imagine learning

Foundations Paper

How Imagine Learning's Supplemental STEM Solutions Align with the Four Cs of STEM

CRITICAL THINKING • COMMUNICATION • COLLABORATION • CREATIVITY

Workforce skills have changed dramatically in the 21st century. Jobs with more "routine" work have decreased and have been replaced with jobs that require adaptability for nonroutine work and analytic, interactive communication skills (National Education Association, n.d.). To prepare for college and careers, K–12 students need to acquire skills aligned with the realities of today's work environments. In response to changes in demand for skilled labor, the National Education Association (n.d.) identified the Four Cs of science, technology, engineering, and math (STEM) as essential for all students to acquire. Specifically, the Four Cs are: critical thinking, communication, collaboration, and creativity (defined in Table 1).

The Four Cs are part of a broader range of skills defined by contemporary literature as 21st-century skills. Enhancing the quality of STEM education is important to support all students in acquiring skills needed to obtain jobs in the current environment. The Four Cs of STEM are vital for college and career readiness, regardless of whether students choose college, careers in STEM, or careers after high school in non-STEM fields such as education, hospitality, or transportation.

Table 1: The Four Cs of STEM

	Definition	Importance
Critical Thinking	Critical thinking involves reasoning effectively, using systems thinking, making judgments and decisions, and solving problems.	Learning requires critical thinking. Critical thinking leads students to develop other skills, such as improved thought processing and higher levels of concentration.
Communication	Communication is the ability to articulate thoughts, listen and extract meaning, and interact in diverse environments.	Students must be able to clearly communicate and effectively analyze and process various forms of communication for success in school and careers.
Collaboration	Collaboration is the ability to work effectively with others to achieve common goals.	Considering the complexity of issues and challenges companies, institutions, and governments face, collaboration with diverse individuals is critical for identifying relevant solutions and making informed decisions.
Creativity	Creativity encompasses exploring and analyzing a wide range of ideas and perspectives, generating original and inventive solutions, viewing failure as an opportunity to learn, and turning ideas into tangible solutions.	The rapid pace of change in the 21st century requires adaptation and continual innovation. Students will need to know how to create and innovate to successfully address workforce and social challenges.

Moreover, 21st-century skills have a broader purpose than just improving today's workforce, as individuals' careers are but a partial manifestation of human development (Bronfenbrenner, 2005; Kegan, 1982). The purpose of education is to provide the necessary tools and a healthy environment to support individuals as they develop, grow, and thrive as human beings (Shirley, 2020; Greenlaw, 2015). Developing workforce skills is simply an integral part of human development. Twenty-first-century skills are important because they are life and career skills that apply to all aspects of life. It is therefore crucial to foster the development of such skills for all students by making high-quality STEM education accessible to them. The purpose of this paper is to explore how 21st-century skills are integral to STEM education and to describe research recommendations for fostering the development of these 21-century skills in STEM education.

The Research

As previously discussed, STEM refers to science, technology, engineering, and mathematics. For the purposes of this paper, we focus on science, technology/engineering (computer science specifically), and mathematics. These disciplines are defined as follows. Science is the observation, identification, description, experimental investigation, and theoretical explanation of phenomena. Computer science, a component of the technology and engineering portion of STEM, is "the study of computers and algorithmic processes, including their principles, their hardware and software designs, their applications and their impact on society" (Computer Science Teacher Association, 2011, p. 1). Mathematics is the study of the measurement, properties, and relationships of quantities and sets, using numbers and symbols.

These STEM branches offer much more than simply teaching students scientific theories, mathematical theorems or formulas, or how to build computers, write code and manage data, or explain natural phenomena. In the process of learning STEM subject-matter content, students develop computational and critical thinking, including skills such as problem solving and creative thinking. These disciplines also require strong collaboration and communication, which foster persistence and the development of confidence as students engage with others in solving scientific, technological, and mathematical problems (Bottoms & Sundell, 2016; Burbaite et al., 2018).

Science

Science is knowledge or a system of knowledge concerned with the physical world and its phenomena, covering the operation of general laws as obtained and tested through the scientific method. Therefore, science cannot be defined outside of scientific inquiry. The study of science naturally supports the development of critical thinking. Science education fosters the development of critical thinking through scientific reasoning (Friedler et al., 1990), formal reasoning (Lawson, 1985), and the identification of logical fallacies (Jungwirth & Dreyfus, 1980). However, critical thinking is more than a range of behaviors or activities such as problem solving or inquiry activities. Critical thinking requires not only following specific scientific procedures, but doing so while evaluating evidence, questioning emerging results, and drawing conclusions using one's scientific knowledge (Bailin, 2002; Facione, 1990). Thus, scientific thinking processes and scientific knowledge are both integral parts of critical thinking.

Collaboration is also an essential part of scientific work, and has increasingly become so in the last century (Subramanyam, 1983; Lu & Zhang, 2009). Scientific work includes scientific reviews and collaboration on scientific projects and research. Feedback associated with scientific reviews is essential for refining scientific theories and improving and validating scientific work. Some research indicates that collaborative science interactions in schools can improve attitudes toward science and decrease anxiety (Hong, 2010). Collaboration in science education can be achieved as students work with peers to complete science projects and assignments, engage in purposeful classroom and/or online discussions, and share research in science fairs and competitions at the classroom, school, and/or regional level.

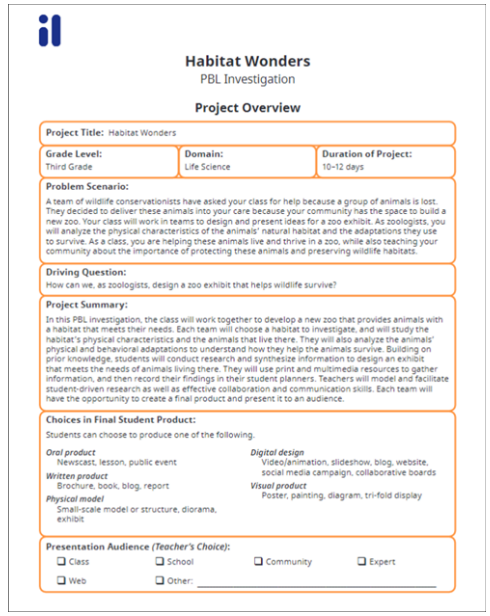
In applying these teaching strategies, scientific discourse and communication skills are essential. Scientific discourse and communication skills in the classroom "hold the key to how students frame their positions, build a case for argument, [and] become aware of fallacious reasoning" (Zeidler, 2003). Thus, fostering communication skills in science education naturally occurs, as richness in both content and scientific literacy are included in the curriculum. As Duschl and Osborne (2002) state, "developing an understanding of science and appropriating the syntactic, semantic and pragmatic components of its language requires students to engage in practicing and using its discourse in a range of structured activities."

Finally, science fosters creativity (Curriculum Development Council, 2017). McCormak and Yager (1989) proposed a science-education taxonomy comprising imagination and invention. Creativity is fostered through both experience and existing knowledge. Scientific knowledge supports creativity through visualization, the multiple interactions between objects or physical observation and ideas, the exploration of diverse uses of objects for alternative solutions, the suggestions of reasonable explanations for observable phenomena, the design of tests to validate explanations, and the communication of new evidence (Yager, 2005). According to Cheng, students need to observe, classify, ask questions, form scientific hypotheses, plan tests, apply measurement methods, and analyze empirical data (Cheng, 2011) to develop scientific reasoning.

Imagine Learning offers both core and supplemental science programs that align with NGSS standards for instruction and emphasize the Four Cs of STEM through inquiry and project-based learning activities and assignments.

Imagine Science Corner: Imagine Science Corner, a K–5 supplemental science program, supports students in learning grade-level concepts and in engaging them with scientific practices. Within the program, each lesson is designed to be developmentally appropriate and visually appealing for elementary learners. Engagement activities keep students interested in learning, and Supported Practice and lesson Mastery Check opportunities require higher-order processing skills for targeted concepts. Students apply learning as they engage with peers in completing project-based learning assignments.

Four Cs Of STEM: Imagine Science Corner's student-driven, Project-Based Learning (PBL) investigations provide all students with access to rigorous, student-centered instruction and opportunities to make meaningful connections to real-world science concepts. Specifically, projects require students to apply the scientific method to investigate a driving question. This activates critical thinking as students determine their method for answering specific questions, explore options for solutions, and evaluate and refine their work for their final product. Creativity is employed as each group of students determines its approach and solution to the problem. Students utilize collaboration and communication skills as they work with peers to complete the project and produce a product that represents their work and scientific thinking, which may be visual or oral products, written material such as blog posts or reports, or models or design illustrations of solutions. Project-Based Learning Investigation builds a shared understanding of big science ideas through discourse and collaboration.


Habitat Wonders
PBL Investigation

Project Overview

Project Title: Habitat Wonders

Grade Level:	Domain:	Duration of Project:
Third Grade	Life Science	10–12 days

Problem Scenario:
A team of wildlife conservationists have asked your class for help because a group of animals is lost. They decided to deliver these animals into your care because your community has the space to build a new zoo. Your class will work in teams to design and present ideas for a zoo exhibit. As zoologists, you will analyze the physical characteristics of the animals' natural habitat and the adaptations they use to survive. As a class, you are helping these animals live and thrive in a zoo, while also teaching your community about the importance of protecting these animals and preserving wildlife habitats.

Driving Question:
How can we, as zoologists, design a zoo exhibit that helps wildlife survive?

Project Summary:
In this PBL investigation, the class will work together to develop a new zoo that provides animals with a habitat that meets their needs. Each team will choose a habitat to investigate, and will study the habitat's physical characteristics and the animals that live there. They will also analyze the animals' physical and behavioral adaptations to understand how they help the animals survive. Building on prior knowledge, students will conduct research and synthesize information to design an exhibit that meets the needs of animals living there. They will use print and multimedia resources to gather information, and then record their findings in their student planners. Teachers will model and facilitate student-driven research as well as effective collaboration and communication skills. Each team will have the opportunity to create a final product and present it to an audience.

Choices in Final Student Product:
Students can choose to produce one of the following.

Oral product
Newscast, lesson, public event
Written product
Brochure, book, blog, report
Physical model
Small-scale model or structure, diorama, exhibit
Digital design
Video/animation, slideshow, blog, website, social media campaign, collaborative boards
Visual product
Poster, painting, diagram, tri-fold display

Presentation Audience *(Teacher's Choice)*:
❑ Class ❑ School ❑ Community ❑ Expert
❑ Web ❑ Other: ____________

Figure 1. Third-grade Project-Based Learning assignment.

Additionally, as students complete lessons and units with the Imagine Science Corner program, they acquire skills necessary for STEM proficiency. Specifically, students are taught academic discourse and vocabulary that provide the foundation for communicating scientific concepts. As they learn new concepts, students apply critical thinking by completing worksheets that require them to articulate understanding and to identify examples and non-examples of specific concepts. In completing lessons, students answer questions that not only assess knowledge of concepts taught, but also require them to apply knowledge to generalize learning. For example, in the Grade 3 Plant Growth lesson (see Figure 2), students learn scientific vocabulary such as germination and seedling. They complete a graphic organizer that requires them to define and describe the terms, and to provide examples and non-examples of the targeted words (see Figure 3). Students then answer questions that require them to critically analyze information to generalize learning in comparing growth rates for oak trees and bamboo.

Figure 2. Grade 3 Plant Growth lesson.

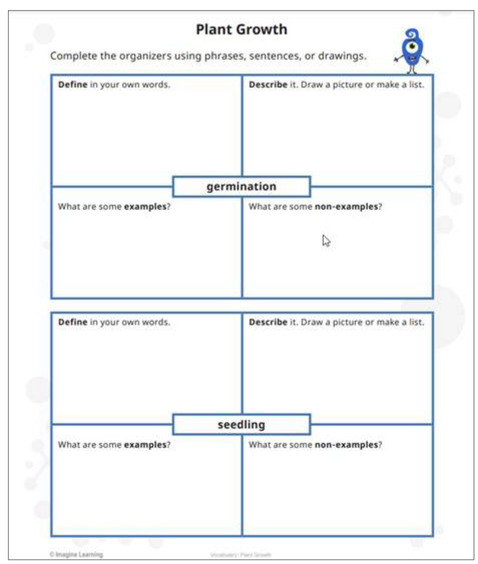


Figure 3. Graphic organizer for academic vocabulary.

Engineering/Technology

Computer science is a branch of science that studies automation, solving computing problems, computational theory, the design of computers including hardware and software design, and ways to use technology. Computational theory is based on theoretical and algorithmic foundations. Computer science incorporates techniques from probability and statistics as it extensively uses hypothesis testing and experimentation in the process of writing and testing algorithms. Computer science, therefore, involves science, technology, engineering, and mathematics; it blends STEM subjects.

An aim of computer-science education is to develop students' ability to engage in computational thinking and creative problem solving (Burbaite et al., 2018). Cognitive processes involved in computational thinking are integral to computer-science concepts and approaches. Computational-thinking elements most referenced in computer science are decomposition, abstraction, algorithms, and debugging (Shute et al., 2017). Decomposition involves breaking down a problem into manageable units. Abstraction entails modeling the main facets of complex problems. Algorithms refer to the design of logical and ordered instructions that are used to execute a solution to a problem. Debugging occurs when a solution does not function as it should; the process involves detecting and fixing errors. These cognitive processes are closely related to fundamental programming concepts used in the field of computer science.

The curricula presented in programming, robotics, and game design each emphasize different elements of computational thinking, and can be utilized to foster computational thinking (Shute et al., 2017) as well as creative problem solving. Programming is often used to promote computational-thinking skills and creative problem solving because writing and using efficient programs entail abstraction, generalization, and debugging. Students apply these processes by determining a goal to achieve, identifying sub-goals and steps to achieve their goal, and proposing efficient solutions. The programming code is meant to be reused to solve similar problems, with minor adjustments. Also, debugging is necessary to test the accuracy and efficiency of the program. The acquisition of programming concepts and practices through programming is considered the most effective way to learn computational thinking (Kong, 2019).

Computer-science education can foster communication, collaboration, and creativity through active-learning tasks such as open-ended projects and the design of creative artifacts (Goldberg et al., 2013; Santo et al., 2019; Vogel et al., 2017). Studies recommend the use of collaborative activities in computer-science education (Clear et al., 2020). Computer science supports the development of creativity and communication through what Resnick (2006) calls creative computing and personal expression. He defines this term through Vogel et al.'s (2017) argument that computers are means to personal expression and creativity. Vogel et al. refer to the "computer as a paintbrush." They postulate that "computers will not live up to their potential until we start to think of them less like televisions and more like paintbrushes. That is, we need to start seeing computers not simply as information machines, but also as a new medium for creative design and expression" (Vogel et al., 2017, p. 1). Their argument is that, though computers can stifle children's creativity and learning through "passive consumption and mindless interaction," computer consumption need not be mindless and passive like television consumption (Vogel et al., 2017; Cordes and Miller, 2000; Oppenheimer, 2003). Much like how the use of a paintbrush allows one to create an infinite number of images through the use of diverse colors, computers and computer science are powerful tools that open the horizon to manifold explorations and creations, such as graphic animation, musical composition, robotic constructions, and so forth (Vogel et al., 2017).

Imagine Robotify: Imagine Robotify provides comprehensive computer-science curricula for students in Grades 3–8. The program is designed to provide real-world application of computer-science concepts and skills as students are immersed in highly engaging programming environments. Instruction focuses on teaching foundational skills, having students apply learning by solving programming challenges, and then refining skills and approaches as students compete with peers in online challenges.

Four Cs Of STEM: All aspects of engaging with the Imagine Robotify program support the acquisition of STEM skills. As students are exposed to foundational programming with Blockly and Python courses (see Figure 4), they engage in hundreds of closed- and open-ended challenges that require critical thinking. To complete tasks, students use iterative design progresses to optimize their success with challenges and to increase the efficiency of solutions (see Figures 5 and 6). These iterative design processes tap into students' creativity as they apply learning in unique and creative ways reflective of their learning. Additionally, students learn to communicate with others as they use built-in-links to share and fork projects with their peers. This helps them to understand that coding is a collaborative process. Finally, students use critical thinking, creativity, communication, and collaboration skills as they engage in online competitions with peers. During competitions, students may collaborate and communicate with peers as they determine solutions for assigned challenges. They apply critical thinking as they determine optimal approaches for beating competitors within specific timeframes.

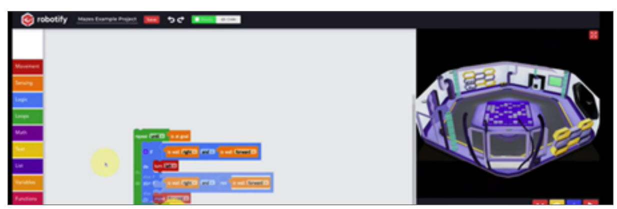


Figure 4. Blockly programming example. Student-driven lesson that develops all 4Cs of STEM skills.

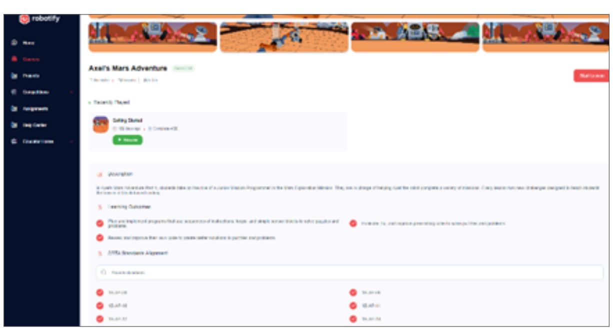


Figure 5. Axel's Mars Adventure: Algorithm/coding lesson that inspires critical thinking, iterative design processing, and creativity.

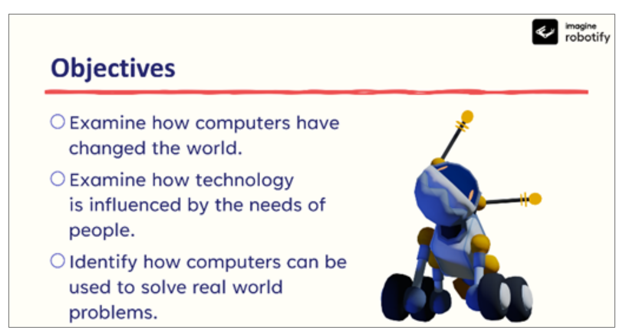


Figure 6. Offline lesson objectives: Impact of Technology and Computing.

This instructional sequence focuses on applying computer-science knowledge to real-world problems, and also reflects objectives of lessons that can be completed outside of the Imagine Robotify learning platform. For example, Figure 6 shows objectives for a lesson that helps students learn about the impact of technology and computing, and that requires them to apply critical thinking, to collaborate and communicate with peers, and use creativity in exploring and reporting how computers have changed the world and are used to solve important problems.

Mathematics

The word mathematics comes from the Greek máthēma and means "that which is learnt." Mathematics has its own language, which is a powerful structure that enables students to come to a deep knowledge and understanding of various abstract concepts. Its language is used in science, technology, and engineering. Therefore, it is the mortar of communication within the STEM sciences and enables interdisciplinary communication between all these fields of study. Mathematics includes a rich variety of subdisciplines such as algebra, arithmetic, geometry, analysis, probability, and statistics. These subdisciplines of mathematics are, in essence, the epitome of critical thinking.

Mathematics fosters a creative mind through the richness of its conceptual content, within both its abstract sphere and its application sphere. Mathematics touches the realm of pure abstraction and influences the world of physical observation and realities. Inventions in the scientific and technological world are all based on mathematical concepts and language. Additionally, mathematics history shows a substantial portion of mathematics advancement is due to collaboration between researchers (Singh, 2017). The very rich and dense nature of mathematics naturally brings practitioners to work, think, and elaborate collaboratively.

Mathematics in General

Mathematical literacy is critical for society, and students need opportunities to apply mathematics to their everyday lives (Wijaya et al., 2015), whether they end up choosing a STEM-related career or not. Real-world contexts, or contextual representations, are a powerful tool for promoting 21st-century skills such as problem solving (National Council of Teachers of Mathematics, 2014). Real-world contexts are often presented as word problems, which provide a meaningful basis for students to transform the context of a situation into a mathematical form. Grounding mathematics in contexts that are relevant to students (Ladson-Billings, 2009) enriches their understanding (Van de Walle et al., 2018), honors their lives outside of the classroom, affirms their cultural experiences (Ukpododu, 2011), and promotes agency (Schoenfeld, 2014).

Mathematical discourse fosters communication skills. The National Council of Teachers of Mathematics (2014) describes mathematical discourse as "the purposeful exchange of ideas through classroom discussion, as well as other forms of verbal, visual, and written communication" (p. 24) and a "primary mechanism for developing conceptual understanding" (p. 30). Thus, mathematical discourse supports the development of both communication and critical-thinking skills. Studies show positive associations between mathematical discourse that emphasizes reasoning and problem solving and student learning outcomes (Michaels et al., 2008). According to Smith and Stein (2018), mathematical discourse provides benefits for students across grade levels, including those with learning disabilities and struggling in mathematics. It fosters students' language development by promoting their use of words, symbols, and models to represent their mathematical thinking, make sense of their ideas, form connections across concepts, and clarify their understanding (Huinker & Bill, 2017). Opportunities like journal writing help students learn to express their understanding of vocabulary through written text. Graphic organizers help students communicate using multiple representations (e.g., equations, models, or examples and non-examples). Through multimodal communication (e.g., verbal, written, or pictures) students learn how to communicate clearly, while strengthening their conceptual understanding of key mathematics concepts.

To engage students in using mathematical communications and vocabulary, online learning environments should actively engage students in the learning process by incorporating talk moves, such as probing and purposeful questions (e.g., how and why, "What strategy might you use to solve this problem?" etc.) that ask students to explain, elaborate, or clarify their understanding of mathematics concepts, specific questions (e.g., explicit and direct) to draw attention to critical mathematics content and scaffold learning (Banse et al., 2016), or concrete support for students who are struggling ("Could you draw a picture to help you solve this problem?") (Harbour & Denham, 2021). With consistent opportunities to strengthen mathematical discourse, language development, and vocabulary, students' ability to communicate in productive and effective ways deepens, broadens, and becomes increasingly complex.

Finally, as students engage in mathematic discussions and in solving mathematics problems, they are likely to encounter problems that require new ways of thinking. Cognitively demanding tasks in mathematics foster productive struggle, or the struggle to make sense of unfamiliar concepts and procedures that are not immediately apparent (Hiebert & Grouws, 2007). Students who engage in productive struggle delve "more deeply into understanding the mathematical structure of problems and relationships among mathematical ideas, instead of simply seeking correct solutions" (National Council of Teachers of Mathematics, 2014, p. 48), fostering the development of critical thinking and other 21st-century skills. While these tasks may be challenging, they fall within a student's ability to solve without the direct help of a teacher (Smith et al., 2018). Experts agree that productive struggle is a critical part of the learning process because it encourages persistence in problem solving, leads to a stronger conceptual understanding, fosters agency, and improves metacognitive strategies (Kapur, 2014; Sinha & Kapur, 2021).

Geometry

Because mathematics involves a wide and deep variety of subdisciplines, we also highlight the development of the Four Cs within two subdisciplines: geometry, because of its importance in fostering the Four Cs of STEM (Clements & Sarama, 2021); and statistics, because statistical literacy is one of the main 21st-century skills needed today in the workforce (Battelle for Kids, 2019).

The van Hiele Model of Geometric Thinking catalogues students' progressive understanding of geometric reasoning into five levels (van Hiele, 1986). Levels 3 and 4 are levels of deductive reasoning that are part of the broader skill of critical thinking:

- Level 3 (informal deduction)—recognizes and describes the relationships between objects and shapes, and engages in "if…then" reasoning.
- Level 4 (formal deduction)—constructs proofs, analyzes informal arguments and the structure of a system, and begins to establish geometric truth based on logic.

Level 5, which van Hiele calls rigor, is the level at which students understand abstract geometry and see the "construction" of geometric systems. Understanding abstract geometry and visualizing geometric constructions and concepts, such as higher dimensions, are a powerful part of creativity. Having what we often call "vision"—an understanding, or at least a sense, of that which potentially exists but hasn't been created yet—is the initial step of the creative process (Battelle for Kids, 2019).

Despite the importance of this domain, geometry typically receives less attention than other domains (Clements & Sarama, 2021) and instruction often emphasizes vocabulary over application or concept development (Geddes & Fortunato, 1993; Sinclair & Bruce, 2015). To strengthen students' geometric thinking and foster connections between geometry and other mathematics domains, instruction should:

- Provide opportunities for students to reason about two- and three-dimensional shape attributes and properties using precise language, decompose shapes, compare examples and non-examples, and make connections between concepts and the real world (Clements & Sarama, 2021; Dobbins et al., 2014; Groth, 2013; Resnick et al., 2020; Seah & Horne, 2020). These skills encompass communication and critical thinking, as well as creativity.
- Integrate the use of dynamic technology to explore the visual nature of geometry (e.g., interactive manipulatives or geoboards) (Chan & Leung, 2014; NCTM, 2014; Sinclair & Bruce, 2015) and concepts like geometric measurement and transformations (Groth, 2013), thus fostering creativity through the development of computer skills.

Statistics

As the demand for statistical literacy grows, opportunities to reason about data, statistics, and probability have assumed a much deeper and wider role in mathematics curricula (Bargagliotti et al., 2020; Groth, 2013; Leavy et al., 2018). Statistical reasoning involves interpreting real data sets, graphic representations, and statistical summaries (Garfield, 2002). It also includes concepts like distribution, sampling, measures of center, measures of variability, probability, and inferences. While the goal of statistics is to understand the interaction between data and context, research has found many students struggle to make sense of these concepts (Bryant & Nunes, 2012; Groth, 2013; Rahmi et al., 2021) and are unable to develop reasoning skills at the level that is needed (Glancy et al., 2017). A growing body of research recommends the following instructional practices to expand students' statistical-reasoning skills:

- Provide real and motivating data sets; organize and display data using different representations (e.g., tables, charts, graphs); explore statistical concepts beyond measures of center (e.g., variability, inferences); and employ different statistical tests (Biehler et al., 2013; Groth, 2013).
- Utilize technology to make statistics visual, interactive, and dynamic, as this helps emphasize concepts over computation and offers engaging opportunities to analyze data (Biehler et al., 2013).

Imagine Math: Imagine Math provides rich supplemental mathematics curriculum for students at the Pre-K level through Geometry. The program promotes deep conceptual understanding, with an intentional emphasis on academic language development and the development of skills needed for college and career readiness. Pre-K–2 students learn academic vocabulary as they interact in real-world contexts that include fun games and catchy songs to reinforce learning. Students in Grades 3 and above explore mathematical understanding as they are exposed to units and lessons that align with grade-level standards. As students complete lessons, learning is reinforced and extended with journaling opportunities that develop mathematic language skills as students explain thinking, justify reasoning, and reflect on problem-solving processes. These skills are also utilized as students complete application tasks that require generalization of concepts to new challenges and problems to solve. Across all grade levels, learning is supported with various types of scaffolding, including visual representations, the use of animations and games, dictionaries, multiple representations of concepts, and access to live certified teachers who provide instruction when requested.

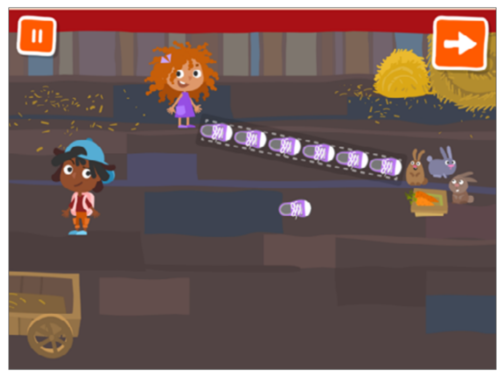


Figure 7. Kindergarten: Measurement I - Activity 3, Exercise 4

Four Cs Of STEM: Problem solving and critical thinking are inherent in learning mathematics. In Imagine Math, Pre-K–2 students enter a storybook reality in which they solve problems to develop number sense, learn mathematic operations, critically analyze measurement problems, read and interpret graphs and data, and learn foundations for algebraic thinking. Critical thinking is activated throughout the program as students solve various problem types. For example, in Figures 7 and 8, kindergarten students learn about measurement, then compare lengths to determine which visual representation is longer.

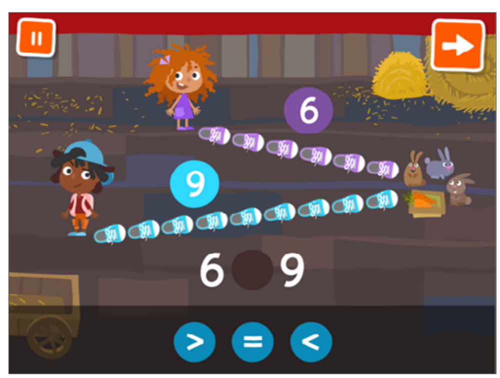


Figure 8. Kindergarten: Measurement I - Activity 3, Exercise 8

Students in Grade 2 use measurement tools to solve problems. In Figure 9, students use the length of a nail to determine the length of a hammer and a pipe wrench.

Figures 10 and 11 illustrate adding fractions and decimals.

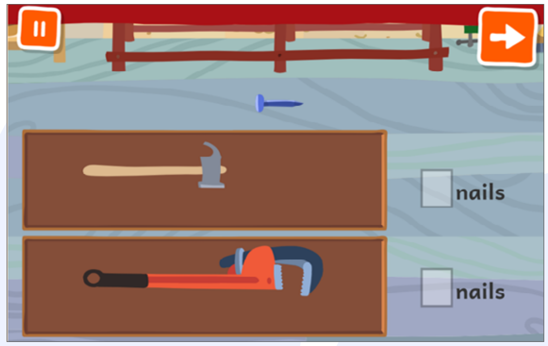


Figure 9. Grade 2: Measuring, solving problems with lengths - Activity 1, Exercise 1

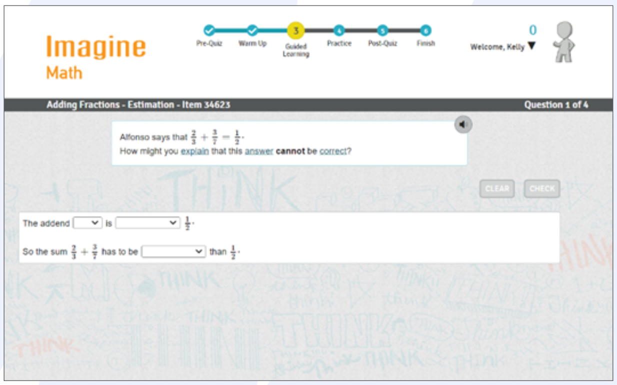


Figure 10. Grade 5 - Adding Fractions - Estimation.

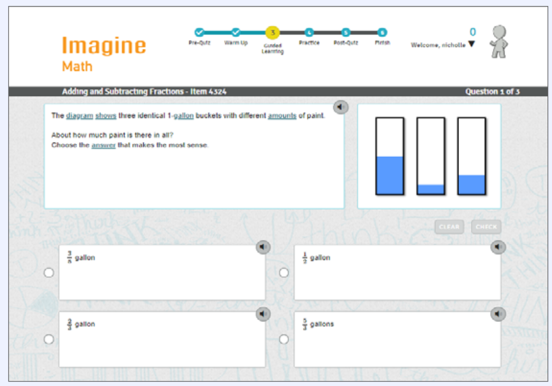
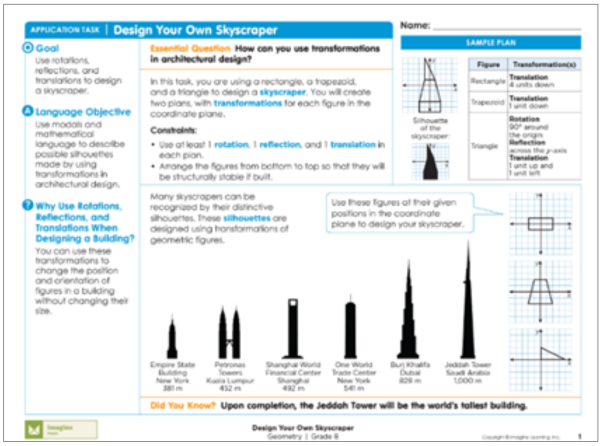


Figure 11. Grade 5 - Adding and Subtracting Fractions

As students in Grade 3 and above complete lessons in Imagine Math, they are encouraged to use journaling to show their work, analyze their thinking, and communicate mathematic understanding. Journaling allows students to utilize mathematic vocabulary and engage in mathematic discourse in representing their work. Additionally, when they engage with live certified teachers to solve problems, they are supported in using mathematic vocabulary and discourse when discussing and solving problems.

Imagine Math Application Tasks are hands-on, cross-curricular, real-world scenarios that bring math to life and require students to utilize the Four Cs of STEM. These rigorous tasks are implemented after a unit of study to extend students' understanding of essential math concepts. They are intentionally designed to foster collaboration, meaningful discourse, and cross-disciplinary connections. For example, in the Design Your Own Skyscraper (see Figures 12 and 13) Application Task for geometry (Grade 8), students use models and mathematical language to describe silhouettes made by using transformations in architectural design. To complete the task, they use rotations, reflections, and translations to design a skyscraper. Students work with peers to design their solutions and to explain their answers. This entire process synthesizes mathematical understanding while teaching students to engage in mathematic practices.



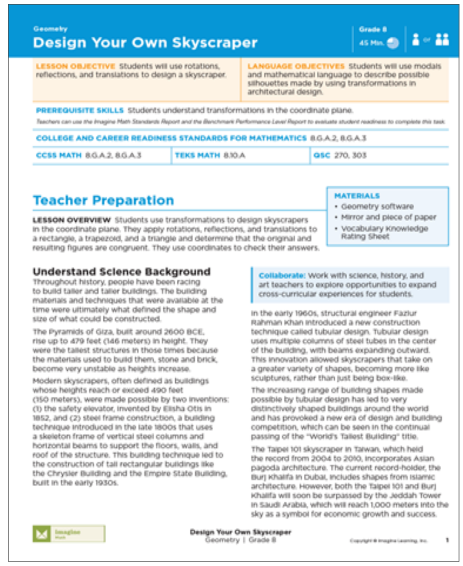


Figure 12 and 13. Grade 8 "Design Your Own Skyscraper" STEM-Focused Application Task.

Imagine MyPath Math: Imagine MyPath Math is a supplemental mathematics program designed to close achievement gaps and maximize academic growth for students in Grades K–12. Mathematics instruction in Imagine MyPath Math focuses on numbers and operations, algebra, measurement and data, and geometry. Imagine MyPath utilizes Smart Sequencer™ technology to prioritize essential skills and create individual learning paths (ILPs) in mathematics. ILPs are grounded in research, and continuously adapt to ensure success among academically diverse learners.

Within Imagine MyPath, student success is supported with a unique cycle of assessment, assignment, adaptivity, analysis, and action. Program assessments identify students' abilities and instructional grades, which are then used to assign students ILPs that prioritize skills for each student. As students progress in the program, the program adapts to student performance, allowing students to skip lessons or skills they have already mastered and to receive instruction necessary for learning grade-level content. Student performance is tracked and analyzed so that teachers know when to provide additional support and instruction necessary for advancing students' proficiency in mathematics.

Four Cs Of STEM: For students in Grades K–12, Imagine MyPath Math supports the development of conceptual understanding, critical thinking, and problem solving. The program utilizes real-world contexts to promote conceptual knowledge, procedural fluency, and problem-solving strategies. For example, elementary students are introduced to a variety of word-problem types to encourage flexibility and efficiency when determining a strategy to use to solve addition, subtraction, multiplication, or division problems. To acquire problem-solving skills, students are taught various strategies such as visual representation, models, reasoning and estimation strategies, and standard algorithms.

In Figures 14–16, elementary students practice solving comparison problems within 20. In Figure 14, they are prompted to identify words that indicate whether they should add or subtract. Figures 15 and 16 illustrate that students are taught how to use bar models to solve problems.

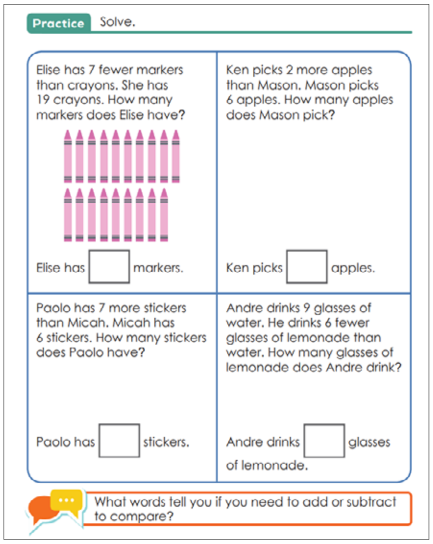


Figure 14. Solving word problems with visual representation and by identifying operation words.

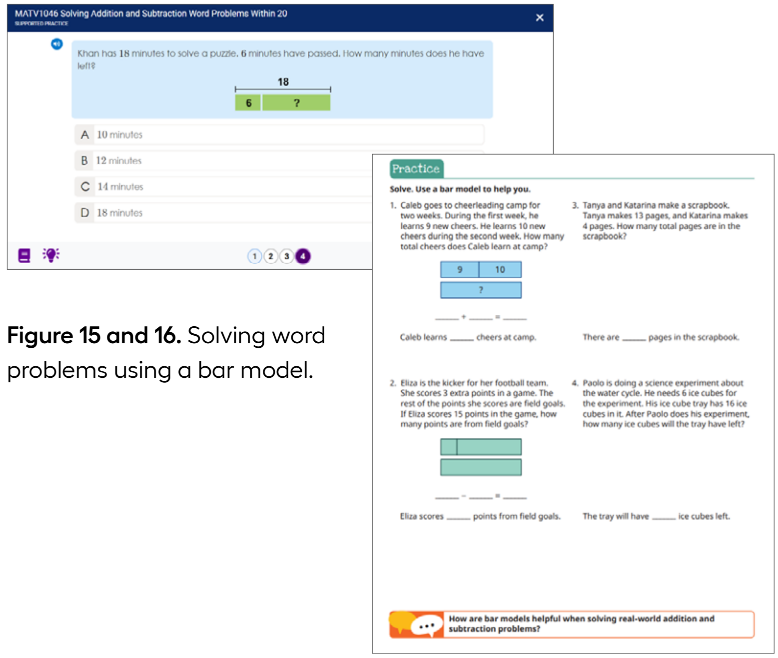


Figure 15 and 16. Solving word problems using a bar model.

As students advance in mathematics, they learn to solve word problems using base-10 blocks, equations, and number lines (Figures 17 and 18).

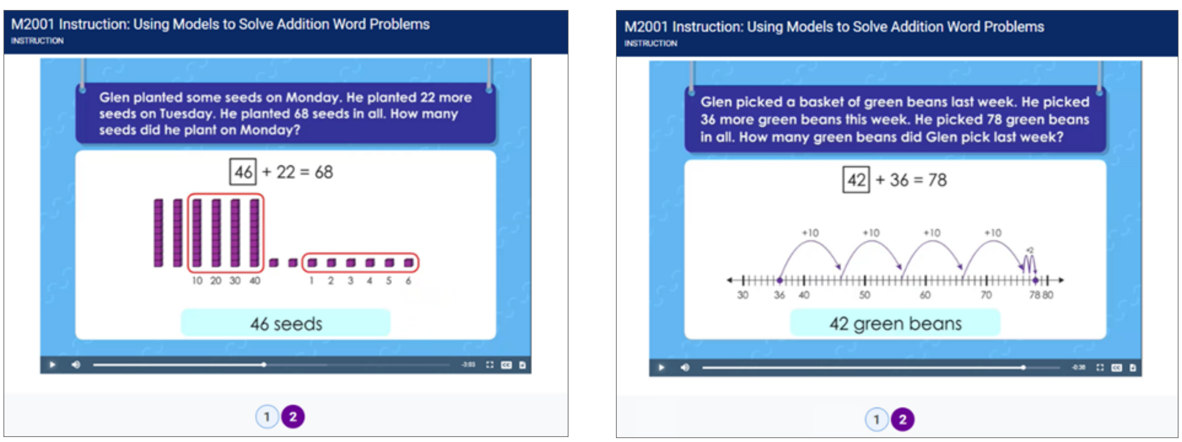
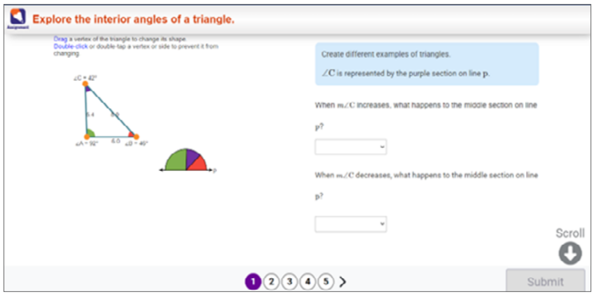


Figure 17 and 18. Solving one-step addition problems using models.

Imagine MyPath Math not only helps students acquire multiple strategies for solving problems, but supports them in critically analyzing information and using logical reasoning to solve problems. For example, middle-school students learning geometry are prompted to think about the relationships between various angles and their measurements. In Figures 19 and 20, students are given an assignment to explore interior angles of a triangle and asked to analyze what happens if changes are made to the size of specific angles. These types of assignments extend learning beyond specific calculations and help students acquire mathematical reasoning skills.



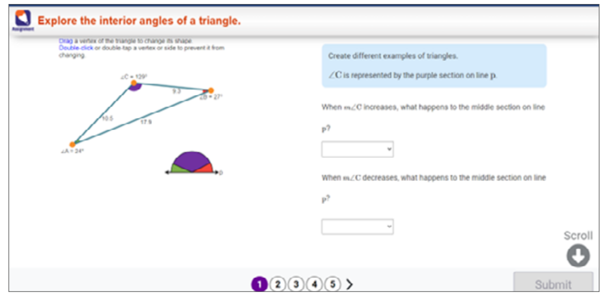


Figure 19 and 20. Assignment to explore the interior angles of a triangle.

High-school students utilize critical thinking in evaluating their own work and analyzing completed examples of math problems. In Figure 21, high-school students are asked to determine the accuracy of a worked solution. In this example, students must determine if the solution is correct and identify reasoning flaws that may have led to an incorrect solution. Assignments of this type are robust for applying analytic reasoning.

When completing their own mathematical proofs, students use creativity and critical thinking to derive solutions. When given assignments to create proofs, students must first analyze problems, identify relevant information, and use logical reasoning to determine steps needed to arrive at their conclusions. In engaging in these processes, students develop analytic skills for understanding how steps in proofs relate to each other and lead to final conclusions. Figures 22–24 illustrate how students can complete proofs in different ways.

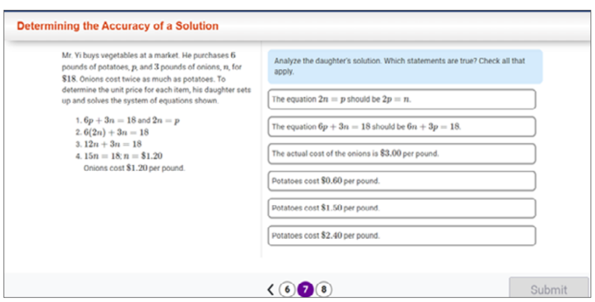


Figure 21. Worked example of modeling with systems of linear equations.

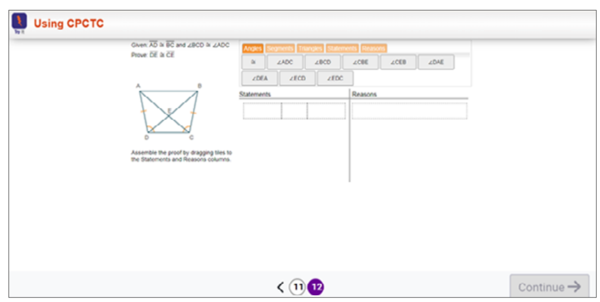


Figure 22. A high-school theorem problem.

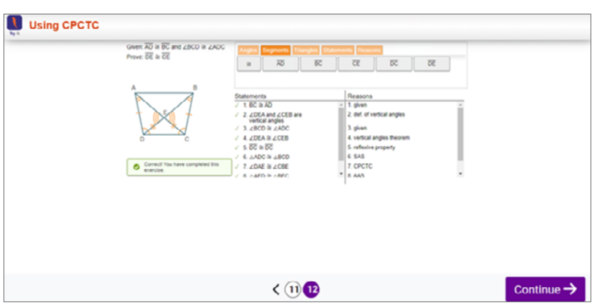


Figure 23. A high-school theorem problem: Solution example 1.

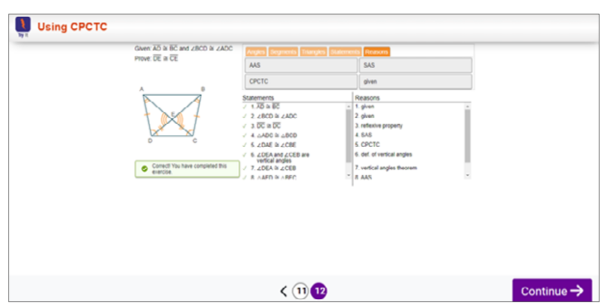


Figure 24. A high-school theorem problem: Solution example 2.

Conclusion

Considering how technology is rapidly changing work environments and how we interact with our world, providing all students access to STEM education is critically important for preparing them for a future that will continue to evolve and change in ways that we may not yet imagine. As discussed throughout this paper, education in STEM subjects inherently supports the development the Four Cs—critical thinking, collaboration, communication, and creativity—in ways that allow students to acquire skills needed for future employment and careers, regardless of whether students pursue STEM careers. Imagine Learning STEM programs provide all students with access to high-quality STEM education that prepares them to thrive in future endeavors.

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