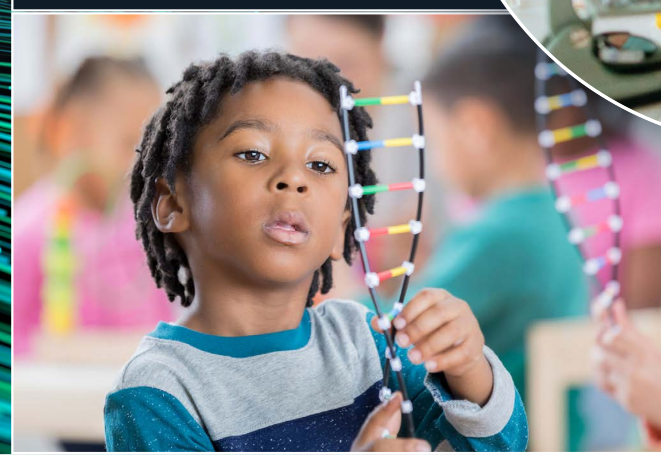
K-8 STEM CAREER COMPETENCIES: DEVELOPING FOUNDATIONAL SKILLS FOR THE FUTURE OF WORK



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Introduction

During their formative years, students are developing foundational skills, knowledge, and abilities that influence their career trajectories. Whether intentional or not, what students learn in grades K–8 about who they are, what they do well, and what they like and do not like influences that trajectory.

Career development begins early in life when children begin to understand that there is such a thing called *work* that adult members of their household often go to when they leave the house or go into their home office. Although schools are not the first shapers of career development, they do begin their influence early. In the elementary grades, when children learn about their community and its workers—doctors, firefighters, teachers, store clerks, scientists, builders—they are also learning that people have different jobs and do different types of things when they go to this place called *work*. As children develop their foundational skills and knowledge, they begin to focus on what that they like to do and what they do well. By middle school, students are beginning to match their own skills and abilities with what they know about careers, and they begin to imagine themselves in various types of adult life roles. By the end of middle school, students are making preliminary career decisions that will set them on career paths by selecting their high school and educational programs (public/private, magnet, comprehensive, classical education, or career technical schools) and participating in selected afterschool or other informal learning activities.

Helping students develop their capacities to succeed in future work can be challenging in a world driven by fast-paced changes in technology. New and emerging fields such as big data, artificial intelligence, robotics, and the Internet of things often give rise to new job titles that did not exist a short time ago. Over the next 5 to 10 years, new jobs that are not yet imagined will be invented. It is important that students at all ages become aware of the changing nature of work and that they are encouraged to imagine, explore, and keep expanding their ideas about what constitutes careers of the future.

This **K–8 STEM Career Competencies** framework is designed to provide K–8 educators, curriculum developers, policymakers, researchers, and other stakeholders with an overview of career competencies, learning objectives, resources, and examples to help students develop the foundational skills that are increasingly needed in order to successfully live, learn, and work in a world driven by technology—where discovery and innovation occur at the intersections of disciplines. Termed the *human-technology frontier*, this future workplace is where technologies and humans will collaborate to discover and innovate (Mervis, 2016; Van Opstal et al., 2008). The 2020 documentary *Speed of Thought* describes, for example, how 5G fifth-generation technologies are being developed to address some of our greatest life challenges, providing a window into the workplace of the future and the amazing things happening there.

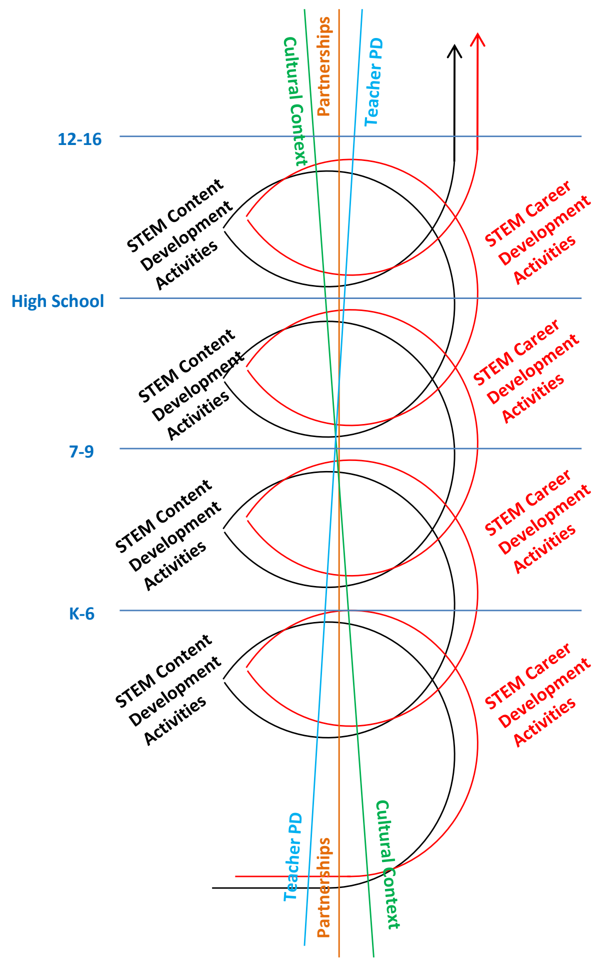
This framework is the second in a series of reports exploring the foundational skills and knowledge that today's students must develop in order to succeed in the workplace of the future. The first report in this series, *Building Foundational Skills Needed for Success in Work at the Human Technology Frontier*, explored two key questions: What do life and work look like at the human-technology frontier? What skill sets will workers need to succeed in those work environments? Informed by research and interviews with thought leaders from high-tech organizations that currently work with advanced technologies and big data, we found that future work environments will likely be characterized by the following:

- A predominance of dynamic, interdisciplinary teams
- A focus on data
- Ubiquitous computational, engineering, and design thinking
- Convergence of technologies and systems and a focus on life sciences
- Increased use of artificial intelligence and machine learning, with blurred boundaries between humans and machines
- Heightened attention to cybersecurity
- An emphasis on problem-based learning
- Increased focus on continual lifelong learning
- Increased attention to ethical considerations that promote innovation and productivity while also ensure the well-being of individuals and societies and guard against building in or hardening our society's inequities

These emerging characteristics require a shift in the way we currently prepare students. Educators can ensure that students have the opportunity to build these competencies over time by practicing relevant skills along a scaffolded and intentional trajectory. The Workforce Education Logic Model for Designing, Developing, and Evaluating STEM Education Programs for K–12 (see Figure 1), developed by a working group of ITEST (Innovative Technology Experiences for Students and Teachers) Principal Investigators and evaluators, uses a "helix" model to illustrate the interaction of STEM content development and STEM career development activities. These activities are implemented as students advance from kindergarten through high school, within the cultural context of schools, with teachers supported by professional development, and school programs supported by effective partnerships. In this way, major elements of the ITEST program come together to support students in realizing STEM content and career outcomes.

Figure 1

ITEST STEM Workforce Education Helix



STEM Content Development Activities
STEM Career Development Activities
Teacher Professional Development
Partnerships
Cultural Context

The foundational skills that students need for success in future work are best introduced during students' early formative years, when their interests, skills, knowledge, and abilities are being shaped and they are beginning to imagine themselves in future life roles. Introduction of these competencies in grades K–8 will better prepare students to explore career pathways and leave K–12 schooling better prepared to transition into postsecondary programs that pave the way for lifelong success.

This framework identifies 10 foundational career competency areas correlated to characteristics of future work at the human-technology frontier, incorporating what thought leaders in the field believe that successful workers in these environments need to know and be able to do. It will be particularly useful for teachers interested in helping their students develop the foundational skills, knowledge, and abilities needed to be successful in life when they exit formal schooling. The framework also suggests competencies and resources to help teachers make connections across disciplines.

Note: Many of the suggested competencies may already be included in the curriculum or pedagogy in K–8 classrooms. In those cases, this framework may simply reinforce what teachers are already doing to prepare their students for success in future work.

Each section begins with a definition of that competency area and why it is an important consideration for the future of work. Next, a chart divided by grade span (K–2, 3–5, and 6–8) lists grade-appropriate skills that support each competency area. When read across the grade spans from left to right, this represents a learning trajectory of the foundational skills, knowledge, and abilities pointing students toward competency attainment. Each section ends with a chart of suggested *Background Reading and References* and *Classroom and Curriculum Resources*, with examples of grade-specific activities and ITEST publications and projects in that competency area. The charts are not intended to cover each competency thoroughly, but rather to provide a snapshot of what teachers can do to help students develop the foundational skills in this area needed for future work success.

Policymakers, education leaders, and researchers can use this framework to:

- Explore the characteristics of future work at the human-technology frontier and the skills, knowledge, and abilities that today's students must develop
- Better understand how to support and guide students' early career development and to broaden their participation in STEM
- Develop new policies, research studies, projects, and programs to support early career development and to broaden participation in STEM efforts

K–8 classroom educators can use this framework to:

- Enhance their curriculum by integrating opportunities for students to develop future-ready career competencies through interdisciplinary problem-based activities
- Make stronger connections between disciplinary content and STEM careers through interdisciplinary activities and problem-based learning activities and projects
- Broaden participation in STEM by sparking interest and ensuring that students have the skills, knowledge, and attributes to start on a STEM career path
- Develop strategies to guide students' lifelong learning and career development
- Enrich and inform the curriculum by providing opportunities for interaction with students' families and with community and business partners

The authors hope that this framework will help teachers, researchers, and policymakers embrace an active, positive role in guiding their K–8 students toward productive and rewarding careers.

Acknowledging Co-Authors

Development team members researched and synthesized the state of the art related to K–8 learning around each of the 10 competency areas, drafted and reviewed learning trajectories, and identified educative materials and resources. We would like to thank the following individuals who co-authored and/or reviewed content for this guide:

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Mervis, J. (2016). NSF director unveils big ideas. *Science, 352*(6287), 755–756.

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STEM Career Competency: Artificial Intelligence Literacy

Artificial intelligence is a branch of computer science designed to explore ways that computers can sense, learn, reason, and take action like humans.

From *Artificial Intelligence (AI) in K–12*:

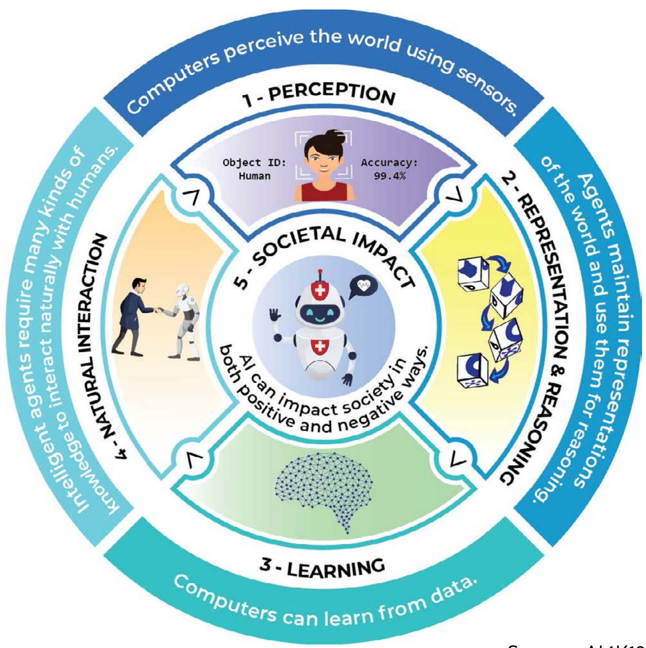
> The Computer Science Teachers' Association (CSTA) and the Association for the Advancement of Artificial Intelligence (AAAI) suggests defining AI as a set of five themes instead of specific technologies.
>
> 1. **Perception.** Computers perceive the world via sensors and then extract meaning from that information. . . .
> 2. **Representation & Reasoning.** AI systems or intelligent agents maintain different models or representations and then apply algorithms to those models as a form of "reasoning." . . .
> 3. **Learning.** Computers learn from data based on statistical inferences made through Machine Learning.[1]. . .
> 4. **Natural Interaction.** Developers struggle to make AI interact in a natural way, including how it attempts to make inferences, understand emotion, and process natural language. . . .
> 5. **Societal Impact.** AI can have both positive and negative impacts on society, raising new questions about ethics, privacy, and bias. (Consortium for School Networking, 2020, pp. 4–5)

The AI-literate individual is an informed citizen and critical consumer of AI technology who has developed the foundational knowledge and skills to support future endeavors in an AI-powered world. The AI-literate individual understands these basic concepts of AI:

1 *Machine learning* is an application of AI that focuses on developing computer programs to give systems the ability to access data and learn from it without being explicitly programmed to do so.

- AI is embedded in the tools and applications we interact with daily.
- AI is used to give "intelligent" behavior to these tools and applications.
- AI systems make decisions and predictions from programmed data.
- AI data sets can be biased.
- AI systems have strengths and limitations.

The AI-literate individual is able to identify where AI systems are embedded in everyday life, assess both the potential for harm and the benefits of AI, and describe how AI systems are built using data.



Source: AI4K12 (n.d.) Licensed under [CC BY-NC-SA 4.0]

Future STEM Workplace Rationale

> The rapid expansion of AI in our world necessitates the development of a STEM workforce that is knowledgeable and capable of understanding and working with AI. To address these evolving needs, we have defined AI literacy as three core domains that students must learn in order to become AI literate citizens: an age-appropriate technical understanding of AI, knowledge of its ethical and societal implications, and AI career awareness and adaptability. (Zhang et al., 2021, p. #2)

AI-literate students will enter the STEM workforce better prepared to perform routine work tasks and solve problems in AI-enabled work environments that are dependent on both human and machine intelligences for discovery and innovation.

References

AI4K12.org. (n.d.) Five big ideas in AI (graphic). https://ai4k12.org/resources/big-ideas-poster/

Zhang, H., Lee. I., DiPaola, D., Ali, S. & Breazeal, C. (2021). *Integrating Ethics and Career Futures with Technical Learning to Promote AI Literacy for Middle School Students: An Exploratory Study* (in review).

Grade-Appropriate AI Skills		
K-2	**3-5**	**6-8**
Students: • Are regularly exposed to AI (i.e., they hear about it in children's TV shows, movies, and books) • Have opportunities to interact with AI systems	Students: • Explore interactions with AI in daily life • Differentiate between what AI is and is not • Investigate how to use AI systems to make predictions • Explore how to use AI systems to generate new artifacts	Students: • Explain that AI systems are programs written by humans that perform tasks that normally require intelligence • Explain that machine learning is an AI technique that allows computers to acquire new behaviors without being explicitly programmed • Identify characteristics of AI that are different from human intelligence • Describe the kinds of predictions that AI systems make • Illustrate the kinds of creations that AI systems make

Background Reading and Reference

- Artificial Intelligence in K–12: The Right Mix for Learning or a Bad Idea? *EdWeek.org* (https://www.edweek.org/teaching-learning/artificial-intelligence-in-k-12-the-right-mix-for-learning-or-a-bad-idea/2020/05)
- Consortium for School Networking, *Artificial Intelligence in K–12* (2020) (https://cosn.users.membersuite.com/shop/store/59ce3069-00ce-cde0-d748-6543255e7fc7/detail)
- Alex Freeman, Samantha Adams Becker, Michele Cummins, Ann Davis, and Courtney Hall Glesinger, *NMC/CoSN Horizon Report: 2017 K–12 Edition* (The New Media Consortium) (see Artificial Intelligence, p. 48) (https://www.learntechlib.org/p/182003/)
- Classrooms of the Future: The Potential of Artificial Intelligence in Kindergarten to Grade 12 Education (https://shared.ontariotechu.ca/shared/department/research/images/2017---srs---bpa---edu.pdf)
- AI4K12 List of Resources https://ai4k12.org/resources/list-of-resources/

Classroom and Curriculum Resources

- AI for Oceans (grade 3 and up) (https://code.org/oceans)
- AI + Ethics Curriculum for Middle School (https://www.media.mit.edu/projects/ai-ethics-for-middle-school/overview/)
- The Intelligent Piece of Paper (middle school) (http://www.cs4fn.org/teachers/activities/intelligentpaper/intelligentpaper.pdf)
- How to Train Your Robot (middle school) (https://aieducation.mit.edu/i2.html)

Exemplar ITEST publications and projects:

- Developing K-12 Education Guidelines for Artificial Intelligence (http://stelar.edc.org/projects/22569/profile/developing-k-12-education-guidelines-artificial-intelligence)
- Developing AI Literacy Interventions to Teach Fundamental Concepts in AI (http://stelar.edc.org/projects/22924/profile/developing-ai-literacy-interventions-teach-fundamental-concepts-ai)
- Engaging Secondary Female Students in Ubiquitous Intelligence and Computing (http://stelar.edc.org/projects/22923/profile/engaging-secondary-female-students-ubiquitous-intelligence-and-computing)
- Narrative Modeling with StoryQ: Integrating Mathematics, Language Arts, and Computing to Create Pathways to Artificial Intelligence Careers (http://stelar.edc.org/projects/22920/profile/narrative-modeling-storyq-integrating-mathematics-language-arts-and-computing)
- Middle School Teacher and Student's Experiences with Artificial Intelligence via Computational Cameras (http://stelar.edc.org/projects/22929/profile/middle-school-teacher-and-students-experiences-artificial-intelligence)

STEM Career Competency: Computational Thinking

Computational thinking is a process that requires people to think in new ways to enable the effective use of analytical thinking to solve problems and create solutions. Computational thinking is characterized by:

- Analyzing, modeling, and abstracting ideas and problems
- Designing solutions and algorithms to manipulate these abstract representations (including data structures)
- Identifying and executing solutions (e.g., via programming)

While the use of computers isn't necessary to engage in computational thinking, there are many instances where computers are helpful in carrying out the tasks envisioned through these core computational thinking characteristics.

Future STEM Workplace Rationale

As humans and machines become more interdependent and share more work tasks, more workers across all industry sectors will engage in computational thinking. Computational thinking is recognized as essential to the creativity and innovation needed to succeed in a world driven by technology (Council on Competitiveness, 2008; Cuny et al., 2010; Isbell et al., 2010; President's Information Technology Advisory Committee, 2005; Wing, 2016). Developing foundational skills in computational thinking will enable youth to explore their own interests and abilities and to make preliminary STEM career decisions, such as choosing to take elective or advanced coursework and participating in out-of-school STEM activities.

References

Council on Competitiveness. (2008). *Thrive. The Skills Imperative.* https://www.compete.org/storage/images/uploads/File/PDF%20Files/Thrive.%20The%20Skills%20Imperative%20-%20FINAL%20PDF.PDF

Cuny, J., Snyder, L., & Wing, J. (2010). *Demystifying computational thinking for non-computer scientists.* Unpublished manuscript, referenced in www.cs.cmu.edu/~CompThink/resources/TheLinkWing.pdf

Isbell, C. L., Stein, L. A., Cutler, R., Forbes, J., Fraser, L., Impagliazzo, J., Proulx, V., Russ, S., Thomas R., & Xu, Y. (2020, January). (Re) defining computing curricula by (re)defining computing. *ACM SIGCSE Bulletin*, *41*(4), 195–207.

President's Information Technology Advisory Committee. (2005). *Computational science: Ensuring America's competitiveness*. National Coordination Office for Information Technology Research and Development.

Wing, J. M. (2016, March). Computational thinking: 10 years later. *Microsoft Research Blog*. https://www.microsoft.com/en-us/research/blog/computational-thinking-10-years-later/

Grade-Appropriate Computational Thinking Skills

K-2	3-5	6-8
Students: • Explore the differences between humans and computing devices • Investigate abstraction by identifying common attributes • Create and enact a simple algorithm or create a simple computer program • Use basic models and simulations	Students: • Differentiate between tasks that are best done by computing systems and those that are best done by humans • Create new representations and break down larger problems into sub-problems • Write, debug, and correct basic algorithms and programs	Students: • Differentiate between tasks and problems that are best solved by computing systems and those that are best addressed by humans • Create new representations, define functions, and use decomposition • Write, debug, and analyze advanced algorithms and programs • Design models and modify simulations

Background Reading and Reference	Classroom and Curriculum Resources
• Jeannette M. Wing, *Computational thinking* (2006) (http://www.cs.cmu.edu/afs/cs/usr/wing/www/publications/Wing06.pdf) • Irene Lee, Fred Lane Martin, Jill Denner, Bob Coulter, Walter Allan, Jeri Erickson, Joyce Malyn-Smith, and Linda Werner, Computational Thinking for Youth in Practice (*ACM Inroads*, 2[1], 32–37, 2011) (https://www.researchgate.net/publication/234810765_Computational_thinking_for_youth_in_practice) • 2016 DLCS Curriculum Framework (see the Computational Thinking Strand) (https://www.doe.mass.edu/stem/dlcs/?section=planningtools)	• Digital Literacy and Computer Science Curriculum Guide for Massachusetts Districts (https://www.dlcsma.org/wp-content/uploads/2020/08/DLCS-Curriculum-Guide-6-30-20.pdf) • Integrating Computational Thinking (integrated modules currently available for reference and as guidance) (https://sites.google.com/site/stemcwithct/home) **Exemplar ITEST publications and projects:** • Supporting Scientific Modeling Through Curriculum-based Making In Elementary School Science Classes (http://stelar.edc.org/publications/supporting-scientific-modeling-through-curriculum-based-making-elementary-school) • The Essence of Computational Thinking (http://stelar.edc.org/publications/essence-computational-thinking) • Computational Thinking in Elementary and Secondary Teacher Education (http://stelar.edc.org/publications/computational-thinking-elementary-and-secondary-teacher-education) • Using Robotics and Game Design to Enhance Children's Self- Efficacy, STEM Attitudes, and Computational Thinking Skills (http://stelar.edc.org/publications/using-robotics-and-game-design-enhance-children's-self-efficacy-stem-attitudes-and-0)

STEM Career Competency: Digital and Media Literacy

Media literacy is defined as "the ability to **access, analyze, evaluate, create, and act** using all forms of communication" (National Association for Media Literacy Education, 2019, ¶1). *Digital literacy*, which merges the competencies of media literacy and computational thinking, is the ability to use digital tools to locate, evaluate, and make use of information; to understand the ways in which technology can produce media; and to understand the impact of this media on our society. Digital and media literacy includes the ability to read and interpret media, reproduce data and images through digital manipulation, and evaluate and apply new knowledge gained from digital environments (Jones-Kavalier & Flannigan, 2006). These skills support critical media analysis and content creation with a specific purpose.

Future STEM Workplace Rationale

Media influences our thoughts and our decisions. Digital tools are used to create, manipulate, analyze, edit, publish, and develop artifacts; to collaborate and communicate; and to conduct research (Massachusetts Department of Elementary and Secondary Education, 2021). In addition to the ability to create with media, media literacy encompasses critical-thinking skills—in particular, the ability to decode and evaluate sources—that are essential to scientific literacy and communications. Media literacy enables individuals to differentiate between legitimate messages based on accurate data and messages intended to misinform and manipulate to gain influence and power. Creativity and innovation at the human-technology frontier will require individuals to develop a deep understanding of technologies: how to modify them to their specific purposes and interests, use them to create and innovate products and systems, and develop new technologies to meet societal needs. Developing foundational skills in media and digital literacy will enable youth to take full advantage of the digital tools and resources available in a technology-driven world and to successfully navigate the world in which we live.

References

Jones-Kavalier, B., & Flannigan, S. L. (2006, January). Connecting the Digital Dots: Literacy of the 21st Century. *EDUCAUSE Review*, *29*(2), 8–10. https://er.educause.edu/articles/2006/1/connecting-the-digital-dots-literacy-of-the-21st-century

Massachusetts Department of Elementary and Secondary Education. (2021). *Digital Literacy and Computer Science (DLCS)*. https://www.doe.mass.edu/stem/dlcs/?section=planningtools

National Association for Media Literacy Education. (2019). *Media Literacy Basics*. https://medialiteracyweek.us/resources/media-literacy-basics/

Grade-Appropriate Digital and Media Literacy Skills		
K-2	**3-5**	**6-8**
Computing and Society Students: • Identify important rules for sharing information and staying safe online • Explore what it means to be a good digital citizen • Observe and describe how people use technology and how technology can influence people *Digital Tools and Collaboration* Students: • Develop basic use of digital tools to create simple artifacts • Develop basic use of digital tools to communicate and exchange information • Develop research skills to create simple artifacts and to communicate and exchange information	*Computing and Society* Students: • Understand safe and appropriate use of technology • Know strategies for how to deal with cyberbullying • Demonstrate responsible use of technology, digital content, and interactions • Observe and describe how technology can influence people • Have a basic understanding of digital media messaging and equity of access to technology *Digital Tools and Collaboration* Students: • Use digital tools and keyboarding skills to publish multimedia artifacts	*Computing and Society* Students: • Identify the main ways to protect their online identity and the importance of maintaining online privacy • Describe methods of dealing with cyberbullying and inappropriate content • Demonstrate responsible use of technology and laws regarding ownership of material and ideas, licensing, and fair use • Identify possible consequences of inappropriate technology use, including harassment and sexting • Examine the impact of emerging technology in schools, communities, and societies

Grade-Appropriate Digital and Media Literacy Skills		
K-2	**3-5**	**6-8**
Computing Systems Students: • Describe the many forms that computing devices take and their different components • Draw a picture of basic structures of computing systems and networks • Explore human and computer differences to determine when technology is most beneficial *Media Literacy*[2] Students: • Name sources of information or media (e.g., title or author of book, name of website) • Know that different sources of information have different intents and purposes (e.g., to inform, persuade, entertain) • Use digital tools and media resources to express their thoughts and ideas in a collaborative manner	• Use digital tools to communicate and exchange information • Develop intermediate research skills to create artifacts, and understand the importance of attributing credit *Computing Systems* Students: • Understand different computing devices and their components • Use a variety of different computing devices • Troubleshoot and solve simple problems • Differentiate between tasks that are best done by computing systems and those that are best done by humans • Understand the components of a network and basic network authentication • Have a basic understanding of *services* (interconnected devices that enable programs and devices through an interface)	*Digital Tools and Collaboration* Students: • Use a variety of digital tools to create artifacts, online content, and online surveys • Describe different uses for a variety of digital tools • Communicate and publish content online • Use advanced research skills *Computing Systems* Students: • Understand hardware and software components of a computing device, and troubleshoot hardware and software problems • Use a variety of computing devices to manipulate data • Differentiate between tasks and problems that are best solved by computing systems and those that are best addressed by humans

2 Adapted from Massachusetts Department of Elementary and Secondary Education (Mass. DESE). (2021). Digital Literacy and Computer Science (DLCS). https://www.doe.mass.edu/stem/dlcs/?section=planningtools

Grade-Appropriate Digital and Media Literacy Skills		
K-2	**3-5**	**6-8**
	Media Literacy[2] Students: • Identify elements of media sources (e.g., visual elements, sound effects) that are designed to inform, persuade, and/or entertain • Evaluate digital sources for accuracy, relevancy, and appropriateness • Create an artifact that answers a research question and clearly communicates their thoughts and ideas	• Draw a picture or diagram of network components, explaining the functions that connect computing devices, people, and services • Provide examples of the capabilities that services can provide (e.g., an app that uses online maps to provide driving directions) *Media Literacy*[2,3] Students: • Discern media bias and how media and technology can be used to distort, exaggerate, and misrepresent information • Evaluate the quality of digital sources for reliability, including currency, relevancy, authority, accuracy, and purpose of the digital information • Use digital tools to communicate to or with different audiences, with practical, personal, and/or social intent

3 Adapted from Mass. DESE. (2018). *History and Social Science Framework*. https://www.doe.mass.edu/frameworks/hss/2018-12.pdf

Background Reading and Reference

- National Association for Media Literacy Education, What is Media Literacy? NAMLE's Short Answer and a Longer Thought (2001) (http://www.medialit.org/reading-room/what-media-literacy-namles-short-answer-and-longer-thought)
- Barbara R. Jones-Kavalier and Suzanne L. Flannigan, Connecting the Digital Dots: Literacy of the 21st Century (2006) (https://er.educause.edu/articles/2006/1/connecting-the-digital-dots-literacy-of-the-21st-century)
- Common Core State Standards K- 12 Technology Skills Scope and Sequence (https://www.cde.state.co.us/cdesped/accommodationsmanual_ccss_k12_techscope)
- A First Step toward Digital Literacy (https://www.edc.org/first-step-toward-digital-literacy)
- Youth Learn Project (https://www.edc.org/youthlearn)
- National Association for Media Literacy Education (https://namle.net/)
- The Media Spot, Media Literacy Standards (https://themediaspot.org/2013/04/25/middle-school-digital-accountable-talk/)
- Common Sense Education (digital citizenship resources) (https://www.commonsense.org/education/digital-citizenship)
- News Literacy Project (https://newslit.org/)

Classroom and Curriculum Resources

- Mass. Digital Literacy and Computer Science Framework, *Quick Reference Guides: Digital Literacy and Computer Science* (for grades K–2, 3–5, and 6–8) (https://www.doe.mass.edu/stem/dlcs/?section=planningtools#resources)
- Center for Media Literacy, Five Key Questions That Can Change the World: Classroom Activity Guide with 25 Core Lesson Plans for K-12 media Literacy (http://www.medialit.org/five-key-questions-can-change-world)
- GET Media L.I.T., Free Comics for Social Emotional Learning and Digital Citizenship (https://getmedialit.com/)
- United Nations Educational, Scientific and Cultural Organization (UNESCO), Media and Information Literacy Curriculum for Teachers (https://unesdoc.unesco.org/ark:/48223/pf0000192971.locale=en)
- Learning for Justice, Advertisements and You (https://www.learningforjustice.org/classroom-resources/lessons/advertisements-and-you)
- CrashCourse (YouTube channel), CrashCourse Series on Media Literacy (https://www.youtube.com/watch?v=sPwJ0obJya0&list=PL8dPuuaLjXtM6jSpzb5gMNsx9kdmqBfmY)
- The Media Spot, Media Literacy Scope & Sequence Template (https://themediaspot.org/category/k-12-curriculum-development/)

Exemplar ITEST publications and projects:

- Understanding Weather Extremes with Big Data: Inspiring Rural Youth in Data Science (http://stelar.edc.org/projects/22767/profile/understanding-weather-extremes-big-data-inspiring-rural-youth-data-science)
- From Data To Awesome (D2A): Youth Learning to be Data Scientists (http://stelar.edc.org/projects/18918/profile/data-awesome-d2a-youth-learning-be-data-scientists)

Background Reading and Reference	Classroom and Curriculum Resources
• IREX, Learn to Discern (L2D)—Media Literacy Training (https://www.irex.org/project/learn-discern-l2d-media-literacy-training)	• Data Modeling with Young Learners and Their Families (http://stelar.edc.org/projects/20171/profile/data-modeling-young-learners-and-their-families)

STEM Career Competency: Cybersecurity and Digital Citizenship

To demonstrate competency in cybersecurity and digital citizenship, individuals must be able to:

- Ethically and effectively interact with digital systems and technologies
- Model appropriate and responsible behavior with regard to the use of technology

Competency in this area entails protecting digital networks, devices, and data from digital attacks; keeping information confidential; maintaining its integrity; ensuring its availability to those authorized to view or use it; and practicing safe and ethical technology use in the workplace and when engaging with the community.

Future STEM Workplace Rationale

As we move into an era when technology systems are continuously under threat and when home and workplace environments are increasingly interconnected, a solid understanding of cybersecurity and ethical digital citizenship is needed. Employees must know how to keep their data secure, appropriately navigate and contribute in an online environment, and assess and navigate both secure and insecure technology environments in the workplace and at home. They must be able to make sound judgments and to work with their employers to continually assess their levels of risk, adapt to changing needs in an unsecure environment, and determine how to respond when a digital environment cannot be trusted.

Grade-Appropriate Cybersecurity and Digital Citizenship Skills		
K-2	**3-5**	**6-8**
Safety and Security Students: • Identify and compare reasons that an individual should keep information private or make information public • Identify basic steps to keep an account secure, such as passwords to protect information and identity • Know strategies to report dangerous or unsafe online behaviors (such as telling a teacher) • Identify unusual activity by applications and devices that should be reported to a responsible adult • Encode and decode simple messages *Critical Information Processing* Students: • Search for and access information in online environments • Locate sources of information in online environments and identify basic factors that affect credibility, such as source and authorship	*Architecture of Networks and the Internet* Students: • Define what the Internet is and describe how information is sent and received • Learn the components of websites and how they are created and customized *Safety and Security* Students: • Identify why someone might choose to share an account, app access, or devices • Recognize threats to online privacy and identify strategies to address them, such as notifying an adult or not clicking on suspicious links • Understand that there is a difference between private and public Internet networks, and apply strategies to mitigate risks (e.g., virtual private networks, strong passwords) • Identify ways that cybersecurity can be compromised (e.g., downloading files from the Internet, clicking on links in emails) and how to avoid them	*Architecture of Networks and the Internet* Students: • Model the architecture of the Internet and how information flows through it, using specific routes and structures • Describe key features of the architecture of the Internet that contribute to its overall stability, such as breaking information into smaller packets and routing information through multiple nodes *Safety and Security* Students: • Understand how encryption and decryption protect information • Use simple encryption and decryption to share information with peers • Recognize current threats to data security, and interventions to reduce those threats • Understand, access, and use online data security tools • Behave safely and responsibly in online communities

Grade-Appropriate Cybersecurity and Digital Citizenship Skills

K-2	3-5	6-8
Ethical Community Engagement Students: • Recognize and model respectful community behavior to others in online environments • Practice strategies for including others when engaging in community experiences online, such as taking turns and calling on others • Recognize and respond appropriately to online controversy and disputes, using such strategies as taking time-outs or talking to a trusted adult • Recognize that just because something is posted online doesn't mean that it is free to use	• Identify and apply strategies for improving device security, such as maintaining and updating strong passwords *Critical Information Processing* Students: • Students distinguish between credible and untrustworthy information sources *Ethical Community Engagement* Students: • Recognize common unethical or disrespectful behaviors in online environments (such as cyberbullying), understand the legal consequences of such behaviors, and apply strategies to address or reduce them, such as telling a responsible adult or peer leader • Demonstrate strategies for appropriately using information they have found on the Internet, such as following acceptable use policies and properly citing references	*Critical Information Processing* Students: • Recognize signs of compromised information or data • Analyze data sources for credibility and integrity *Ethical Community Engagement* Students: • Move beyond individual tasks to identify and work toward collective group goals and outcomes when collaborating online • Demonstrate ethical use of technology and digital content with regard to ownership, licensing, and fair use • Understand district and state policies regarding Internet and technology use and the consequences for violating these policies

Background Reading and Reference

- MA Digital Literacy and Computer Science Framework (2016) (https://www.doe.mass.edu/stem/standards.html)
- Cybersecurity Career Pathway, *Cyberseek* (https://www.cyberseek.org/pathway.html)
- National Initiative for Cybersecurity Education (https://www.nist.gov/itl/applied-cybersecurity/nice/about)
- International Society for Technology in Education, ISTE Standards for Students (https://www.iste.org/standards/for-students)
- National Integrated Cyber Education Research Center (https://nicerc.org/2020/03/nicerc-home/)
- National Cyber Security Centre, United Kingdom (https://www.ncsc.gov.uk/section/education-skills/11-19-year-olds)

Classroom and Curriculum Resources

- SAE International, *Cybersecurity: Keeping Our Networks Secure* (middle school unit of A World in Motion program) (https://www.sae.org/learn/education/curriculum/keeping-our-networks-secure) ($)
- Cyber A.C.E.S. Program, Activities in Cybersecurity Education for Students, Palo Alto Networks (https://start.paloaltonetworks.com/cyber-aces.html)
- NOVA Labs (https://www.pbs.org/wgbh/nova/labs/)
- Common Sense Education, Digital Citizenship Lesson Plans (https://www.commonsense.org/education/digital-citizenship/curriculum)
- Common Sense Education, Quick Digital Citizenship Activities for K–5 Distance Learning (https://www.commonsense.org/education/articles/quick-digital-citizenship-activities-for-k-5-distance-learning)
- Google, Be Internet Awesome (https://beinternetawesome.withgoogle.com/en_us)
- National Center for Missing and Exploited Children, Netsmartz (https://www.missingkids.org/NetSmartz)

Exemplar ITEST publications and projects:

- Cultivating Elementary Students' Interest in Cryptography and Cybersecurity Education and Careers (http://stelar.edc.org/projects/22567/profile/cultivating-elementary-students-interest-cryptography-and-cybersecurity)
- Developing Digital Makers in the Coding Makerspace to Include Boys of Color in Computer Science Learning and Cybersecurity Workforce Development (http://stelar.edc.org/projects/21274/profile/developing-digital-makers-coding-makerspace-include-boys-color-computer)
- SEEK18 Cybersecurity Module Teacher Guide (http://stelar.edc.org/projects/22536/curricula/seek18-cybersecurity-module-teacher-guide)
- How to Teach Internet Safety to Younger Elementary Students (https://www.edutopia.org/blog/internet-safety-younger-elementary-mary-beth-hertz)

STEM Career Competency:
Data Literacy

Data literacy is the ability to identify, collect, work with, evaluate, analyze, interpret, and communicate with data (EDC, 2016). Data-literate individuals understand the utility and limitations of data by becoming critical consumers of data, controlling their own personal data trail, finding meaning in data, and acting based on data. They are empowered to become civically active citizens who engage with "big data" (data too large and complex for traditional tools to store or process efficiently), use it to inform their perspectives and decisions, and advocate on behalf of the individuals, families, and communities who are impacted by data-driven policies.

Future STEM Workplace Rationale

Our world economy and jobs are increasingly shaped by data and by the knowledge and skills required to use data effectively. At the human-technology frontier, continuous streams of data between and among humans and machines are being used by scientists, engineers, and business leaders to create, innovate, and make decisions to optimize products and services. Data that is available within minutes of capture is accelerating the pace of innovation and change—particularly in the life sciences, where large data sets are used to conduct research on previously intractable health issues. Data-literate students enter the STEM workforce prepared to perform critical work tasks and solve problems in high-tech work environments that depend on data for discovery and innovation.

The standards listed below were derived from the Massachusetts Department of Education Curriculum Frameworks, Massachusetts Digital Literacy and Computer Science Curriculum Framework, Massachusetts K–12 Computer Science Curriculum Guide, and Real World, Real Science: Using NASA Data to Explore Weather and Climate.

References

EDC. (2016, May 4). *Defining Data Literacy for Students*. https://www.edc.org/defining-data-literacy-students

Grade-Appropriate Data Literacy Skills		
K-2	**3-5**	**6-8**
Develop Questions Students: • Identify questions that can and cannot be answered by data • Define the types of data that could be used to answer questions *Collect and Organize Data* Students: • Make observations and measure differences • Collect data • Understand that computers play a role in storing and accessing data • Use simple keywords or phrases to locate online data (e.g., in digital resources, via library catalogs) • Describe ways data can change over time (e.g., weather data)	*Develop Questions* Students: • Form investigative questions that can be explored through data • Identify sources of data and describe the limitations of data • Make predictions based on data that change over time • Identify and understand the roles of databases in everyday life (e.g., library catalogs, school records, contact lists) *Collect and Organize Data* Students: • Collect data via multiple methods (observations, experiments, surveys) • Identify the structural components of data representations (e.g., axes on a graph, table rows and columns, a scale on a geographic map, a key on a color map)	*Develop Questions* Students: • Develop complex questions and design appropriate data collection methods • Use data, math, and statistics to develop and/or support claims that address specific scientific questions *Collect and Organize Data* Students: • Decode data by identifying and extracting measurements, values, and/or data points from graphs, tables, or other data representations, and describing what they represent • Describe how computing devices represent information • Identify different study designs and the limitations of each • Identify potential biases and missing data in data sets

Grade-Appropriate Data Literacy Skills		
K-2	**3-5**	**6-8**
Analyze Data Students: • Discuss data presented in various forms (e.g., charts, graphs, text) • Compare data and draw conclusions • Organize and arrange data into charts or graphs *Interpret the Results ("Tell the Story")* Students: • Describe how information is collected, used, and presented • Explain how visualizations (e.g., charts, tables, graphs) illustrate data	• Understand data sets with multiple categories and arranged in scaled graphs • Use more complex charts that record more variables (e.g., dot plot charts) *Analyze Data* Students: • Organize and manipulate their own data sets • Describe how databases are used to organize and analyze data • Identify the limitations of data and potential issues with data collection methods *Interpret the Results ("Tell the Story")* Students: • Students tell the data story through visualizations (e.g., charts, graphs)	*Analyze Data* Students: • Create, modify, and manipulate databases • Identify the most appropriate visualization for a given data set • Make quantitative and qualitative comparisons of data • Decode and analyze data and identify and describe meaningful patterns in the data *Interpret the Results ("Tell the Story")* Students: • Accurately interpret data representations • Connect position statements with data sets that support them • Communicate scientific information, and separate factual information from inferences

Background Reading and Reference

- Massachusetts Curriculum Frameworks (http://www.doe.mass.edu/frameworks/search/)
- Real World, Real Science: Using NASA Data to Explore Weather and Climate (http://oceansofdata.org/projects/real-world-real-science-using-nasa-data-explore-weather-and-climate)
- 2016 Massachusetts Digital Literacy and Computer Science (DLCS) Curriculum Framework (http://masscan.edc.org/documents/publications/DLCS_MA_Curriculum_Framework-June_2016.pdf)
- Massachusetts K–12 Computer Science Curriculum Guide (http://masscan.edc.org/documents/publications/K-12_CS_Curriculum_Guide.pdf)
- Guidelines for Assessment and Instruction in Statistics Education (GAISE) Reports (https://www.amstat.org/asa/education/Guidelines-for-Assessment-and-Instruction-in-Statistics-Education-Reports.aspx)
- National Council of Teachers of Mathematics, Principles and Standards for Data Analysis and Probability (https://www.nctm.org/Standards-and-Positions/Principles-and-Standards/Data-Analysis-and-Probability/)
- Common Core State Standards, Mathematics, Measurement and Data (K–5) and Statistics and Probability (6–8 and high school) (http://www.corestandards.org/Math/Content/MD/)
- Joan Garfield and Dani Ben-Zvi, *Developing Students' Statistical Reasoning: Connecting Research and Teaching Practice* (2008) (https://www.springer.com/gp/book/9781402083822)

Classroom and Curriculum Resources

- The Oceans of Data Institute, Resources for Educators Using Data in the Classroom (data activities, lessons, and resources, organized by grade level) (http://oceansofdata.org/our-work/teacher-resources)
- Beauty and Joy of Computing (http://bjc.edc.org/)
- Strengthening Data Literacy Across the Curriculum (https://cadrek12.org/projects/strengthening-data-literacy-across-curriculum)

Exemplar ITEST publications and projects:

- Understanding Weather Extremes with Big Data: Inspiring Rural Youth in Data Science (http://stelar.edc.org/projects/22767/profile/understanding-weather-extremes-big-data-inspiring-rural-youth-data-science)
- From Data To Awesome (D2A): Youth Learning to be Data Scientists (http://stelar.edc.org/projects/18918/profile/data-awesome-d2a-youth-learning-be-data-scientists)
- Data Modeling with Young Learners and Their Families (http://stelar.edc.org/projects/20171/profile/data-modeling-young-learners-and-their-families)

STEM Career Competency:
Dynamic Interdisciplinary Teaming

Dynamic interdisciplinary teaming refers to the ability to function in and contribute to a variety of teamed groups. It is both fluid in nature and specific to the task and purpose at hand. It encompasses a number of components, for example:

- The ability to both contribute expertise and learn from others
- A flexible understanding of group processes and when and how to use them
- The ability to identify and fulfill a variety of team roles and functions pertaining to specific project tasks
- The ability to collaboratively set common priorities, goals, and outcomes and measure progress toward them
- Cultural competence
    - The ability to learn from and work within a global context unrestricted by geography and respectful of diverse national and regional workplace norms

Leaders of dynamic interdisciplinary teams must be skilled at negotiation, resilience, and systems thinking.

Future STEM Workplace Rationale

Dynamic interdisciplinary teams that include machines will drive innovation at the convergence of disciplines. Some team members will bring deep content knowledge, others sophisticated technical skills, and still others the ability to synthesize and get the best synergies among the different actors moving in and out of projects as needed. This future workforce, often virtual in nature, invites and requires distributed teamwork and collaboration with colleagues who may be based anywhere in the world, thus requiring greater technological expertise, individual flexibility, and cultural competence among all team members. Current research indicates that agile organizations require the work of numerous small teams that are constituted and reconstituted over time by the unique demands of the challenge or task at hand, rather than static departments or groups.

Grade-Appropriate Dynamic Interdisciplinary Teaming Skills		
K-2	**3-5**	**6-8**
Understanding of Collaborative Processes and Roles Students: • Students play simple cooperative games, thinking together about how to beat the game *Cultural and Personal Competence* Students: • Students value the contributions of all team members *Flexibility and Resilience* Students: • Students learn that making mistakes is inevitable, natural, and part of the learning process and have opportunities to do things over	*Understanding of Collaborative Processes and Roles* Students: • Play more complex cooperative games, thinking together about how to beat the game • Assume different roles on a team • Participate in team sports, learning to personally achieve in service of the team *Cultural and Personal Competence* Students: • Recognize their own personal strengths and how they add value to a team • Acknowledge and value differences in others, and appreciate that others can be expert in and knowledgeable on various topics *Flexibility and Resilience* Students: • Understand that other team members make mistakes and should have the opportunity to do things over • Recognize the expertise of team members and others and make recommendations to teammates for whom to call on as a resource	*Understanding of Collaborative Processes and Roles* Students: • Take on different roles on a team and perform these roles while moving from team to team • Work together to identify alternative approaches to solving a problem, try each approach and test its efficacy, analyze the outcomes, and report their results to others *Cultural and Personal Competence* Students: • Learn about and can recognize contributions to science, mathematics, medicine, arts, and more from members of cultures different from their own • Value the unique contributions and perspectives of team members with gender identities and/or cultural backgrounds different from their own *Flexibility and Resilience* Students: • Students figure out what is correct within a mistake or wrong answer and work with the team to build on it to develop a better solution

Background Reading and Reference

- Deloitte Insights, *The Organization of the Future: Arriving Now* (https://www2.deloitte.com/us/en/insights/focus/human-capital-trends/2017/organization-of-the-future.html)
- Academy of Management, *Virtual Teams: Technology and the Workplace of the Future* (https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1054&context=management_pubs)
- Asia Society, *Educating for Global Competence: Preparing Our Youth to Engage the World* (https://asiasociety.org/files/book-globalcompetence.pdf)
- Okta, *The Future of Work Is Dynamic* (https://www.okta.com/dynamic-work)
- Sean Newman Maroni, *Interdisciplinary Is Not Multidisciplinary* (2015) (https://blog.seannewmanmaroni.com/interdisciplinary-verses-multidisciplinary-40024faafeee)
- American Speech-Language-Hearing Association, *Collaboration and Teaming* (https://www.asha.org/Practice-Portal/Clinical-Topics/Intellectual-Disability/Collaboration-and-Teaming/)
- Jared Spataro, *The Future of Work—The Good, the Challenging & the Unknown* (2020) (https://www.microsoft.com/en-us/microsoft-365/blog/2020/07/08/future-work-good-challenging-unknown/)

Classroom and Curriculum Resources

- Cooperative games, such as Sandcastles (Family Pastimes Games, https://familypastimes.com/) for ages 5 and up, and Hanabi for ages 8 and up ($)
- SAE International, A World in Motion Challenges (https://www.sae.org/binaries/content/assets/cm/content/learn/education/awim_flyer.pdf) ($)
- *TeachThought*, 20 Collaborative Learning Tips and Strategies for Teachers (August 2020) (https://www.teachthought.com/pedagogy/20-collaborative-learning-tips-and-strategies/)
- *Edutopia*, Resources on Developing Resilience, Grit, and Growth Mindset, (January 2016) (https://www.edutopia.org/resilience-grit-resources)•
- *PositivePsychology.com*, 27 Resilience Activities and Worksheets for Students and Adults (September 2020) (https://positivepsychology.com/resilience-activities-worksheets/)
- Engineering is Elementary (EiE) (in-school curriculum resources for grades K–5 and out-of-school-time resources for grades 3–5 and 6–8) (https://eie.org/stem-curricula/engineering-grades-prek-8/engineering-is-elementary) ($)
- PLANETS (a NASA-funded partnership between Northern Arizona University Center for Science Teaching and Learning, Engineering is Elementary, and USGS Astrogeology Science Center) (https://planets-stem.org/)

Exemplar ITEST publications and projects:

- Including Students' Geographies in Geography Education: Spatial Narratives, Citizen Mapping, and Social Justice (http://stelar.edc.org/publications/including-students'-geographies-geography-education-spatial-narratives-citizen-mapping)

Background Reading and Reference	Classroom and Curriculum Resources
	• Supporting Students' STEM Innovations with Industry Partners (http://stelar.edc.org/publications/supporting-students'-stem-innovations-industry-partners) • Middle School Pathways in Computer Science: Computing with a Community Focus (http://stelar.edc.org/videos/middle-school-pathways-computer-science-computing-community-focus)

STEM Career Competency: Design Thinking

Design thinking is a research-driven, systematic, and non-linear approach to problem exploration and innovation in fields at the intersection of the human-technology frontier. The Henry Ford Learning Institute defines design thinking as "a collection of mindsets and methods that allow us to creatively explore problems, then reframe and act on them" (Kreinbring, 2019, ¶1). Design thinking is most useful in contexts where the challenges are ambiguous and a range of solutions may be possible. The needs of the user drive the design process and form the criteria for selecting an eventual innovation or design. Successful designers develop a deep understanding of human needs, clarify the problem constraints, actively search for information, summarize and prioritize learnings, and generate and test ideas to address problems in new and creative ways.

Future STEM Workplace Rationale

As the pace of technology, discovery, and innovation increases, so will the need for employees who translate fundamental experiments into products and services with a societal impact. Design thinking plays a significant role in the future of work, not only because it captures a structured but flexible process by which ideas are formulated into potential solutions, but also because it provides a common language and methodology for engineers and team members from other disciplines to define a problem and develop pathways toward a solution.

Real-world problems are messy and complex. Design thinking provides a process through which that complexity can be unpacked, explored, and addressed.

References

Kreinbring, L. (2019, January 9). *What Is Design Thinking?* Henry Ford Learning Institute. https://hfli.org/what-is-design-thinking/

Henry Ford Learning Institute. (2019). *What Is Design Thinking?* https://hfli.org/what-is-design-thinking/

Grade-Appropriate Design Thinking Skills		
K-2	**3-5**	**6-8**
Students: • Identify the thoughts and feelings of others • Name the intended users and uses for an invention • Practice informal brainstorming • Use physical materials to create an invention for a specific user • Test their invention and get feedback from users • Explain how to make their invention better based on user or tester feedback	Students: • Practice active listening and make observations • Distinguish between social and personal problems to be solved through a design • Interview users and collect information • Use a formal brainstorming process to generate ideas • Develop, test, and iterate prototypes • Refine their prototypes based on user feedback	Students: • Identify a challenge of social importance and personal interest • Engage in research to understand a challenge more deeply • Develop problem statements embedded within a complex challenge • Develop effective interview questions to surface user needs and perspectives • Analyze user data to define design challenges • Create stakeholder maps • Develop point-of-view statements for users • Develop a blueprint for a prototype • Gather feedback from users • Revise their prototypes and present a rationale for the final design

Background Reading and Reference

- Sarah Gibbons, *What Is Design Thinking, Really? (What Practitioners Say)* (2018) (https://www.nngroup.com/articles/design-thinking-practitioners-say/)
- Lisa Kreinbring, *What Is Design Thinking?* (2019) (https://hfli.org/what-is-design-thinking/)
- Rim Razzouk and Valerie Shute, What is design thinking and why is it important? (2012, *Review of Educational Research*, *82*[3], 330–348) (https://learningenvironmentsdesign.pressbooks.com/chapter/lbd-chapter-1/)
- Ideo, Design Thinking for Educators (https://designthinkingforeducators.com/design-thinking/)
- Anamika Singla, *Design Thinking for Kids* (2020) (https://uxdesign.cc/design-thinking-for-kids-52b5c7351ba4)
- IdeaCO, Stanford's Design Process for Kids: Teaching Big Picture Problem Solving (2013) (http://www.ideaco.org/2013/07/standfords-design-process-for-kids-teaching-big-picture-problem-solving/)
- ASCD, Design Thinking in Play: An Action Guide for Educators (2020) (http://www.ascd.org/Publications/Books/Overview/Design-Thinking-in-Play.aspx) ($)
- David Lee, *Design Thinking in the Classroom* (https://www.davidleeedtech.org/designthinkingintheclassroom) ($)
- ASCD, Design Thinking for School Leaders (2018) (http://www.ascd.org/Publications/Books/Overview/Design-Thinking-for-School-Leaders.aspx) ($)

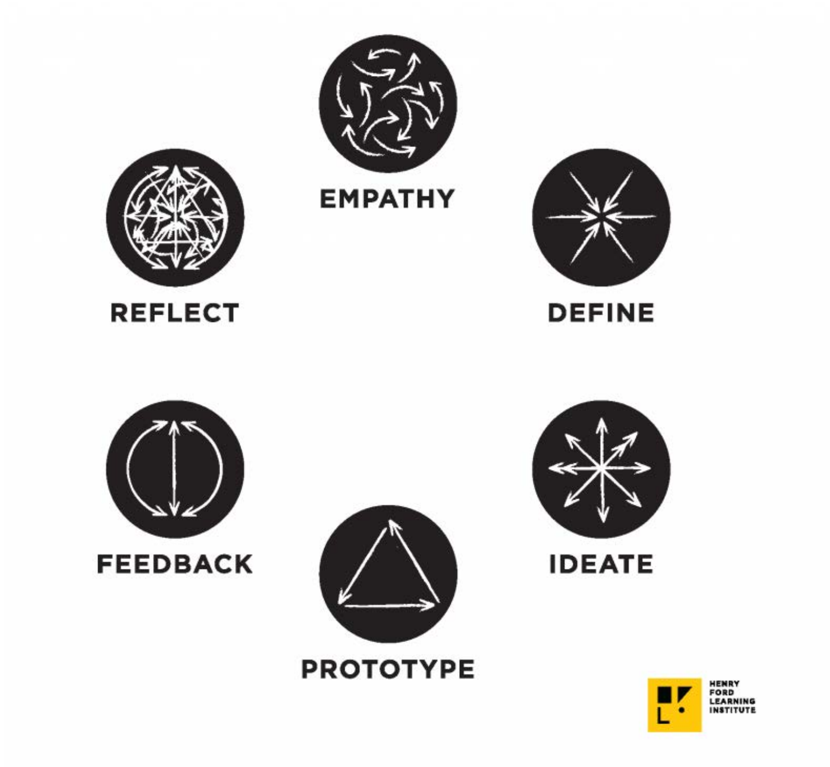
Classroom and Curriculum Resources

- Engineering is Elementary (https://www.eie.org/stem-curricula/engineering-grades-prek-8/engineering-is-elementary) ($)
- SAE International, *A World in Motion* (design-based engineering challenges that embed the engineering design experience (https://www.sae.org/learn/education) ($)
- Design for Change, "I Can" Lesson Plans (https://icanlessonplans.dfcworld.com)
- Destination Imagination (team challenges) (https://www.destinationimagination.org/challenge-program/)
- Invention Convention curricula (https://www.nationalinventioncurriculum.org)
- TRY Engineering (IEEE lesson plans) (https://tryengineering.org/) ($)
- Design Thinking Educator Resources (HFLI 2021). (https://learn.hfli.org) After completing a free registration, teachers can enroll in any posted course and download classroom resources.

Exemplar ITEST publications and projects:

- Additive Innovation in Design Thinking and Making (http://stelar.edc.org/publications/additive-innovation-design-thinking-and-making)
- Stretch, Dream, and Do—A 21st Century Design Thinking & STEM Journey (http://stelar.edc.org/publications/stretch-dream-and-do-21st-century-design-thinking-stem-journey)
- Shoot For The Moon! The Mentors and the Middle Schoolers Explore the Intersection of Design Thinking and STEM (http://stelar.edc.org/publications/shoot-moon-mentors-and-middle-schoolers-explore-intersection-design-thinking-and-stem)

Background Reading and Reference	Classroom and Curriculum Resources
• Metropolis, IDEO's Ten Tips for Creating a 21st Century Classroom (2009) (https://new-ideo-com.s3.amazonaws.com/assets/files/pdfs/news/Metropolis_Feb09.pdf) • The Elementary STEM Journal (https://www.iteea.org/39195.aspx) ($)	



Source: Henry Ford Learning Institute, 2021. Used with permission.

STEM Career Competency: Systems Thinking

A *system* is a network made up of individual components that have some influence on one another and affect both the broader system and the environment in which that system operates. For example, a classroom operates as a system made up of a teacher and a group of students, each of whom influences both the others and the broader operation of the class. A number of factors—including individual choices made by the human actors, external influences (such as school policies and curriculum requirements), and the availability of community resources—all contribute to the operations of the class as a system. This class also needs to be seen as a system within nested and overlapping systems, including the school and the community, as well as the many systems constituted by the families involved.

Systems thinking is an approach to complex challenges or problems that considers how discrete parts influence and interact with one another, rather than view individual components as independent or acting in isolation. Competency in systems thinking includes the ability to understand and describe the context in which a system or organization operates, to identify and map the individual components of that system, and to understand how the components interact with and impact one another. Key ideas include the influence of feedback loops and how to differentiate complex challenges from the merely complicated.

Future STEM Workplace Rationale

Real problems do not take place in a vacuum. To make sense of complex problems and challenges, future-ready employees who employ a systems approach will take a holistic view of a system: spot patterns; uncover root causes and effects; predict the impact of small and large changes across the system; and envision efficient, effective, and impactful solutions that assume and build on interrelationships within a product, company, or network and support healthy organizational functioning. Systems-thinking employees will be able to predict and plan for organizational change and to develop and manage context-appropriate solutions to problems that are responsive to the system as whole, rather than just its separate components.

Grade-Appropriate Systems Thinking Skills		
K-2	**3-5**	**6-8**
Students: • Recognize and define a system • Identify different parts in a system (e.g., a school, a family, a human or animal body) • Describe the differences between systems and collections • Draw arrows showing how one part of a system interacts with other parts	Students: • Determine the purposes and functions of different systems • Observe and analyze different systems that have the same outcome (e.g., how one class transitions from reading to lunch compared to another class) • Describe (in writing and verbally) the interactions between parts of a system • Reflect on cause and effect within an observed system	Students: • Recognize relationships between variables in a system (e.g., feedback loops, interactions between human and physical environments, different information sources related to the same problem) • Complete a systems map demonstrating interrelationships between components of a system • Select, observe, and improve a specific component of a system • Conduct interviews and use empathy to understand the roles of specific stakeholders within a system

Background Reading and Reference

- Peter Senge, *The Fifth Discipline* (1990) ($) (https://books.google.com/books?id=bVZqAAAAMAAJ)
- Amy Ahearn, *Beyond Design Thinking: Why Education Entrepreneurs Need to Think in Systems* (2017) (https://www.edsurge.com/news/2017-12-22-beyond-design-thinking-why-education-entrepreneurs-need-to-think-in-systems)
- Sarah York, Rea Lavi, Yehudit Judy Dori, and MaryKay Orgill, Applications of Systems Thinking in STEM Education (2019, *Journal of Chemical Education*, 96[12], 2742–2751) (https://doi.org/10.1021/acs.jchemed.9b00261)
- Linda Booth Sweeney, *Learning to Connect the Dots: Developing Children's Systems Literacy* (2016) (https://www.thesolutionsjournal.com/article/learning-to-connect-the-dots-developing-childrens-systems-literacy/)
- Daniel Kim, *Introduction to Systems Thinking* (2018) (https://thesystemsthinker.com/introduction-to-systems-thinking/)

Classroom and Curriculum Resources

- Water Bears (https://www.commonsense.org/education/app/water-bears) ($)
- PBS Kids Cart Kingdom (https://www.commonsense.org/education/app/pbs-kids-kart-kingdom)
- Systems Literacy Curriculum (https://illinois.pbslearningmedia.org/collection/systemsliteracy/)
- Institute of Play, Design Pack: Systems Thinking (http://educators.brainpop.com/wp-content/uploads/2014/07/IOP_QDesignPack_SystemsThinking_1.0.pdf)
- Willow School Systems Thinking Ebook (https://willowschool.org/systems-thinking/)
- Leyla Acaroglu, *Tools of a Systems Thinker* (2017) (https://medium.com/disruptive-design/tools-for-systems-thinkers-the-6-fundamental-concepts-of-systems-thinking-379cdac3dc6a)
- Tatum Moser, *How to Practice Systems Thinking in the Classroom* (2016) (https://teacher-blog.education.com/how-to-practice-systems-thinking-in-the-classroom-9cbfa3dcd2cf)
- Agency by Design, *Mapping Systems: A Practice for Fostering the Maker Capacities: Looking Closely, Exploring Complexity & Finding Opportunity* (Project Zero, Harvard Graduate School of Education) (http://www.agencybydesign.org/sites/default/files/AbD%20Mapping%20Systems%20.pdf)

Exemplar ITEST publications and projects:

- Digital Technology Integration and Engineering Contexts to Support Elementary Students' Systems Thinking (http://stelar.edc.org/projects/22565/profile/digital-technology-integration-and-engineering-contexts-support-elementary)

Background Reading and Reference	Classroom and Curriculum Resources
	• Examining a Place-Based and Technology Driven Curriculum that Focuses on Systems Thinking Among Students (http://stelar.edc.org/projects/22380/profile/examining-place-based-and-technology-driven-curriculum-focuses-systems) • Teaching Spatial Thinking and Geospatial Technologies Through Citizen Mapping and Problem-Based Inquiry in Grades 7-12 (http://stelar.edc.org/publications/teaching-spatial-thinking-and-geospatial-technologies-through-citizen-mapping-and)

STEM Career Competency:
STEM Career Development

STEM career development refers to the iterative lifelong learning experiences during which individuals develop the interests, knowledge, skills, and dispositions they will carry through into adulthood and then translate them into productive and rewarding careers. Career development begins at home and is nurtured through in-school and out-of-school experiences, ultimately influencing adult career choices.

Career development is grounded during youth's formative years, when students are guided through distinct stages:

- Career awareness: Elementary school children learn about their families, communities, and people who work.
- Career exploration: Middle school youth explore and align their interests and values with adult roles and lifestyle choices that can be made possible through various careers.
- Career preparation: High school youth make preliminary career decisions by selecting courses, enrolling in programs, and choosing career pathways.

Well-guided STEM career development begins early. Purposefully guiding STEM career development in K–8 and offering opportunities for students to develop interest in and persist along STEM career paths helps to ensure that all students have opportunities to become aware of, explore, and—if they are interested and supported—start on a pathway toward a high-tech STEM career, thus enabling them to access the benefits afforded by such careers in the future and to contribute to society in this important way.

Future STEM Workplace Rationale

Rapid advances in technologies and access to big data have changed the way we live, learn, and work. Guided career development during the foundational years can provide opportunities for students to:

- Explore and discuss new discoveries in STEM
- Learn about traditional and emerging STEM fields at the edges of the human-technology frontier

- Meet people working in the fields of science, engineering, mathematics, technology, and computer science; ask them questions; and seek career advice
- Uncover and solve real-world problems, using real-world tools and resources

Career guidance can stimulate students' interest in and excitement about STEM, encourage them to try new STEM skills, tie STEM to the realities of their lives and what they are learning, and help them recognize the contributions they can make in these fields.

Grade-Appropriate STEM Career Development Skills		
K-2	**3-5**	**6-8**
Students: • Identify, ask questions about, and discuss different kinds of work and STEM careers, how things are made, and how services are provided (e.g., Who makes or builds this digital device? Who draws the characters? Who makes it work and/ or creates the software?) • Practice simple goal-setting and decision making • Recognize what it is to be a good worker and a collaborative community member, and know how to appropriately interact with others • Communicate their feelings, needs, and interests	Students: • Develop positive attitudes about themselves as unique and special individuals by identifying their personal interests, skills, and abilities and how these might relate to various STEM careers • Make choices about and demonstrate behaviors that lead to success in school and work • Identify social and life skills and demonstrate behaviors that influence interpersonal relationships in positive ways • Discuss STEM career pathways and clusters • Enjoy and appropriately interact with others, and demonstrate increased awareness and acceptance of human differences	Students: • Explain how specific interests, skills, and attitudes support and help maintain a positive self-concept • Analyze how personal traits, choices, and behaviors affect success in school and careers • Demonstrate behaviors that reflect positive interpersonal and life skills and are critical for most jobs in the future, including communication, critical thinking, teamwork, and managing conflict

Background Reading and Reference

- Maine Department of Education and Great School Partnerships, 2013 Career Development and Exploration Competencies (https://www.maine.gov/doe/careerandeducation/standards/index.html)
- STEM Strategic Plan: An Integrated K–12 STEM Proposal for Tennessee Division of College, Career & Technical Education (October 2016) (https://www.tn.gov/content/dam/tn/education/ccte/ccte_stem_strategic_plan.pdf)
- Pennsylvania Department of Education, Academic Standards for Career Education and Work (https://www.stateboard.education.pa.gov/Documents/Regulations%20and%20Statements/State%20Academic%20Standards/Career%20Education%20and%20Work%20Standards.pdf)
- National Center for College and Career Transition and Pathways Innovation Network, Career Development Competencies and Activities for the K–12 System (https://www.nc3t.com)

Classroom and Curriculum Resources

- SparkPath, Challenge Cards (https://mysparkpath.com/collections/all/products/challenge-card-deck) ($49)
- Common Sense Education resources (search under "Teacher-Created" using the keywords "career awareness" and "career exploration" and then sort by grade) https://www.commonsense.org/education/search?contentType=flows&page=1&limit=25&includeFacets=true&search=&sort=
- Career Exploration Videos, https://roadtripnation.com/

Exemplar ITEST publications and projects:

- Urban Middle School Students, Twenty-First Century Skills, and STEM-ICT Careers: Selected Findings from a Front-End Analysis (http://stelar.edc.org/publications/urban-middle-school-students-twenty-first-century-skills-and-stem-ict-careers-selected)
- Supporting Students' STEM Innovations with Industry Partners (http://stelar.edc.org/publications/supporting-students'-stem-innovations-industry-partners)
- Digital East St. Louis: An Urban Place-Based Learning Model to Promote Information Technology and Computer Science Career Interests of Minority Youth (http://stelar.edc.org/projects/14649/profile/digital-east-st-louis-urban-place-based-learning-model-promote-information)
- YouthLink: Comprehensive, Innovative and Advanced Digital Technology Experiences for Underserved Teens (http://stelar.edc.org/projects/11341/profile/youthlink-comprehensive-innovative-and-advanced-digital-technology)
- Innovation Challenges for Middle School Mathematics in a Digital Learning System: Student Participation Impact on Achievement, Affect, and STEM Career Interest (http://stelar.edc.org/projects/21557/profile/innovation-challenges-middle-school-mathematics-digital-learning-system)

STEM Career Competency: Lifelong and Flexible Learning

Lifelong learning refers to the ongoing acquisition of knowledge, skills, and understandings "from the cradle to the grave" (International Commission on Education for the Twenty-First Century, 1996).

> Lifelong learning is the development of human potential through a continuously supportive process which stimulates and empowers individuals to acquire all the knowledge, values, skills and understanding that they will require through their lifetimes and to apply them with confidence, creativity and enjoyment in all roles, circumstances, and environments. (Longworth & Davies, 1996, p. 22)

Flexible learning refers to the concept that learning takes place both in and outside of school, including in the workplace. A flexible learner is self-directed and embraces opportunities for growth in a variety of formal and informal settings.

Lifelong and flexible learning is an integral component of the technology-driven workplace.

Future STEM Workplace Rationale

We are already experiencing a shift in expectations for learning at work. While informal learning in the workplace is recognized and highly valued, ongoing formal learning on their own time is increasingly expected of employees. And as humans and machines become more interdependent, the need for lifelong and flexible learning will only increase (Friedman, 2015). Organizations will be pressured to stay at the forefront of change—not just to gain a competitive edge, but to survive. Increasingly, learning will be the responsibility of employees, who must identify and pursue new knowledge to be learned and skills to be developed. New technology innovations will provoke an immediate rush of self-directed learning by employees, who must learn to apply those innovations and to understand, learn from, and build on them.

There is also increasing evidence that corporations will invest directly in upskilling and reskilling of their workforces—so the lifelong, flexible learner is likely to be "in the front of the line" when such investments are made. Students who develop self-directed habits of lifelong and flexible learning will be better prepared to succeed in the workplaces of the future.

References

Friedman, A. (2015). *Continuing professional education: Lifelong learning of millions*. Rutledge.

International Commission on Education for the Twenty-First Century, Delors, J., & UNESCO. (1996). *Learning, the treasure within: Report to UNESCO of the International Commission on Education for the Twenty-First Century.*

Longworth, N., & Davies, W. K. (1996). *Lifelong Learning: New Vision, New Implications, New Roles for People, Organizations, Nations and Communities in the 21st Century.* Kogan Page.

Grade-Appropriate Lifelong and Flexible Learning Skills

K-2	3-5	6-8
Students: • Recognize that learning takes place in a variety of environments • Ask questions about their world and things that provoke their curiosity, both in and outside of school • Experience learning environments characterized by joy and inclusion • Understand how their actions affect situations and other people • Are encouraged to be creative and try new things • Understand that daily life presents opportunities to learn	Students: • Grasp that learning can occur in both formal and informal environments • Seek learning opportunities outside of school • Develop a positive attitude toward learning • Understand how the learning process relates to various careers • Identify habits of mind that support lifelong learning • Begin to familiarize themselves with and adopt professional qualities, such as self-management, agency, self-efficacy, initiative, and enterprise	Students: • Describe how people in various work roles engage in ongoing learning in order to upgrade their skills and adapt to change • Execute projects that demand critical and creative thinking, planning, problem-solving, research, and investigation skills • Apply multiple literacies (e.g., data, information, historical) to identify and understand problems, ask appropriate questions, and design an appropriate solution

Grade-Appropriate Lifelong and Flexible Learning Skills		
K-2	**3-5**	**6-8**
• Engage with learning in a positive way and learn to see it as a marvelous adventure • Feel and express a sense of belonging within circles of trust and acceptance • Give examples of how people (parents, workers, teachers, grandparents, etc.) learn throughout their lifetimes	• Have opportunities to practice interpersonal skills and the ability to work collaboratively	• Have opportunities to develop cross-generational programs that encourage them to learn from and with friends, family members, and caregivers • Adopt a three-tiered approach that enables them to move from participation to deeper engagement to having a transformative experience

Background Reading and Reference

- The State Library of Queensland, *The Lifelong Learning Framework: Children and Young People* (2011) (http://ck.slq.qld.gov.au)
- Lisa Gueldenzoph Snyder and Mark J. Snyder, Teaching Critical Thinking & Problem-Solving Skills (2008, *The Delta Pi Epsilon Journal*) (http://reforma.fen.uchile.cl/Papers/Teaching%20Critical%20Thinking%20Skills%20and%20problem%20solving%20skills%20-%20Gueldenzoph,%20Snyder.pdf)
- Jacques Delors, *Learning: The treasure within. Report to UNESCO of the International Commission on Education for the Twenty First Century* (1998) (https://www.eccnetwork.net/sites/default/files/media/file/109590engo.pdf)
- The Institutes of Achievement of Human Potential (https://www.iahp.org)
- Michael J. Lawson, Helen Askell-Williams, and Rosalind Murray-Harvey, *The Attributes of the Lifelong Learner: Queensland Studies Authority* (2006) (https://www.qcaa.qld.edu.au/downloads/publications/research_qsa_lifelong_learner.pdf)
- Jaswinder Kaur and Anoop Beri, Coping as a life skill for lifelong learning (2016, *Man In India, 96*[5], 1365–1376) (https://serialsjournals.com/abstract/89420_9.pdf)
- Valerie McGrath, *Reviewing the Evidence on How Adult Students Learn: An Examination of Knowles' Model of Andragogy* (2009) (https://files.eric.ed.gov/fulltext/EJ860562.pdf)
- *Framework for 21st Century Learning Definitions* (http://static.battelleforkids.org/documents/p21/P21_Framework_DefinitionsBFK.pdf)

Classroom and Curriculum Resources

Exemplar ITEST publications and projects:

- Personal Learning Journeys: Reflective Portfolios as "Objects-to-Learn-With" in an Etextiles High School Class (http://stelar.edc.org/publications/personal-learning-journeys-reflective-portfolios-"objects-learn-"-etextiles-high-school)
- STEM21: Equity in Teaching and Learning to Meet Global Challenges of Standards, Engagement and Transformation (http://stelar.edc.org/publications/stem21-equity-teaching-and-learning-meet-global-challenges-standards-engagement-and)

This framework identifies **10 foundational career competency areas** correlated to characteristics of future work at the Human Technology Frontier and what thought leaders in the field believe successful workers in those environments need to know and be able to do. It is meant as a guide for teachers interested in helping their students develop the foundations of skills, knowledge, and abilities needed to be successful in life when they exit formal schooling. Many of the suggested competencies may already be included in the curriculum or pedagogy in K-8 classrooms. In those cases, this guide may simply help teachers connect what they are already doing to prepare their students for success in future work. It also suggests competencies and resources to help teachers make connections across disciplines.

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