	41%
Not very knowledgeable	30%

Your awareness of other **people or projects** that focus on imagination in STEM. (N = 87)

Aware of many, and could list quite a few	11%
Aware of some, and could list a handful	36%
Aware of some, but couldn't list any	31%
Not aware of any	22%

Your awareness of **ways to foster** and develop imagination in STEM. (N = 87)

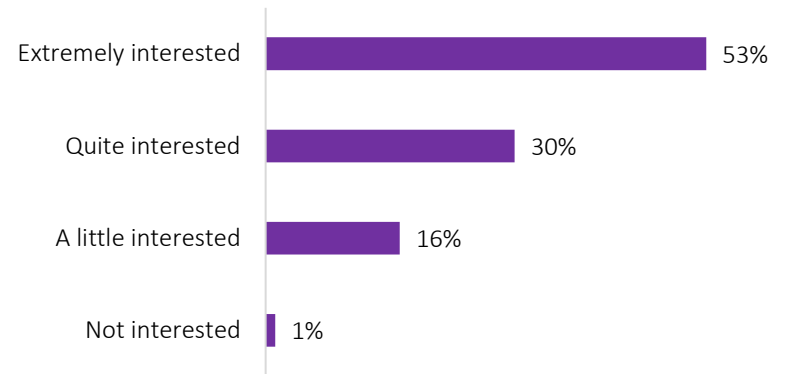|	
Aware of many, and could list quite a few	15%
Aware of some, and could list a handful	56%
Aware of some, but couldn't list any	22%
Not aware of any	7%
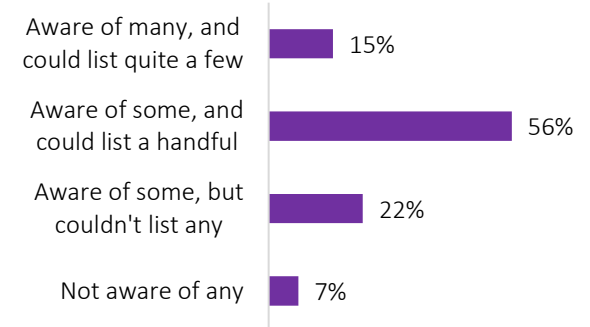
There were gaps in knowledge around research, projects, and practices associated with imagination in STEM.

Your <u>plans</u> to begin or continue projects that focus on imagination in STEM. (N = 87)
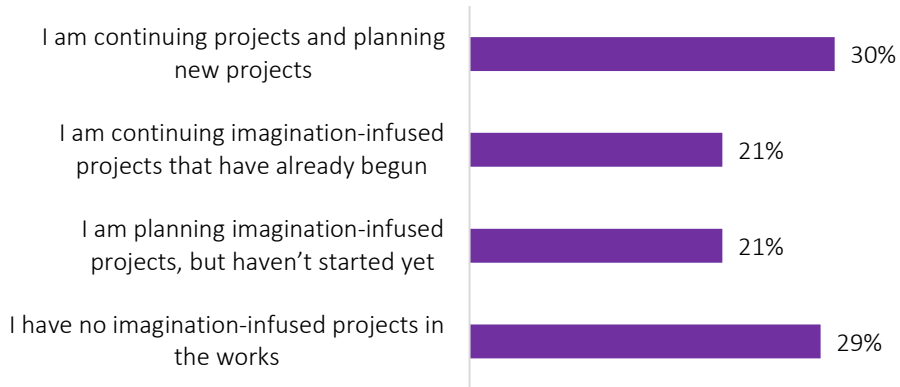
I am continuing projects and planning new projects	30%
I am continuing imagination-infused projects that have already begun	21%
I am planning imagination-infused projects, but haven't started yet	21%
I have no imagination-infused projects in the works	29%

Your <u>interest</u> in continuing or beginning projects that focus on imagination in STEM. (N = 87)

Extremely interested	53%
Quite interested	30%
A little interested	16%
Not interested	1%

Half of respondents were actively engaged in imagination-infused work, and nearly all expressed interest in beginning or continuing such projects.

Professionals shared a range of questions they had addressing imagination and STEM.

Two-thirds of respondents shared open-ended descriptions of what felt most exciting or compelling about the potential for this project to inform their own work, ranging from enhancing their knowledge, to informing practice, and engaging with new or interdisciplinary perspectives.

Participant quotes included:

- "Would love to learn about the variety of approaches educators are taking to integrate imagination and STEM."
- "The potential for research to inform practice is most exciting to me. How can we practically implement strategies for encouraging visitors to use/push their imagination."
- "I'm most excited to hear and learn from a diversity of interdisciplinary perspectives on the nature of imagination and its relationship to STEM."

Specifically, participants called out questions about the relationship between imagination and STEM, addressing the following topical categories:

- **Outcomes**: How does imagination impact learning?
- **Audiences**: How can we foster imagination among different audiences (e.g., adults and children)?
- **Buy-in**: How can we better communicate the value of imagination in STEM?
- **Inclusion**: How might more imaginative STEM education broaden participation in STEM?
- **Strategies**: What strategies effectively foster imagination in STEM?
- **Measurement**: How can we measure or identify imagination when it's happening?
- **Arts integration**: What role can the arts play in addressing imagination in STEM/STEAM?

Where do we go from here?

Visioning imaginative futures

Visioning Imaginative STEM Futures

Overall, results of this survey suggested that professionals in STEM education (and adjacent) sectors collectively hold rich understandings of the role of imagination in STEM, but more work is needed to support professionals in developing and implementing imagination-infused efforts.

What might the formal and informal STEM education landscape look like if we more intentionally fostered imaginative ways of thinking in all aspects of our efforts?

More Resources

Learn more about the Museum's imagination convening and project resources:

- [Informalscience.org project page](#)
- [Convening YouTube Playlist](#)

Learn more about strategies to support imagination in your work:

- [The Centre for Imagination in Research, Culture & Education](#)

Glossary

Sample Definitions of Imagination

Imaginative Ways of Thinking

Sample Definitions of Imagination and their Categories

Participant Definition	Essence	Context(s)
"Imagination is the ability to see what is possible and to communicate that vision with others."	Ability	Others, Reality, Self
"When you use your imagination, you are thinking of the possibilities (not just what actually is or what is actually possible), being creative, incorporating storytelling, being playful. Imagination opens our minds to think in a different way."	Way of thinking	Narrative, Play, Self, Reality
"Forming new ideas, or combining ideas in new ways, to create mental representations of things, situations, possibilities of any kind that you may or may not have experience with."	Activity	Experiences, Self, Senses
"I define 'imagination' as envisioning something that is not already there, whether it's an object or scenario or anything else. I believe that everyone has imagination, but it is like a muscle that you can exercise and grow or let get weak. Not all of us have opportunities to engage in imaginative thinking in our daily lives, but when we do, it helps to exercise that muscle and lead to more creativity."	Capacity	Senses, Self
"Using your experiences and knowledge base to formulate answers to difficult problems. Essentially creative thinking. Imagination is any use of your mind that stretches your pre-supposed view of the world."	Faculty of mind	Self, Fictitious possibilities, Reality, Experiences, What is known
"The process by which humans form new ideas and concepts from a semi-fictitious space in order to visualize beyond "what is" and consider "what could be" for the purposes of creating innovative solutions that have yet to exist."	Process	Self, Fictitious possibilities, Reality, Future
"...The most crucial role in STEM is taking a problem and figuring out how to correct it. Looking at said problem and imagining how it could be creates two points on a line. Imagination is key to filling in the area between those points. It creates the path to get to the solution. Imagination doesn't just create one path, however. It creates multiple paths that are able to go around and/or through obstacles."	Foresight	Self, Reality

Imaginative Ways of Thinking: Descriptions and Examples

Conceptualizing
- Engaging in purely mental (internal) thought processing, thinking, ideating, or forming concepts.
- Participant quote: "thinking about something mildly or fully abstract"

Creativity
- Thinking creatively or engaging in creative problem solving or ideation.
- Participant quote: "creative problem solving, freedom, visioning new paths"

Embodying
- Engaging movement, gesture, or the body to represent or simulate a concept or idea.
- Participant quote: "Using the power of the mind [and] interaction of the body and physical objects to explore how objects and phenomena relate"

Feeling
- Engaging with or generating emotional experiences.
- Participant quote: "think about and feel things one hasn't literally experienced"

Generating Novelty
- Creating, making, innovating, or synthesizing new ideas or concepts.
- Participant quote: "creating new connections, possibilities, or experiences"

Moral Thinking
- Taking a stance or perspective of "should"; formulating a judgement.
- Participant quote: "Imagination is ... believing in the power of an improved future."

Navigating Inconsistency
- Exploring connections where there are differences.
- Participant quote: "the ability to see opportunity in the seemingly impossible."

Organizing
- Organizing, categorizing, or rearranging ideas or concepts.
- Participant quote: "Predicting, problem solving, and categorizing (to name a few) all require imagination"

Playing
- Engaging in pretend play, storytelling, or open-ended ideation; freely exploring ideas.
- Participant quote: "For younger learners, imagination is exploring through play and pretend."

Imaginative Ways of Thinking (cont.)

Problem Solving
- Purposefully working to find solutions or overcome obstacles; could be iterative and manifested in physical form, like prototyping.
- Participant quote: "Using your experiences and knowledge base to formulate answers to difficult problems."

Possibilities Thinking
- Engaging in thinking about potential outcomes, realities, or ideas, without necessarily being limited by reality; generating hypotheses.
- Participant quote: "Being able to think beyond the current context or constraints to possibility."

Relating
- Forming connections, making associations, or finding patterns; using analogy or metaphor.
- Participant quote: "To explore connections that others don't. To see the world with new eyes."

Self-identifying
- Considering one's own identity; imagining oneself "as-if"; imagining future selves.
- Participant quote: "... imagination is a powerful tool ... to help them imagine themselves as engineers."

Sensing
- Engaging the senses when mentally representing objects, phenomena, concepts, stories, memories.
- Participant quote: "envision something that cannot be seen, heard, touched, smelled, or tasted"

Socializing
- Thoughts of or relating to other individuals or a collective beyond oneself; perspective taking, empathizing, or collective imagination.
- Participant quote: "seeing oneself or community in the future."

Understanding
- Synthesis of thought that resolves a problem, question, or gap in knowledge.
- Participant quote: "taking what you know.... and creating new connections, possibilities, and solutions"

Visualizing
- Mentally "seeing" what is not present to the senses.
- Participant quote: "make pictures and form ideas in your brain using previous schema and new information"

"What if?"-ing
- Wondering, exploring beyond limits, or engaging with questions to expand one's thinking.
- Participant quote: "the ability to simulate *what-if* scenarios in a way that draws from experiences and interests to evoke a response of wonder in the individual"

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