7th & 8th Grade STEM Applications

Revised by Jason Erdreich - Version 2.0

Course Description:
Science, Technology, Engineering, and Mathematics (STEM) Applications is an innovative instructional program that prepares students to engage in future academic and vocational courses of study in high school, community college, and institutions of higher learning. Students in STEM Applications complete studies in technology literacy, the design process, emerging technologies, computer-aided design, sustainable design and technology, power and energy, financial and economic literacy, and workplace skills for the 21st century. The STEM Applications curriculum framework is built upon the New Jersey Student Learning Standards for Science, the New Jersey Student Learning Standards for Math, and the National Educational Technology Standards for Students.

Revision Overview and Summary:
This course outline covers many key topics within the STEM fields and computer science, and also does well in providing different topics to cater to a wide range of student interests. In general, alternating between so many topics in a short period of time can be a challenge, and also prevents students from creating deeper connections to what they are learning and the real-world. To assist, I am suggesting that pacing is slowed down to allow for larger projects with a more in-depth approach to the engineering design process. I like to alternate between larger "design challenges" and "mini challenges" to break up the flow of content, while also adding buffers for accommodating student needs and the school schedule.

Additionally, it's important to continue to offer opportunities to grow in problem solving, brainstorming, collaboration, sustainability, and empathy, which are all key concepts for design thinking experience and a successful STEM program. These skills are often more important than the subject or academic content, and should have time dedicated to working on them through the duration of the course. To achieve this, I have reduced the quantity of topics and placed opportunities for these key concepts to be discussed. As an example, I am using this 5-step design loop which I've created for the Middle School age group.

Computer Science is also a large topic in its own right, and teaching it while alternating between comp-sci and engineering like this may add an instructional challenge for this age group. I've worked to rearrange the flow of content to assist with this challenge, but I suggest considering splitting this into two courses in the future; One that focuses on Design Thinking and another that focuses on Computer Science, each with some overlap and integration between the two. As this course is outlined now, I recommend working to find overlapping projects between STEM and Comp Sci, challenging students to combine the physical world and digital world when possible. Some products, like a micro:bit, make this more achievable in a wider range of applications.

There is also room to integrate the NJ Student Learning standards for Computer Science (8.1) and Design Thinking (8.2), which I have annotated in the revised outline below in green.

Course Break-Down:
3 day a week class. (2 Semester)
2 days in the Science Lab
1 days in the STEM lab

Revised Course Break-Down:
Wk 1-3 - Introduction to Coding and Robotics

- Day 1 -
  - Create connections between the mechanical systems designed in the previous challenge to motorized ones used every day. Discuss the concepts of electricity, and how we can create circuits to manipulate these types of motors. If applicable, complete an electronics lab (either virtually using phet or Tinkercad, or physically)
- Day 2 -
  - Introduce the concepts of robotics, what is a robot? We often think of sci-fi examples or robots that roll around and drive, but robots are any machine which can complete a task autonomously, like an air conditioning unit or even an alarm clock.
  - Introduce the concepts of coding as a method to communicate our ideas with a computer. **Complete an unplugged coding activity**. The hardest part about learning a new computer language isn't the terms or vocabulary, but it's the syntax. We struggle to take our thoughts and turn them into commands, which is essentially the core of all programming languages.
    - 8.1.8.AP.1
- Day 3+
  - Introduce the Cue Robots. Refer to the Cue Robotics curriculum to offer a series of challenges and activities to learn the fundamentals of programming with Cue Robots.
    - 8.1.8.CS.4, 8.1.8.DA.5, 8.1.8.AP.2, 8.1.8.AP.3

Wk 4 - Introduction to STEM & the Engineering Design Process (EDP)

- Day 1 -
  - Start with an introduction to the concept of STEM - Why is this important in school, but also how will this class relate to Industry and careers? The importance of being knowledgeable of how different subjects relate can allow for more successful products, but also more efficient ones, etc
  - Transition into the concept of Technology, or a tool, and Engineering, or problem solving, and the role they play in STEM (students will be largely familiar with science and math from their core classes, but make connections to careers within these fields as well)
  - Introduce the engineering design process as a method for solving problems, connect to scientific method
  - Do an example problem as a class with an emphasis on **brainstorming** different ideas because there is never one right way to solve any single problem. Conclude with a discussion on **Redesign**. Consider introducing thumbnail sketches or a morphological chart as you collaborate on designing solutions to a real-world problem as a class.
    - 8.2.8.ED.2
- Day 2 & 3 -
  - Start with a basic discussion on Safety. Discuss procedures for working with basic tools, and overview room rules and expectations (if not already covered)
  - Review the concepts of STEM and EDP
  - Place students in groups, assign a mini design challenge that allows for them to collaborate to develop a prototype solution to a real-world problem
    - Possible challenges include paper towers, paper cantilevers, marble roller coasters,

        - balloon cars, mobile device stand, fishing devices, etc
    - Emphasis on this first challenge should be collaboration, problem solving, brainstorming, and redesign. Allow students to develop a prototype, then offer time to reflect and discuss how they could improve. This should also be a heavily constrained challenge to foster creative thinking and get students acclimated with the types of open-ended projects they will be facing.

Wk 4-5 - Introduction to Structures / Forces

- Day 1 -
    - Introduce Forces, provide a mini lab or way for students to get hands on with learning the concept of forces (phet simulation, play doh, etc)
- Day 2 -
    - Introduce the concept of structures, and how technology has allowed for us to create things that withstand and manipulate forces → connect to Wk 1 mini challenge if applicable
    - Do a mini challenge (paper table, paper tower, paper cantilever, etc) to allow students to understand how forces can be interacted with through material sciences
- Wk 2 Day 3 & Wk 3 -
    - Introduce larger design challenge apply new topics while utilizing the engineering design process to solve a real-world problem (parachute project, egg drop, bridges, catapults, paper shoes, etc)
    - Offer constraints for time and materials, as well as target objectives (height goals, distance goals, weight goals, etc)
    - Typical Design Challenge Pacing:
        - D1 - introduction, initial research & brainstorming
        - D2 - complete brainstorming, obtain materials
        - D3 - construction
        - D4 - construction, initial testing
        - D5 - testing, reflection / redesign
    - It is rare that you will have time or materials to allow students to create a redesigned prototype solution, but always offer an opportunity to reflect and to design an improved version via sketch, discussions, or 3d models
        - 8.2.8.ED.3, 8.2.8.ED.5

Wk 6-7 - Computer Aided Design

- Conclude forces challenge (as needed)
- Introduce the concepts of Computer Aided Design, or CAD. Up to this point, students should be familiar with the concept of sketching in order to communicate our ideas. CAD was developed to make sketching more efficient and to allow us to communicate more effectively with each other, and machines! I find that CAD is often taught just for 3D printing in many STEM programs, but it is a far more powerful than that
- Introduce a CAD program suitable for this age group, like <u>Tinkercad</u>.
- Do a warm up activity as a group, like making a real-world object, which teaches students the fundamentals of dimensioning and design in this program. I like to make a <u>coffee mug</u>.
- Introduce a mini CAD challenge that allows students to develop a design for a real-world problem in CAD (room redesign, locker redesign, animal habitat, furniture redesign, etc)
- Offer opportunities for students to share and present their designed solutions

Wk 8-10 - Materials, Empathy, and Ergonomics

- Continue and conclude CAD challenge as needed
- For this next project, the focus should be on combining materials & ergonomics, as well as considering empathy at a higher level in our prototype construction. Challenge students to analyze products and solutions that we use every day from the perspective of the designer. Why did they choose the materials they did? How are these products designed to make them easier to use? What problems do

they solve for us?

- Introduce 3D printers, a basic understand of how they work and how they can interpret our designs we make in CAD, but also how they are being used to change almost every industry today.
    - 3D Printing is a really big deal, though it's largely viewed as a way to make plastic trinkets. Share some real-world examples as to how it is being used to shape manufacturing, constructing, fashion, automotive, and medical industries catered to student interests.
    - Also discuss the limitations of 3D printers. Not everything we make in CAD can be 3D printed, we need to design for the correct dimensions and tolerances if we want to produce parts using the 3D printers available.
- For this design challenge, allow students to 3D print a part in addition to receiving other materials for prototyping. Also challenge them to utilize CAD to not only create their 3D printed part, but also to brainstorm prototype construction (Tinkercad has a great collection of everyday objects)
    - I've never had enough 3D printers to allow students to 3D print the entirety of a project, so I've always constrained them to 3D printing just one part, or within a volume of material. This not only supports resource and time allocation, but also adds real-world challenges to foster creative thinking
- This project should also allow for an opportunity for peer review or peer feedback during the presentation and reflection stages. Challenge students to make instructions or a user guide for their prototypes, as if it was a product that they are going to put on sale. Consider choosing a challenge that can be tested by students in the classroom (puzzles + games, acoustic amplification devices, tools, storage solutions, mobile device accessories, prototypes for our pets, etc)
    - LulzLessons are design challenges that are free, and include usable samples, handouts, and rubrics revolving around 3D printing in the STEM classroom
- This challenge may take longer than the typical design challenge pacing previously mentioned, possibly 5-7 days depending on constraints
    - 8.2.8.ED.1, 8.2.8.ED.6

Wk 11-12 - Machines & Mechanisms -

- Introduce the concept of simple machines and mechanisms. Create connections with previously learned topics of structures, forces, and materials. Overview the 6 simple machines. Discuss velocity and energy concepts.
- Introduce a design challenge that allows students to combine previously learned topics and skills while designing and constructing their own prototype machine. This is also a great opportunity to integrate **sustainability**, challenge students to incorporate at least one recycled item in their designs.
- Possible challenges include cars, solar powered vehicles, wind turbines, mouse trap cars, balloon cars, prosthetics, catapults, etc
- This challenge should be the biggest yet, with the most materials but also the greatest expectations for applying the EDP. Challenge students to research, brainstorm, use CAD to plan, and work through developing complex prototype models. If time allows, challenge students to make test models using paper or cardboard before working with the final models.
- Testing stages could be a competition, with time for students to refine their designs as they conclude construction
    - 8.2.8.ED.7, 8.2.8.ITH.3, 8.2.8.NT.2, 8.2.8.NT.3

Wk 13 - Introduction to Micro:bit

- Introduce the Micro:bitss. Refer to the Micro:bit projects and curriculum by Microsoft to offer a series of challenges and activities to learn the fundamentals of programming and building with Micro:bits.
    - 8.1.8.CS.1, 8.1.8.CS.3, 8.1.8.AP.4, 8.1.8.AP.7, 8.2.8.ED.4

Wk 15-20 - Real-world Autonomous Systems

- In this final unit, the overarching theme should be connecting designing thinking concepts with computer science concepts by developing real-world autonomous systems.

- Challenge students to apply their knowledge in programming and circuitry using micro:bits, while also incorporating materials like paper, cardboard, and 3D printed items, to construct a prototype solution for a real-world problem
- Example projects include: parade floats, locker alarms, automatas, animatronics, robot vacuums / floor sweepers / snow plows, etc
- Challenge students to also develop a culminating presentation that shares the steps taken in designing and constructing their prototypes. Include opportunities to connect these concepts to the real-world, how would these solutions improve our lives or the lives of others?
    - 8.1.8.CS.2, 8.1.8.AP.5, 8.1.8.AP.6, 8.1.8.AP.9

Additional Suggestions and Strategies:

- When creating a design challenge or problem-based project, I utilize a design process for students to not only work through this learning experience, but also as to how the classes are broken down as well. In general, a typical Middle School design challenge may span 5 days:
    - D1 - introduction, initial research & brainstorming
    - D2 - complete brainstorming, obtain materials
    - D3 - construction
    - D4 - construction, initial testing
    - D5 - testing, reflection / redesign
- For faster pacing or a smaller challenge, the introduction and brainstorming could be combined to a day. For longer or more in-depth challenges, additional time could be allotted for construction, and testing could be its own day or series of days with reflection and presentations also getting dedicated time. There is no wrong way to run a challenge, as long as students have the opportunities to consider possible solutions, collaborate, and reflect on ways to improve based on what we have learned.
- For resource allocation, consider staggering projects. For example, the projects planned for Weeks 5-7 and 8-10 could be swapped and constraints could be changed so only a population of your students were working with the 3D printers at a time. Similarly, one population of students could start with Design Thinking concepts while the other starts with Computer Science concepts.
- See this slideshow template as a starting point for creating a design challenge through a five-step EDP.
- Consider mini challenges to break up larger projects or to cater to scheduling challenges during the school year. Seasonal challenges with themes around Fall, halloween, thanksgiving, the holidays, winter, valentines day, etc are great topics to incorporate for this.
- Sustainability and Recycling also make for great speed challenges. Challenging students to “upcycle” something into a new product or purpose is one of my personal favorites. This also ties to NJSLS 8.2 standards nicely
- CAD mini challenges are also fun ways to break up projects, or support students who finish something early. Tinkercad offers a series of lessons and projects
- Instructables is one of my favorite sources for project and lesson ideas, but there is an extensive list of resources on my website as well.

Suggestions for Grading and Assessment:

- Rubrics are commonly used for grading in the PBL learning environment. I often use this rubric when assessing a project developed through the EDP
- Self assessment and reflection is also a powerful tool for assessment as students are challenged to engage with the concepts of redesign. Consider a google form to collect ideas when completing the redesign stages of a design challenge.
- In general, I never assess the performance or success of a designed solution, but instead the application of the EDP and the skills used to develop it