
STEAM

An Introductory Framework for STEAM

By Matthew Hains

> You can be creative in anything - in math, science, engineering, philosophy - as much as you can in music or in painting or in dance.
>
> Sir Ken Robinson

About Matthew Hains

I have been a teacher for 14 years. Computer Applications Technology is a subject that I am most passionate about and thoroughly enjoy teaching it. I have been involved in the research and implementation of STEAM at a Grade 8 and Grade 9 level.

In 2016, I received the Microsoft Innovative Educator nomination from Microsoft and I've been a Microsoft Innovative Educator Expert ever since.

I have been a Chief marker for Grade 12 C.A.T. and was also the Gauteng Regional and the National C.A.T. Moderator for the IEB for 2016 and 2017.

Due to my cumulative experience, I've provided input as a consultant with the re-writing of the Subject Assessment Guidelines for Computer Applications Technology for the IEB and also as an author for the new Computer Applications Technology Grade 10 textbook to be published by the South African Department of Basic Education in 2019.

I enjoy playing drums when I get the chance and I used to teach drumming professionally whilst including a specialisation in West African Djembê drumming.

I am is presently the Computer Applications Technology teacher at Saheti, a private school in Johannesburg, South Africa where I oversee the staff professional training and development as well as the enhancement of ICT skills throughout the school.

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WHAT IS STEAM?

STEAM is an educational approach to learning that uses **Science**, **Technology**, **Engineering**, the **Arts** and **Mathematics** as access points for guiding student/learner inquiry, dialogue, and *critical thinking*.[1]

The end results are student/learners/learners who take thoughtful risks, engage in experiential learning, persist in problem-solving, embrace collaboration, and work through the creative process. These are the innovators, educators, leaders, and learners of the 21st century!

"STEAM empowers teachers to employ project-based learning that crosses all 5 disciplines (Science, Technology, Engineering, Arts, Math) and fosters an **inclusive** learning environment where all student/learners/learners are able to engage and contribute. As opposed to traditional models of teaching, educators using the STEAM framework bring the disciplines together, leveraging the dynamic synergy between the modelling process and math and science content in order to blur the boundaries between modelling techniques and scientific/mathematical thinking. Through this **holistic** approach, student/learners/learners are able to exercise both sides of their brain at once."[2]

The purpose in implementing STEAM in any grade is for student/learners/learners/learners to have an intellectual space where freedom in decision-making can be encouraged and 21st century-thinking skills nurtured to have a greater impact on all subjects that the student/learners/learners may choose, in a school environment, from Grade 10 onwards - or even perhaps in how they make choices in life as they grow up. Also, we create a physical space, where access to computers, 3D-printing technology, software and hardware, tools and materials is always available including fast Internet access for research, networking and online data storage and digital peer collaboration.

The objective in the implementation of STEAM focuses on emphasizing the following core skills:

- Collaboration and teamwork
- Creativity and imagination
- Critical thinking
- Problem solving

[1] http://educationcloset.com/steam/what-is-steam/
[2] https://onlinedegrees.sandiego.edu/steam-education-in-schools/

THE OBJECTIVE:

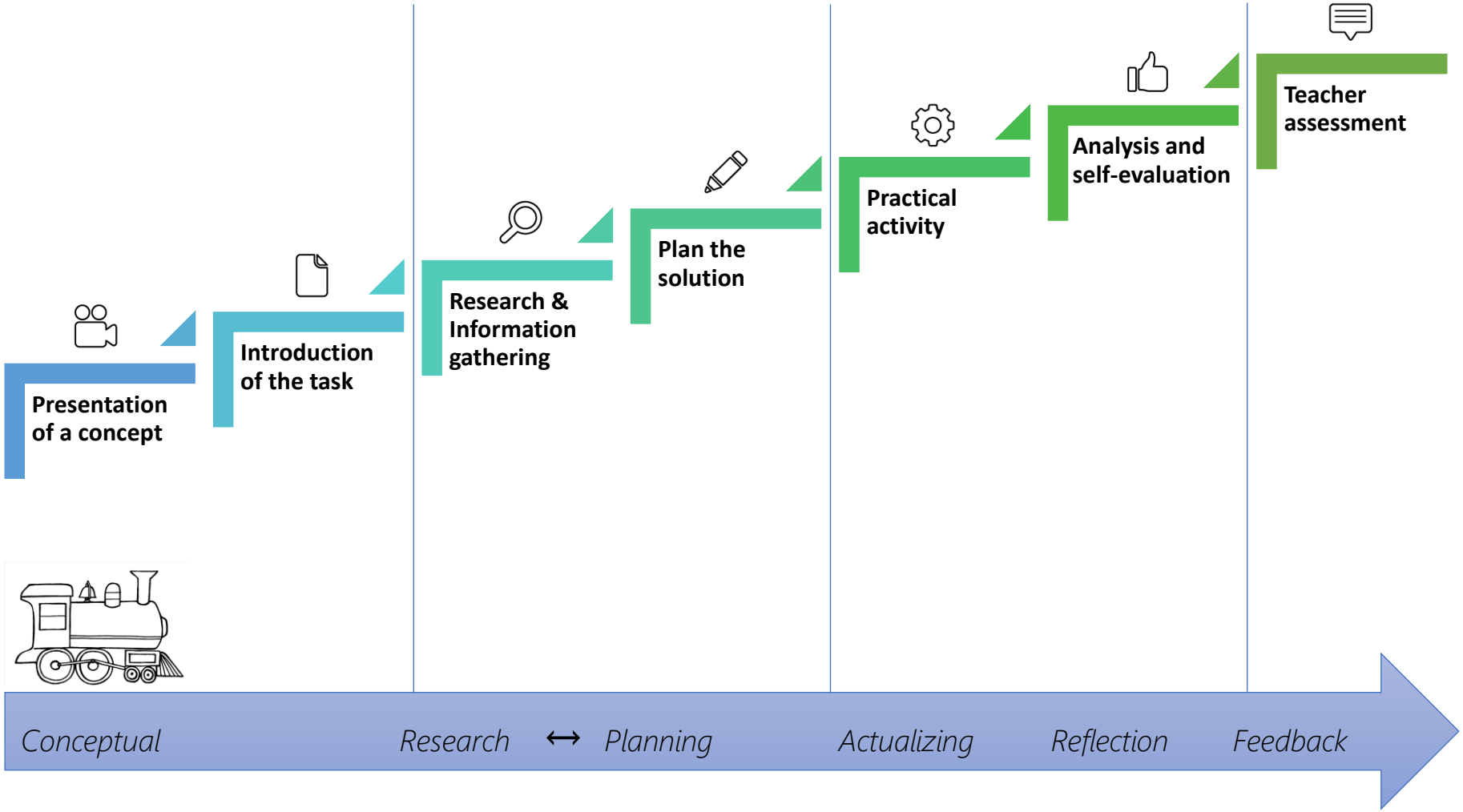
21st Century Thinking[3]

- Collaboration and teamwork
  - Develop, implement and communicate new ideas to others effectively
  - Be open and responsive to new and diverse perspectives; incorporate group input and feedback into the work
  - Demonstrate originality and inventiveness in work and understand the real-world limits to adopting new ideas
  - Demonstrate ability to work effectively and respectfully with diverse teams
  - Assume shared responsibility for collaborative work, and value the individual contributions made by each team member
- Creativity and imagination
  - Use a wide range of idea-creation techniques (such as brainstorming)
  - Create new and worthwhile ideas (both incremental and radical concepts)
  - Elaborate, refine, analyze and evaluate their own ideas in order to improve and maximize creative efforts
- Critical thinking
  - View failure as an opportunity to learn; understand that creativity and innovation is a long-term
  - Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation
  - Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems
  - Reflect critically on learning experiences and processes
- Problem solving
  - Act on creative ideas to make a tangible and useful contribution to the field in which the innovation will occur
  - Solve different kinds of non-familiar problems in both conventional and innovative ways
  - Identify and ask significant questions that clarify various points of view and lead to better solutions

Class activities and tasks are designed to address, and balance, all aspects of S.T.E.A.M. and follow a path created by the teacher to guide each student/learner from the introduction of a concept towards the achievement of an objective within the context of the concept.

[3] Adapted from: http://www.p21.org/our-work/resources/for-educators

TEACHING PATH – A SUGGESTED PROCESS



THE PATH

Presentation of the concept/topic

The topic, challenge or problem is presented to the class. This could be in the form of a video, multimedia presentation or class discussion.

The concept should be presented in a way that stimulates the curiosity and interest of the student/learner and **creates** opportunities for discussion and general conversation on the topic.

Introduction of the task

The task involves introducing the students/learners with a challenge, a problem or an objective in order to resolve a particular issue.

The topic can embrace any learning area from where problem/project-based-learning can evolve.

Discussion is important and questions should be encouraged at this stage.

Research & Information Gathering

Once familiarity with the concept has been adequately established, student/learners/learners are then required to gather further information by means of research. This can be real-world or online.

Information-gathering skills are crucial here, especially the ability to discern between relevant and irrelevant information.

The storage and sharing of information is also an important aspect to focus on – before even starting any STEAM project.

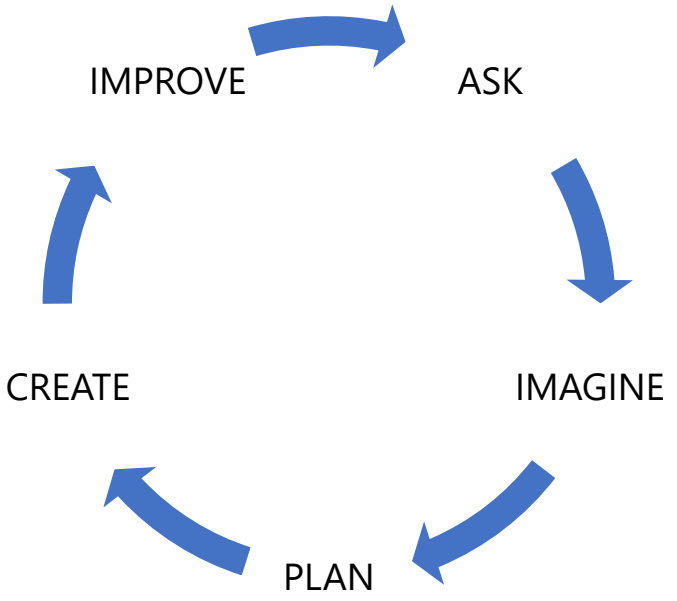
Planning of the solution

Once information has been gathered, the next stage is to begin planning the solution to accomplish the objective of the task.

The student/learners/learners are encouraged to work through a given design process to help formulate and organize their thoughts.

The process can be identified as follows:

1. Identify the objective/problem/challenge (Ask)
2. Propose a solution (Imagine)
3. List the materials required/available (Plan)
4. Sketch an idea of the solution (Create)
5. Re-evaluate (Improve)



Practical Activity

The practical activity is where the student/learners/learners initiate their plan and proposed solution using the tools and materials provided or sourced. A suitable time-allocation is important so as to keep the pace of work at a level of positive productivity.

Access to tools, machinery, printers, the Internet etc. is required to maximize efficiency of work and allowing the student/learners/learners to progress without too many technological or physical hindrances.

Analysis & Self-Evaluation

A crucial part of the process. Self, peer or teacher evaluation is needed to be able to reflect on the task as whole. Questions asked in the beginning may now have answers. Or, there may be new questions now at this stage in the process for which answers may be sought.

It is quite important to mention here that failure should be an "always-expected" outcome and approached from the point of view that failure is simply a step towards success.

With failure in a task comes the opportunity to reflect, to ask questions, to research further or identify what went wrong and how to remedy that for next time.

Teacher Assessment

Whichever form of assessment has been chosen by the teacher, its main purpose should be that of feedback to the student/learner and illuminate the thinking skills they employed in the process from start to finish.

Keeping in mind the thinking skills mentioned previously, a standardized assessment may not necessarily be the most effective way of assessing the student/learner's progress or path of progression on particular concepts.

Student/learner feedback, however, is crucial.

ASSESSMENT

Student/learners/learners should be able to demonstrate competency with tasks like: [4]

- ✓ developing and refining models;
- ✓ generating, discussing and analyzing data;
- ✓ constructing spoken and written scientific explanations;
- ✓ engaging in evidence-based argumentation; and
- ✓ reflecting on their own understanding.

Assessments, ideally, should: [5]

- ✓ **Focus** on 21st century skills, content knowledge and expertise
- ✓ **Emphasize** deep understanding rather than shallow knowledge
- ✓ **Engage** student/learners/learners with the real-world data, tools, and experts they will encounter in university, on the job, and in life -- student/learners/learners learn best when actively engaged in solving meaningful problems
- ✓ Allow for **multiple measures** of mastery

[4] Adapted from: https://sites.google.com/a/freeholdtwp.k12.nj.us/steam/home/curriculumPlanning/conductingAssessments

[5] Adapted from: http://www.p21.org/our-work/p21-framework

ACTIVITY RUBRIC EXAMPLE

Building A Structure

Student/learner Name: _____

CATEGORY	4	3	2	1
Modification/Testing	Clear evidence of troubleshooting, testing, and refinements based on data or scientific principles.	Clear evidence of troubleshooting, testing and refinements.	Some evidence of troubleshooting, testing and refinements.	Little evidence of troubleshooting, testing or refinement.
Function	Structure functions extraordinarily well, holding up under atypical stresses.	Structure functions well, holding up under typical stresses.	Structure functions pretty well, but deteriorates under typical stresses.	Fatal flaws in function with complete failure under typical stresses.
Scientific Knowledge	Explanations by all group members indicate a clear and accurate understanding of scientific principles underlying the construction and modifications.	Explanations by all group members indicate a relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations by most group members indicate relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations by several members of the group do not illustrate much understanding of scientific principles underlying the construction and modifications.
Plan	Plan is neat with clear measurements and labelling for all components.	Plan is neat with clear measurements and labelling for most components.	Plan provides clear measurements and labelling for most components.	Plan does not show measurements clearly or is otherwise inadequately labeled.
Information Gathering	Accurate information taken from several sources in a systematic manner.	Accurate information taken from a couple of sources in a systematic manner.	Accurate information taken from a couple of sources but not systematically.	Information taken from only one source and/or information not accurate.

Data Collection	Data taken several times in a careful, reliable manner.	Data taken twice in a careful, reliable manner.	Data taken once in a careful, reliable manner.	Data not taken carefully OR not taken in a reliable manner.
Construction - Materials	Appropriate materials were selected and creatively modified in ways that made them even better.	Appropriate materials were selected and there was an attempt at creative modification to make them even better.	Appropriate materials were selected.	Inappropriate materials were selected and contributed to a product that performed poorly.
Construction - Care Taken	Great care taken in construction process so that the structure is neat, attractive and follows plans accurately.	Constuction was careful and accurate for the most part, but 1-2 details could have been refined for a more attractive product.	Construction accurately followed the plans, but 3-4 details could have been refined for a more attractive product.	Construction appears careless or haphazard. Many details need refinement for a strong or attractive product.
Journal/Log - Content	Journal provides a complete record of planning, construction, testing, modifications, reasons for modifications, and some reflection about the strategies used and the results.	Journal provides a complete record of planning, construction, testing, modifications, and reasons for modifications.	Journal provides quite a bit of detail about planning, construction, testing, modifications, and reasons for modifications.	Journal provides very little detail about several aspects of the planning, construction, and testing process.
Journal/Log - Appearance	Several entries made and all are dated and neatly.	Several entries are made and most of the entries are dated and neatly entered.	Several entries are made and most of the entries are dated and legible.	Few entries are made AND/OR many entries are not dated or very difficult to read.

The above rubric is an automatically generated one from http://rubistar.4teachers.org/index.php?screen=NewRubric&section_id=9#04

The construction of a rubric for assessment must reflect the skills being assessed and keep in mind the context of the task and the purpose of the task.

ESSENTIAL & PRACTICAL SKILLS

<table>
<tr>
<td>SCIENCE
✓ Nature and the world around us
✓ Testing and recording of results
✓ Physics
✓ Working with cause and effect
✓ Computational thinking
✓ Critical thinking</td>
<td>TECHNOLOGY
✓ Proper and ethical use of ICT
✓ Mastery of software to perform daily tasks (send email, do research, store information)
✓ Use of various hardware technologies (tablets, phones, laptops, desktops)
✓ Sharing of files between peers and devices
✓ Cloud computing and storage
✓ Email and online communication
✓ Word Processing
✓ Spreadsheet
✓ Creating graphs
✓ Creating presentations
✓ Using 3D software
✓ Coding</td>
</tr>
<tr>
<td>ENGINEERING
✓ Building structures
✓ Creating 3D objects
✓ Building/Programming robots and electronic components
✓ Coding</td>
<td>ART
✓ Design
✓ History
✓ Culture
✓ Future design
✓ Visual and spatial design</td>
</tr>
<tr>
<td colspan="2">MATH
✓ Calculations
✓ Angles
✓ Area
✓ Perimeter
✓ Shapes
✓ Volume
✓ Mass</td>
</tr>
</table>

HARDWARE & SOFTWARE

The following applications are utilized for the effective gathering, storage and retrieval of information as well as the communication between teacher and student/learner.

Microsoft

- Microsoft OneNote
- Microsoft Teams
- Microsoft OneDrive
- Microsoft Office Suite or 365 (Word, Excel, PowerPoint)
- Microsoft Lens
- Microsoft Forms
- Microsoft Sway
- Minecraft

Google

- Google Classroom
- Google Drive
- Gsuite (Docs, Sheets, Slides)
- Google Forms
- Google Photos

Suggestions

	Laptop with Windows 10 and a touch-screen is the ideal! Also suggested is a built-in webcam and microphone. A stylus would be beneficial to make full use of the touch-screen and the functionality of Microsoft OneNote for example.
	Any smartphone with a good camera, mic and decent screen size is good. The phone can be used as an instrument for photos, recording audio and video and the use of applicable applications that can aid the learning process.

TOOLS & EQUIPMENT

Appropriate tools are recommended for practical projects. Many tools and materials can be sourced at home or purchased by student/learners/learners at a nominal cost. Certain equipment, however, should be provided by the school, such as:

- Glue guns and sticks
- Soldering irons and consumables
- Safety goggles for any cutting tools
- Tools such as spanners, screwdrivers, hammers, electrical wiring kits
- Arduino boards/kits (or Raspberry Pi)
- Microbits, at least one between two student/learners/learners with a long mini-USB cable
- Lego robotics
- Computer workstations for Internet access
- 3D Printer with ABS or PLA filament

This list is far from exhaustive.

DOCUMENTATION, RESOURCES & ARTICLES

- 21st Century Framework Definitions document by P21 : http://www.p21.org/storage/documents/docs/P21_Framework_Definitions_New_Logo_2015.pdf
- 21st Century Framework Skills document by P21 : http://www.p21.org/storage/documents/docs/P21_framework_0816.pdf
- http://educationcloset.com/steam/what-is-steam/
- https://21centuryedtech.wordpress.com/
- https://steameducation.wordpress.com/
- https://www.commonsense.org/education/blog/24-apps-games-and-websites-teachers-are-using-in-steam-classrooms
- https://21centuryedtech.wordpress.com/2014/02/17/stem-education-over-25-steam-links-filled-with-resources-and-information/
- http://www.huffingtonpost.com/vidcode/the-importance-of-steam-l_b_9488898.html
- https://www.envisionexperience.com/blog/13-essential-21st-century-skills-for-todays-student/learners/learners
- http://www.p21.org/our-work/p21-framework
- https://www.ted.com/talks/ken_robinson_says_schools_kill_creativity
- https://www.washingtonpost.com/news/answer-sheet/wp/2014/04/22/11-problems-created-by-the-standardized-testing-obsession/?utm_term=.967301a1ff64
- Bloom's Digital Taxonomy verbs (infographic)
- http://edtechteacher.org/assessment
- http://rubistar.4teachers.org/index.php?screen=NewRubric&section_id=9#04
- https://steameducation.wordpress.com/2014/04/14/recycled-art-steam

CONTACT

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