Exploring the Intersection of Engineering and Technology:

Tinkercad in the Middle School Classroom

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Interdisciplinary education is a teaching strategy that enables learners to explore the interrelated nature of STEM disciplines (Daugherty & Carter, 2018; Gao et al., 2020). Middle school interdisciplinary STEM opportunities have been shown to encourage deeper explorations into STEM content, also improving long-term STEM engagement (Kloser et al., 2018). Hands-on learning activities that are designed to support engagement of tools and technology are particularly advantageous for inspiring STEM learning and interdisciplinary experiences (Kennedy & Odell, 2014). Using Tinkercad, the use of a three-dimensional (3D) simulation is highlighted to encourage interdisciplinary STEM explorations in the middle school science classroom. Tinkercad is a user-friendly platform to explore and apply various interdisciplinary STEM concepts, potentially fostering creativity, problem-solving skills, and a deeper understanding of content.

Tinkercad Overview

Tinkercad (*www.tinkercad.com*) is a free graphics interface that focuses on the use of 3D shapes and simulations. Concepts of science, engineering, coding, design, electronics, mathematics and more can be easily explored using the technology (Diaz et al., 2019; Juanda et al., 2021). Mazes, robotics, dominos, prototyping, 3D printing, roller coasters, circuits, code blocks and other contexts can be explored using Tinkercad. Tinkercad can fruitfully support a plethora of investigations, challenges, and activities. Free templates are provided, so teachers can build their own templates for classroom use or build lessons that start with a blank work plane. Iterative modifications to designs based on the results of their experiments is one of the key components of Tinkercad.

Abbreviated How-To Guide

To use Tinkercad, a free account will need to be set up. This should be completed before lessons or tasks are provided. Figure 1 provides an overview of Tinkercad features. It may be intimidating to use Tinkercad for the first time in the classroom. Nonetheless, the interface is very user friendly and logical. Learners will likely immediately engage in the technology, and collectively experiencing the technology as a class might be the most productive way to learn its features and associated limitations.

There might be initial challenges for students when they begin using Tinkercad. Students who are unfamiliar with 3D software may struggle with navigation and the effective use of features. To reduce struggle, students should work in pairs so that they can problem solve together. Time to get to know Tinkercad should be offered before students engage in a formal task. If students are working in pairs, provide 10 minutes of exploration time for Student A, then switch and provide 10 minutes of exploration time to Student B. Repeat the process one more time so that each student has 20 minutes to explore without the pressure of completing a task—just let the students play and discover features. There are also step-by-step guides freely available online that can be used in the classroom. Using these free resources can help teachers and their students develop skills, become familiar with features, and learn how the interface performs. Students may struggle with 3D modeling because they are more familiar with technology that emphasizes two-dimensional content. Before completing a more formal task, opportunities to explore smaller tasks might help students become more familiar with features and 3D modeling. For example, students might be asked to create a simple house, ice cream cone 3D art, or other task that provides opportunities to become familiar with Tinkercad features, premade shapes and shape movement.

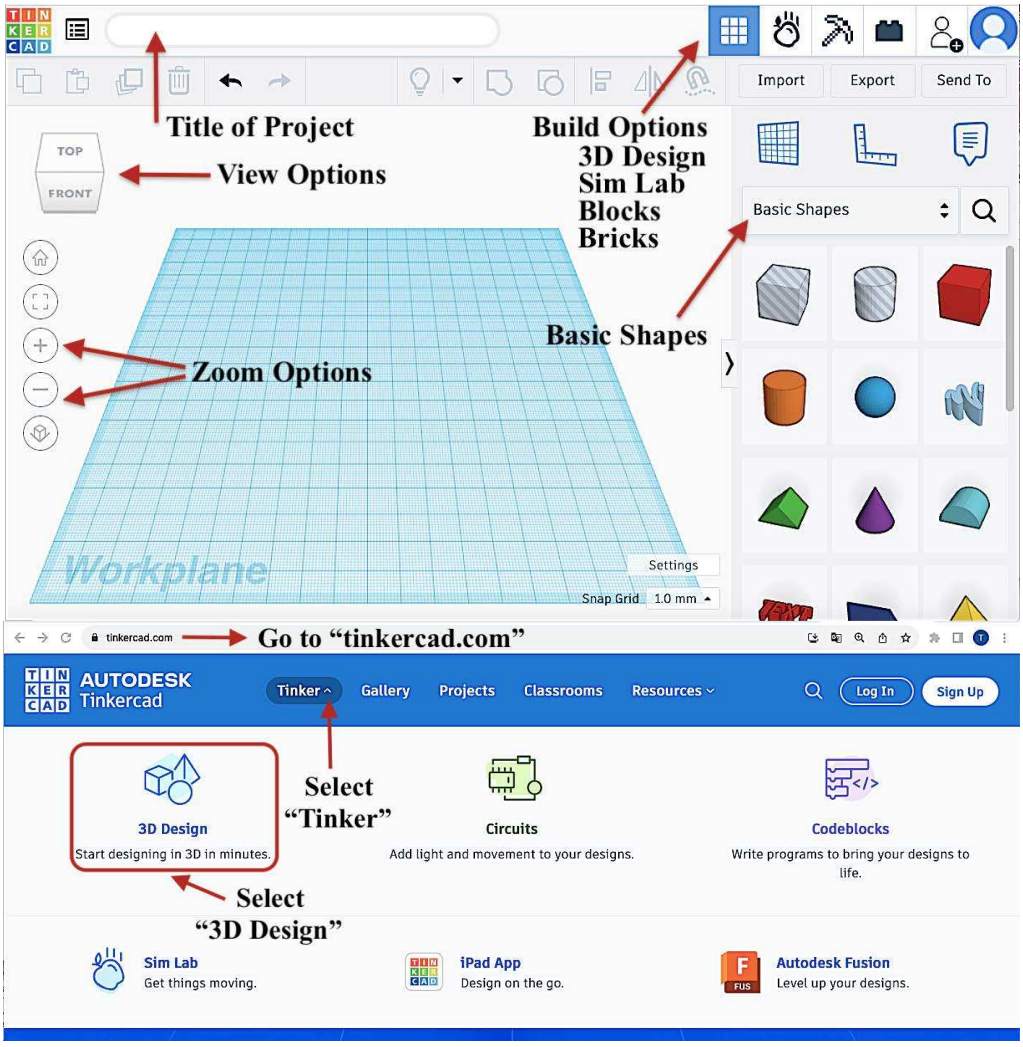


Figure 1. Tinkercad Guide.
Go to ***www.tinkercad.com***
Select "Tinker"
Select 3D Design
Some features include:

- Title of Project
- View Options
- Zoom Options
- Build Options
  3D Design
  Sim Lab
  Blocks
  Bricks
- Basic Shapes

Shapes Library Options

A Tinkercad Activity

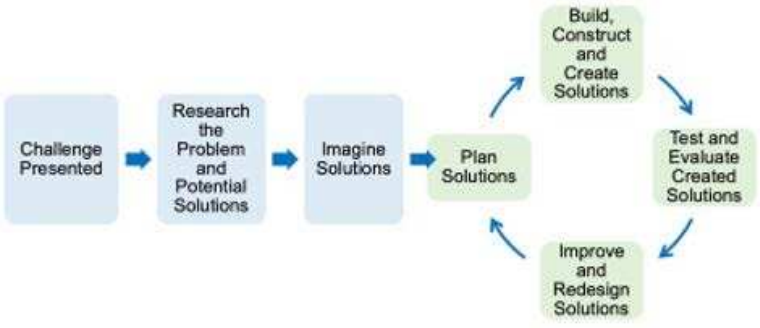
The presented activity, entitled *Building a Virtual Table,* emphasizes the iterative engineering design process. Table 1 highlights the lesson, associated standard, dimensions, classroom connections, and performance expectations. The lesson could take up to three hours if there is full engagement in the engineering design process. Two or three students per group are most efficient for this task. Using Tinkercad, the lesson emphasizes the iterative design of a sturdy table with two tiers that is made from at least four different 3D shapes (cylinder, cone, rectangular prism, hexagonal pyramid, and so on). The table must be able to withstand a large metal sphere being dropped on it. The simulation feature in Tinkercad can be used to drop a large metal sphere on the table. After noting the flaws in design after the sphere is dropped, table designs should be iteratively adjusted to produce a successful model, see Figure 2. Students work in small groups or pairs to problem solve and to plan, construct, test, evaluate, and improve their model attending to the affordances and constraints of 3D shapes' features

There are multiple ways to differentiate instruction, focusing solely on modifications to the original tasks (rather than accommodations). To reduce the cognitive load of the original task, students can be asked to create a table without a required number of 3D shapes. They can be asked to create a table without the requirement of the metal sphere being dropped on it, or they can be asked to create a table that can withstand a rubber sphere being dropped on it. To increase the cognitive load of the original task, there can be more requirements for the table creation (e.g., three tiers, or table base or leg restrictions). Students can be challenged to write their own engineering design challenge using Tinkercad.

There are potential challenges that teachers may need to consider. First, there is a learning curve with Tinkercad. Initially, it may take some time for both the teacher and students to understand how it works; perhaps the students will catch on quicker than the teacher, and that's okay. Second, the engineering design process is not always im-

Task

Using the engineering design process and Tinkercad, design a sturdy table with two tiers that is made from at least four different three-dimensional (3D) shapes (cylinder, cone, rectangular prism, hexagonal pyramid and so on). The table must be able to withstand a large metal sphere being dropped on it. Follow the framework for the engineering design process (University of Colorado, Boulder, 2022) and create several design iterations.



Please turn in: 1) a screenshot and short description of the first iteration; 2) a screenshot and short description of another iteration (but not the final iteration); 3) a screenshot and short description of the final iteration. Then, answer the following questions: 4) How did the iterations differ and why were changes made? 5) Which shape features are most advantageous for the tabletop? Which shape features are most advantageous for the legs? Explain your reasoning. 6) What is the impact of the height of the legs? 7) Are right or oblique 3D shapes better? Why? 8) How does the sphere's composition (e.g., metal or rubber) impact the table design?

Standard

MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

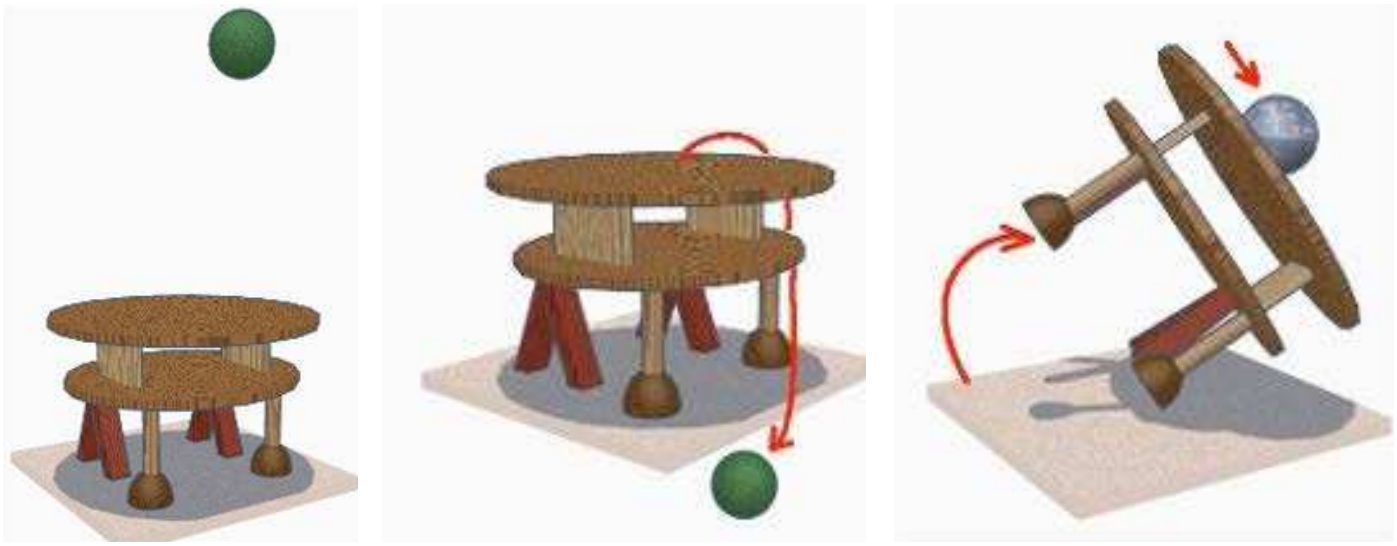
Using Tinkercad, the engineering design process is used to create a virtual table that can withstand a metal sphere being dropped on it. The assessment will focus on the design and build of a table using Tinkercad that can withstand the impact of a metal sphere being virtually dropped. The assessment will evaluate their explanation of structural stability and strength, as well as their ability to apply appropriate design principles, such as reinforcement and load distribution. However, the assessment will not consider factors such as the material cost or the aesthetic appeal of the table design.

Possible Rubric:

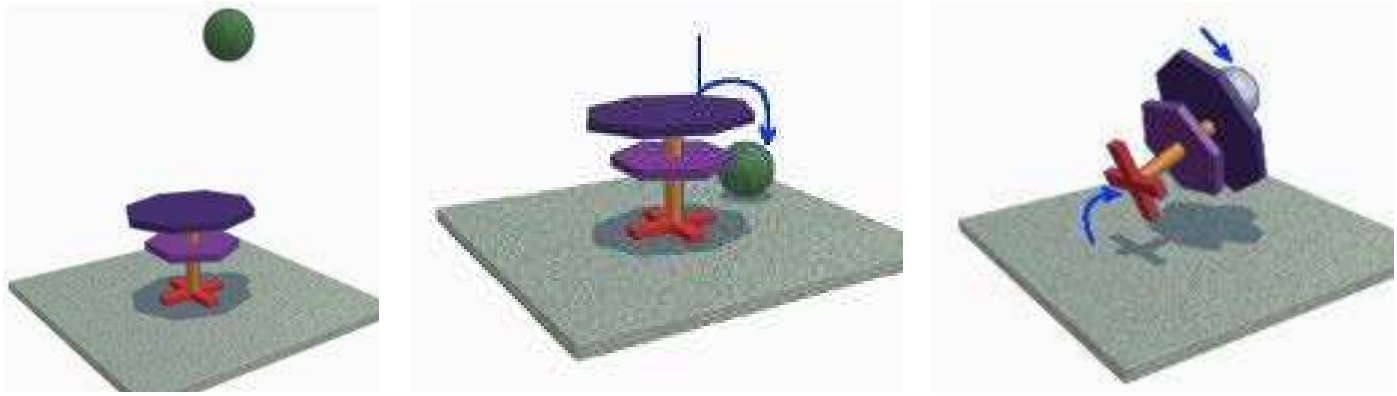
	Excellent	Good	Fair
Iterative Engineering Design Process	Demonstrating an exceptional use of the engineering design process, accurately identifying and defining design problems, generating solutions, and iteratively refining	Demonstrating the engineering design process, including accurately identifying and defining a problem, generating limited solutions with limited evaluation	Demonstrating a basic understanding of the engineering design process, by identifying a problem and creating a prototype
Application of Scientific Principles	Successfully applying, justifying, and explaining scientific principles in a timely and efficient manner	Using scientific principles to troubleshoot and solve practical problems in a timely and efficient manner	Ineffectively using scientific principles inconsistently or inaccurately resulting in errors or failed outcomes
Creativity and Innovation	Displaying high levels of creativity and innovation in approach, generating unique ideas	Showing moderate creativity and innovation, offering some original ideas and solutions	Demonstrating limited creativity and innovation, primarily relying on traditional methods and ideas
Collaboration	Exhibiting a high level of cooperation and collaboration, with members seamlessly integrating skills and expertise	Demonstrating collaboration by actively planning, organizing, and coordinating efforts	Limited collaboration, cooperation, and coordination to achieve a common goal

Table 1. Curricular features of the *Building a Virtual Table* activity.

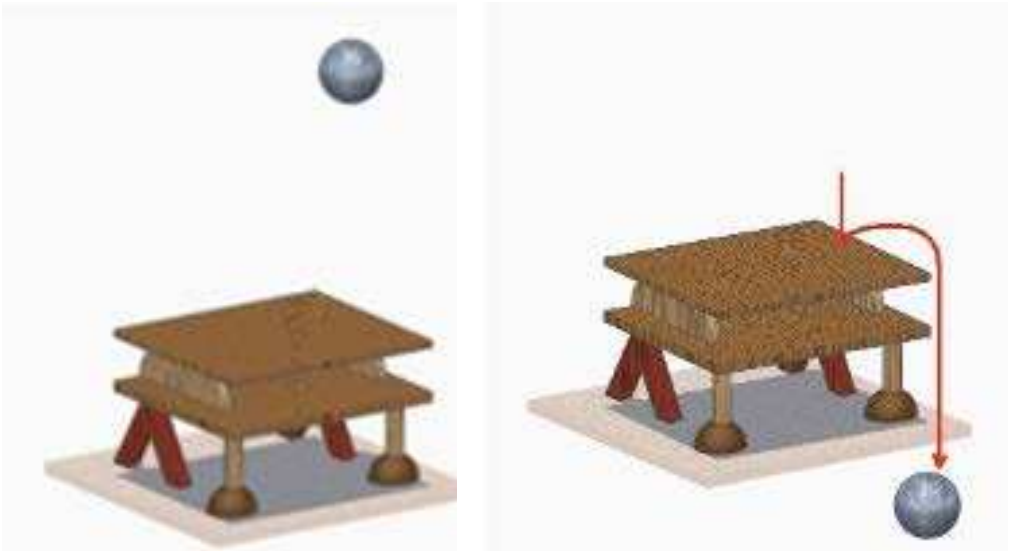
Figure 2. Screenshots from the *Building a Virtual Table* Activity



Iteration 1: A table is built using Tinkercad, then initially tested using a rubber sphere before being tested using a metal sphere. Left: The sphere is dropped on the table. Center: A rubber sphere is dropped on the table indicating a successful build. Right: A metal sphere is dropped on the table, indicating an unsuccessful build



Iteration 3: The table is again redesigned and rebuilt. Because the other trials were successful with the rubber sphere, the new table is tested using just the metal sphere. (If a table can withstand a metal sphere, a rubber sphere test is not needed.)



A successful build was achieved.

plemented properly in classrooms. In Table 1, the initial steps after the "challenge presented" step ("research the problem and potential solutions," "imagine solutions," and "plan solutions") are critical. Sometimes, students go directly into the "build, construct, and create solutions" step. Instead, students should engage in the planning aspect of the engineering design process before tinkering begins. Third, students may need to be reminded to keep copious notes regarding their iterative engineering design process. Encourage students to fully engage in the process while keeping a notebook of their iterations and adjustments. Finally, patience is important. Provide students with time to tinker, play, and iteratively evaluate their designs. Rushing through the lesson will not provide enough time for students to engage in the engineering design process and collaboration.

More Activities

ImageSTEAM aims to introduce visual computing lessons that emphasize visual and computational media. The primary goal is to inspire the exploration of STEM fields and equip teachers with the necessary skills to educate the next generation about the rapidly advancing technologies. Open-source videos, lesson plans and other supportive content highlighting the application of Tinkercad in the middle school classroom are freely available for use here: *https://www.imagesteam.org*. A lesson index (*https://www.imagesteam.org/lesson-index*) provides a searchable overview of lessons that includes Tinkercad activities. Some Tinkercad lessons include Convex and Concave Identification, Plant versus Animal Cells, The Cotton Gin and Westward Expansion, Designing Assistive Devices using Pixlr X and Tinkercad, Volume of an Action Figure, and Surface Area and Volume using Tinkercad.

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