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Designing Meaningful STEM Lessons

Dr. Maeve Liston

In a previous article of *Science (*Volume 53, No. 3) entitled *Unravelling STEM: Beyond the acronym of Science, Technology, Engineering, and Mathematics*, I discussed that there is quite a lot of uncertainty around the design and understanding of STEM (Science, Technology, Engineering and Mathematics) activities. The article questioned what is STEM education? and explored the emergence of STEM, and the characteristics of true authentic STEM activities and lessons. This article will explore the concept of STEM education in further detail i.e. characteristics of STEM literacy, what do STEM lessons look like? attributes of a STEM classroom and the Engineering Design Process (EDP). The article will finish with examples of how you could introduce EDP to your students through a variety of STEM challenges.

Characteristics of STEM and STEM Literacy

STEM education allows students to learn and apply content, practices and skills of the STEM disciplines to situations they encounter in their lives and thus developing STEM literate students (Bybee, 2013). STEM education is the input i.e. what we deliver to our students, through scientific inquiry, formulating questions, investigations and the engineering design process to solve problems (Kennedy & Odell, 2014).

Attributes of a STEM classrooms and lesson:

- Active and student centred
- Equipped to support spontaneous questioning as well as planned investigations
- A centre for innovation and invention
- Classroom, laboratory and engineering lab are physically one
- Supportive of teaching in multiple modalities serves students with a variety of learning styles and disabilities
- Integrates real-world situations or problems.

(Huling & Speake Dwyer, 2018)

STEM literacy is the outcome i.e. the knowledge, skills, and attitudes the students develop as a result of participating in STEM education. STEM-educated students are problem solvers, innovators, inventors, self-reliant, logical thinkers and technologically literate (Huling & Speake Dwyer, 2018).

Characteristics of STEM literacy:

- Knowledge, attributes, and skills to identify questions and problems in life situations, explain the natural and designed world, and draw evidence-based conclusions about STEM related-issues.
- Understanding of the characteristic features of STEM disciplines as forms of human knowledge, inquiry, and design.
- Awareness of how STEM disciplines shape our material, intellectual, and cultural environments.
- Willingness to engage in STEM-related issues and with the ideas of science, technology, engineering, and mathematics as a constructive, concerned, and reflective citizen.

(Bybee, 2013)

Making crosscutting STEM connections is complex and requires teachers to teach STEM content in deliberate ways so that students understand how STEM knowledge is applied to real-world problems (Kelley & Knowles, 2016). Well-integrated instruction provides opportunities for students to learn in more relevant and stimulating experiences, encourages the use of higher level critical thinking skills, improves problem solving skills, and increases retention (Stohlmann *et al.* 2012).

In order for us to embrace an integrated approach to STEM which is meaningful and effective in our classrooms, high quality STEM teaching and learning materials and resources are needed, along with well-informed professional development. In the proceeding sections, I will provide you with a few checklists from literature on what STEM activities and lessons should include. We will then look at the Engineering Design Process (EDP) and I will describe design and build STEM challenges I use as an introduction to the EDP.

What do STEM lessons look like?

STEM initiatives and lessons should include the following features:

- Driven by problem solving, discovery, exploratory learning and independent and collaborative research projects
- Incorporating habits if mind for students to use technology; integrates engineering design requiring collaboration and communication and trouble shooting
- Innovative instruction that allows students to explore greater depths of all of the core subjects
- Technology that provides creative and innovative ways for students to solve problems and apply what they have learned conceptually.

(Morrison, 2006)

Components of a STEM lesson

Jolly (2017) set out a STEM Design tool to help teachers to analyse and select STEM lessons. Every STEM lesson does not have to contain all 11 components. This list can be used as a checklist when designing STEM activities:

1. Does the lesson present a real problem (an engineering challenge)?
2. Will students relate to the problem?
3. Does the lesson allow students multiple acceptable and creative approaches and solutions for successfully solving the problem?
4. Does the lesson integrate and apply important science and math grade-level content?
5. Does the lesson clearly use the engineering design process as the approach to solving problems?
6. Does the lesson use a student-centred, hands-on teaching and learning approach?
7. Does the lesson lead to the design and development of a model or prototype?
8. Is the role of technology in the lesson clear to the students?
9. Does the lesson successfully engage students in purposeful teamwork?
10. Does the lesson include testing the solution, evaluating the results, and redesigning to improve the outcome?
11. Does the lesson involve students in communicating about their design and results?

The Engineering Design Process

Engineering has to take centre stage during STEM activities. Engineering is the glue that integrates science, mathematics and technology.

'*Many worthwhile lessons ad projects focus on student-centred learning, innovation, creativity, teamwork, design approaches, and some of the same skills that STEM projects focus on. For that reason, many people think of these as STEM. However stick with the original purpose of STEM in your lessons. STEM lessons are engineering lessons that integrate math and science. Keep that all-important engineering component front and centre'* (Jolly, 2017, p. 69).

Engineering Design Process (EDP)
The Engineering Design Process provides a model that guides students from identifying a problem—or a design challenge—to creating and developing a solution. Students

- develop multiple ideas for solutions
- develop and create a prototype
- test the prototype
- evaluate and
- redesign

Steps to the Engineering Design Process (EDP)

1. Defining the problem: introducing criteria and constraints
2. Conducting research: look up videos, images, architecture etc.
3. Imagining: brainstorming informed ideas on how to solve the problem posed and come up with a number of possible solutions and ideas
4. Planning: Choose the idea that the group predicts will work best and design their prototype. This involves sketching out their design.
5. Creating: designing and developing the prototype they have all selected.
6. Testing and evaluating the prototype
7. Redesigning based on the testing and evaluation stage if required.
8. Communicating and presenting their results and conclusions.

Introducing the Engineering Design Process through design and build STEM challenges
I have used the following STEM challenges to introduce the ESD process to primary, second and third level students and in-service teachers during professional development sessions. I found the challenges very effective, as they focused in on 'Engineering' that provided a structure for the integration of Science, Technology and Mathematics together. They are also very engaging, fun and collaborative.

ST<u>E</u>M Challenges:

1. Marble Madness

- You and your team have been selected to make the longest, trickiest course in which to deliver a marble to its final destination. The longer and trickier the better.

2. All Ramped Up

- You and your team have been selected to design a ramp for a matchbox car to jump as far as possible.

3. Down the Chute

- You and your team have been selected to design and deliver a device that can take a marble 1.5 metres across the room and drop it into an open and empty plastic bottle.

The above activities were adapted from a book by Andrew Frinkle *50 Stem Labs - Science Experiments for Kids* including 50 hands-on STEM activities. All you need is anything that you can recycle i.e. plastic bottles, cardboard, toilet roll/kitchen towels rolls, cellotape etc. they have to work with the materials tou give them

Worksheets were distributed to the teams setting out the following:

- Their challenge and brief.
- Set conditions: must use the materials that are provided to them only.
- Specific requirements: you can all work together deciding on the set conditions for example for activity 1 Marble Madness: the marble must change directions during its journey, it must fly through the air, it must go up and must go down, etc.
- Plan your design: Sketching their design of their prototype**:** questioning why they chose that design? Why they chose the materials? Etc.
- Design, Construct and Test:
    - Testing their design: What are they testing? How are they going to test it? What worked? What didn't work
- Improve the design: How did they improve the design?
    - Future plans for the design.

STEM 1 Workshops: Design and Make

1. **Your challenge was to/your brief:**

Set Conditions:

Specific Requests/requirements:

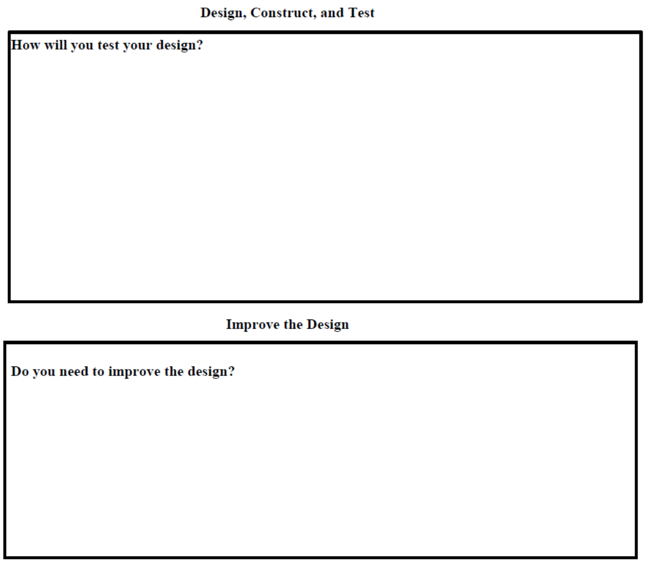
Figure 1. STEM Challenges Worksheet (part 1).

1. **Plan your design (label and justify why you are doing what you are doing)**

Questions (to remain mindful of the goals and intentions of the design challenges as well as to remain focused on the task):

- What is the end product??
- What are the overall goals?

Figure 2. STEM Challenges Worksheet (part 2).



Design, Construct, and Test

How will you test your design?

Improve the Design

Do you need to improve the design?

Figure 3. STEM Challenges Worksheet (part 3).

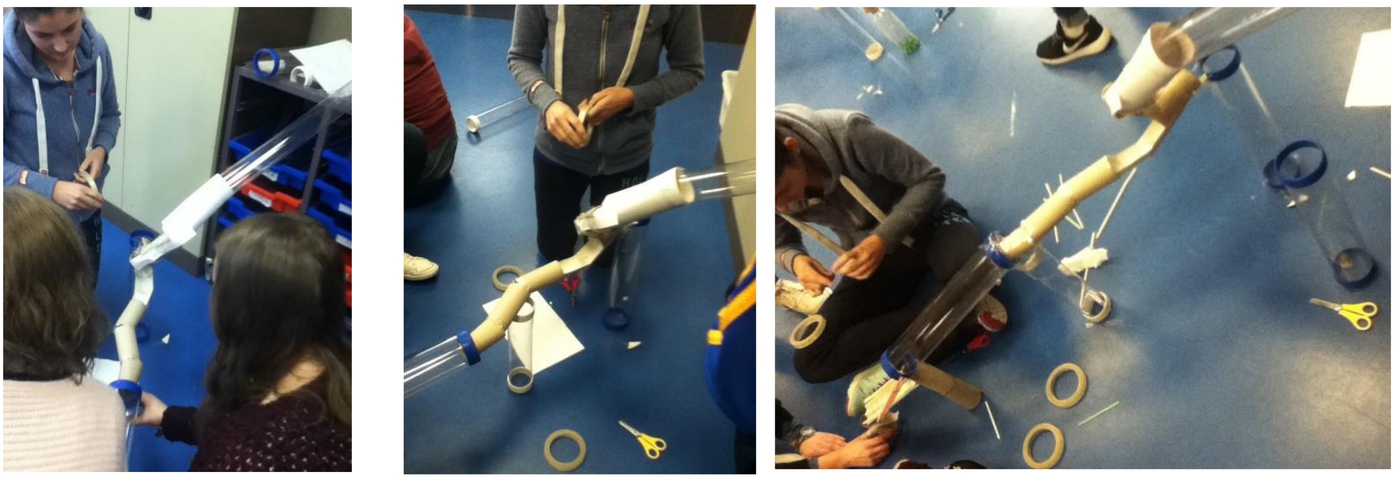


Figure 4: Marble Madness

Figure 5: All Ramped Up Activity

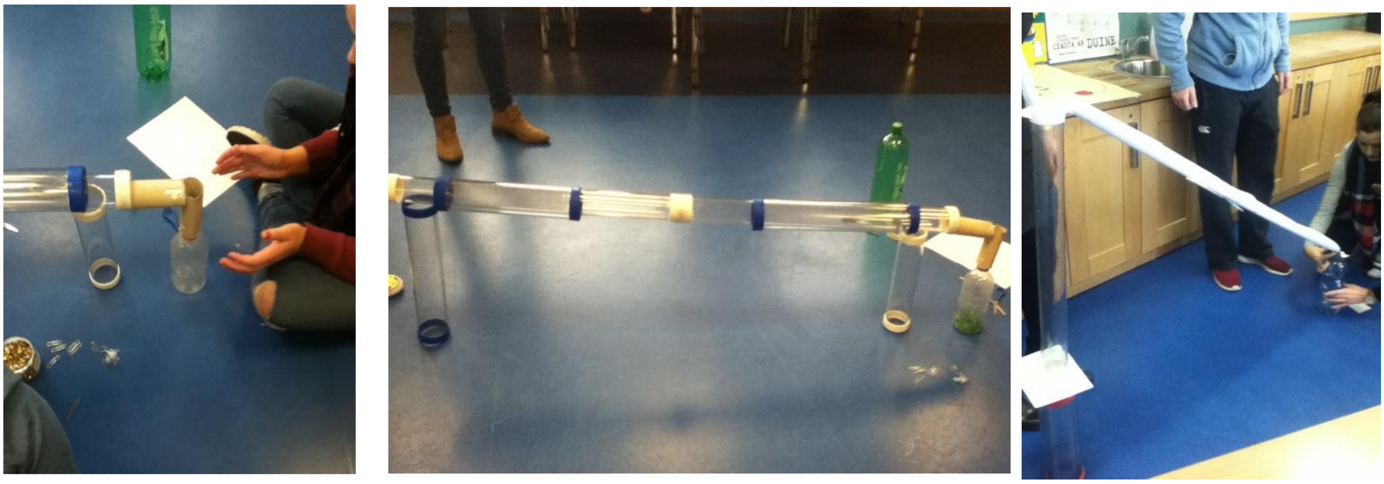


Figure 6: Down the Chute Activity

I will leave you with this message: '*it's ok to go slowly at first. Don't feel that you need to embrace STEMmania too quickly. But when you do, you may wonder, 'why haven't I been teaching this way all along?*' (Vasque, 2015).

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