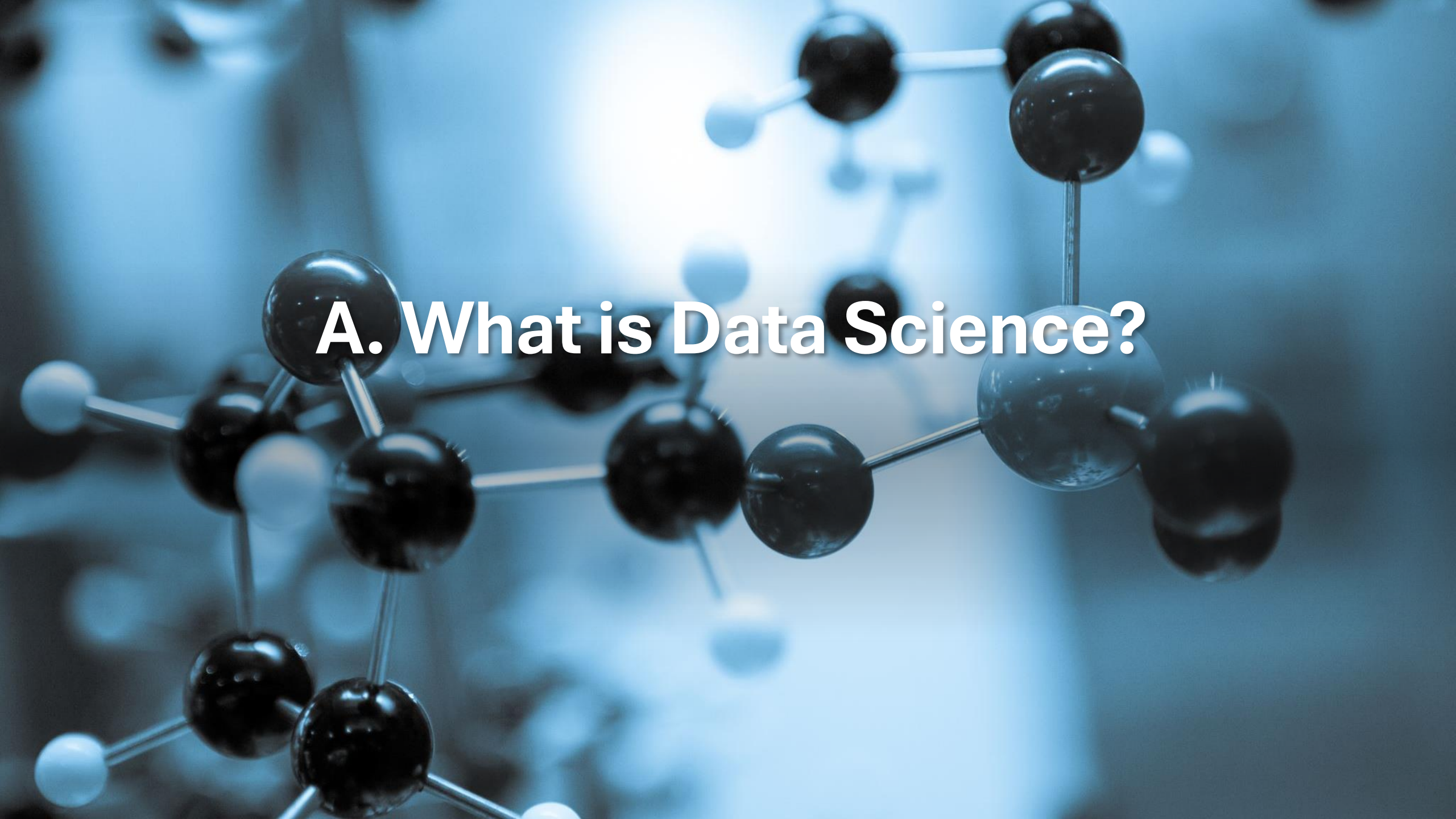
Conceptual Framework for Data Science within STEAM Education [DataScEd4CiEn]





A. What is Data Science?



How is data science different from statistics?

Extending the statistical view of “data”

Extending the statistical view of “data”

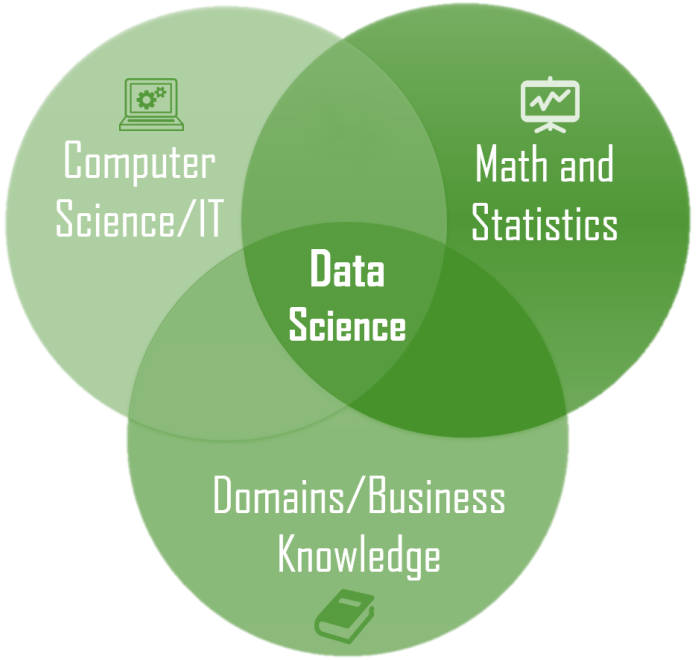
- Data science is broader and deals with new types of data and big data
- New types of data
  - Data collected by sensors
  - Data collected by personal devices
  - Transactional data (traffic, supermarket buys)
  - Images and texts
  - Data scraped from webpages
  - Data with geographic information

→ Big data; open data (Ridgway, 2016)

Data Science and its context

- Big Data
- Digitalisation
- Data protection in social networks
- Artificial intelligence, machine learning
- Data driven learning algorithms
- Digital humanities

- Data Literacy
- Statistical Literacy
- News Literacy
- Algorithm Literacy
- ….



And:

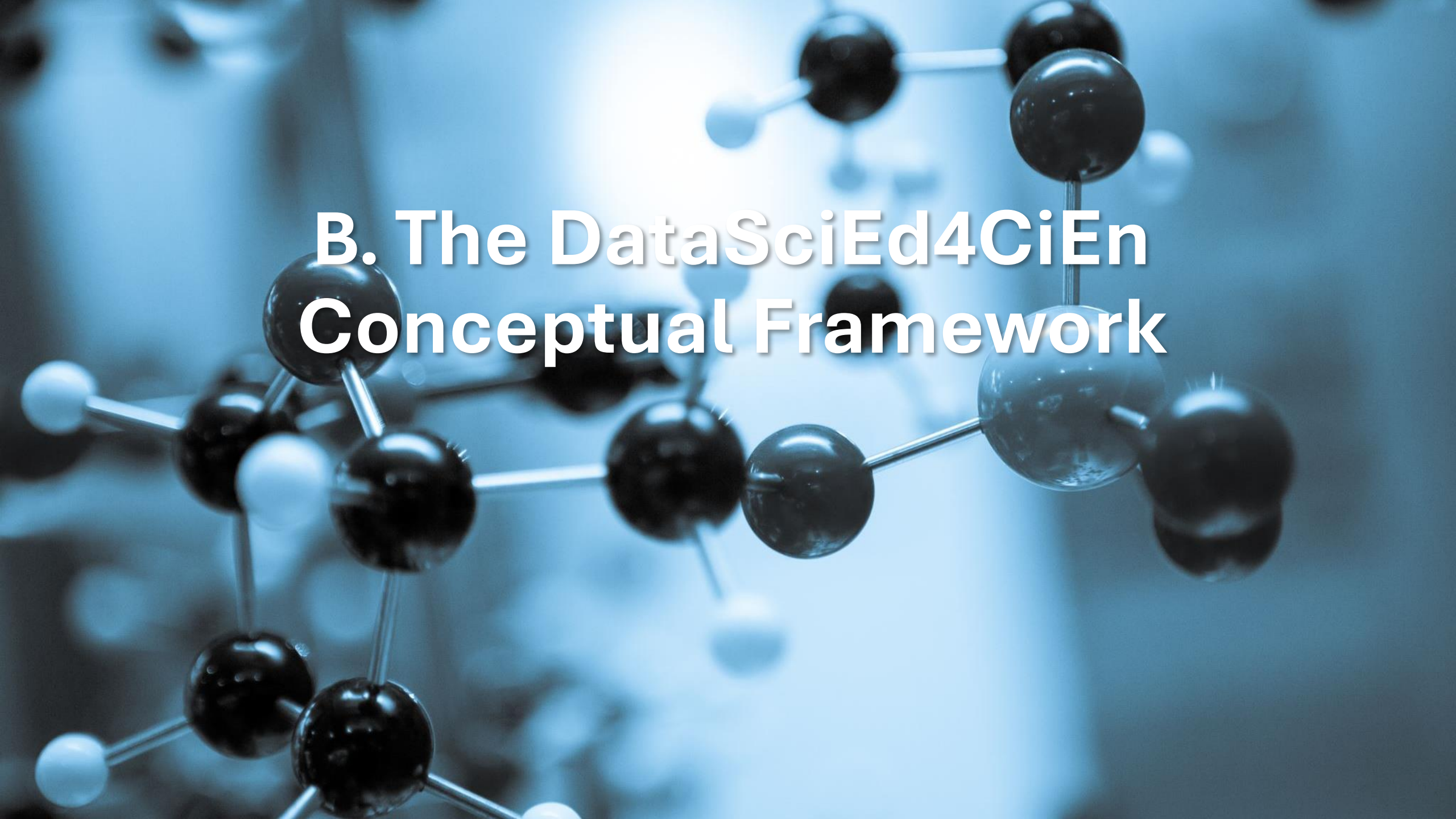
- **Social responsibility**
- **Civic statistics** like statistics about migration, economy, crime, health, etc.

LINK to reading....

These are the sensors in the school in the STEAM-Ed project which **use sensors** collect data in real time and continuously throughout the day and night.

What is different about the nature of the data generated from this problem?





B. The DataSciEd4CiEn Conceptual Framework

Explore the image of the DataSciEd4CiEn Conceptual Framework.

What do you notice?
What do you wonder?



Think back to the STEAM-Ed case study reviewed in the Essential Viewing and Reading.

How do different parts of the study **map onto** the DataSciEd4CiEn Conceptual Framework?

*What is the **problem** the children addressed?*

*What is the **STEM** and **STEAM** part of the study?*

*What were the **data science** aspects?*

*Are there **social justice** or **civic engagement** links?*



C. From STEM to STEAM education

STEAM Education

STEAM is an acronym for **S**cience, **T**echnology, **E**ngineering, **A**rts, and **M**athematics

An extension of the interdisciplinary **S**cience, **T**echnology, **E**ngineering and **M**athematics (STEM) model

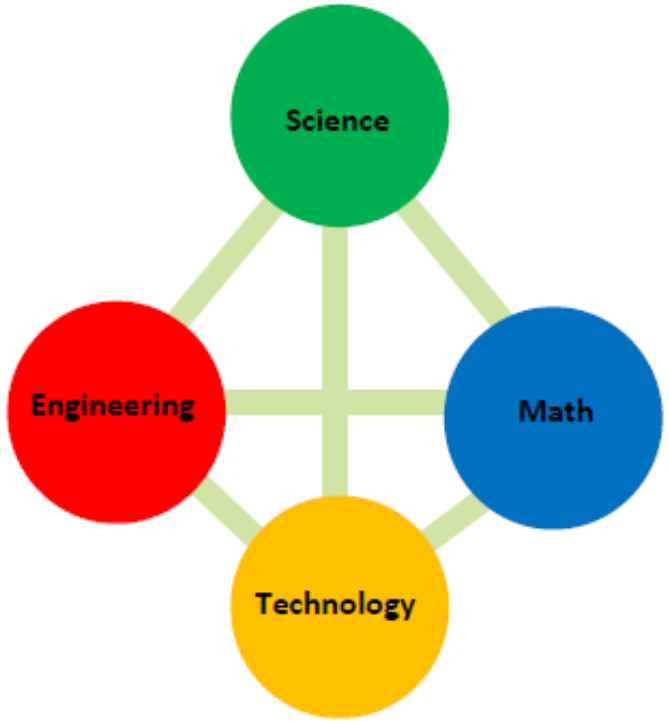
What is STEM Education?

A global trend that emerged at the start of the 21st century as recognition of the need to equip students with knowledge and skills for solving genuine problems of the ever-changing, technology driven society

Acknowledges that current socio-economic issues are too complex and multi-dimensional to be dealt with exclusively in the light of a single science

Emphasizes an integrated approach that underscores the interrelationship of science, technology, engineering, and mathematics

Removes the traditional barriers erected between the four disciplines, by integrating the four subjects into one cohesive curriculum

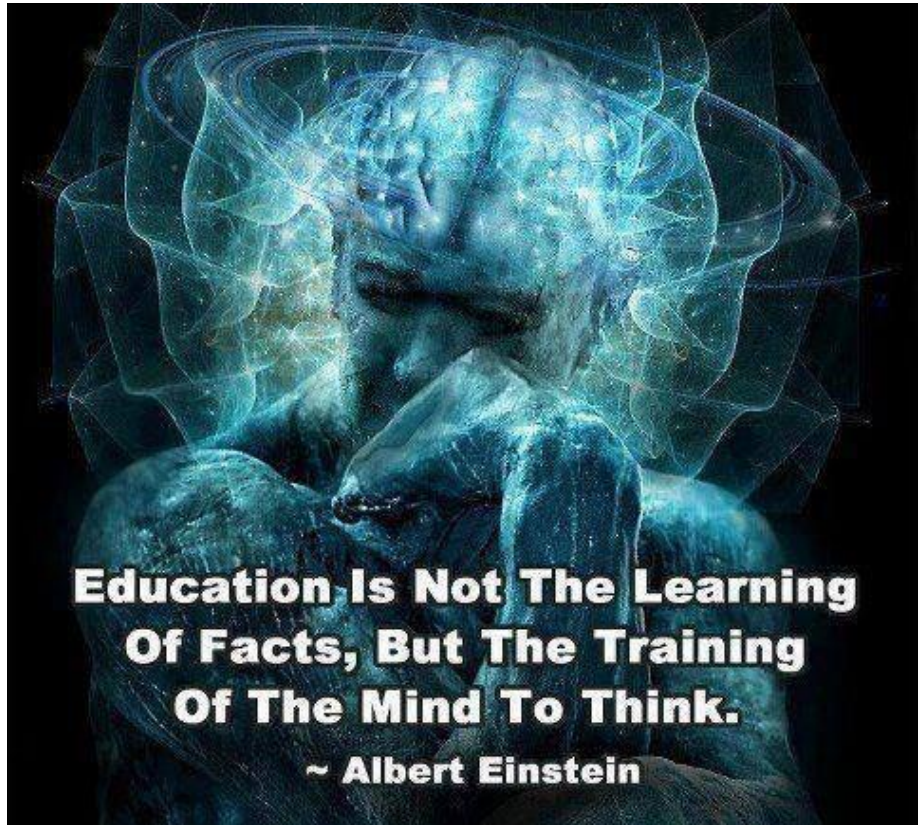


Why STEM Education?

Incorporates several research-based best practices: project-based learning, inquiry-based learning, collaborative learning, laboratory investigations, work-based learning

In addition to fostering in-depth knowledge of STEM fields, it equips students with:

- Critical and analytical thinking skills
- Proficiency at solving non-routine problems
- High-level communication abilities
- Project management experience
- Teamwork and leadership skills



Skills required for success in college and the world of work!

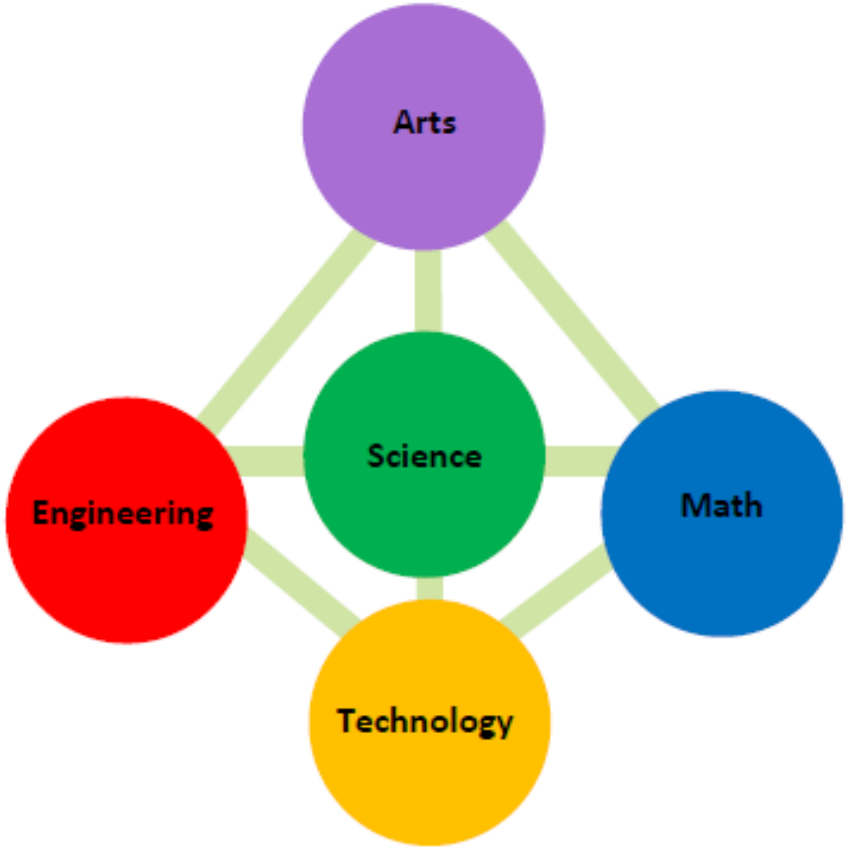
From STEM to STEAM

What is STEAM?

- Science
- Technology
- Engineering
- **Arts**
- Mathematics

STEM + Arts

- Arts - “ How society develops, impacts, is communicated and understood with its attitudes and customs in the past, present and future “
- Society, culture, belief, religion, politics, …

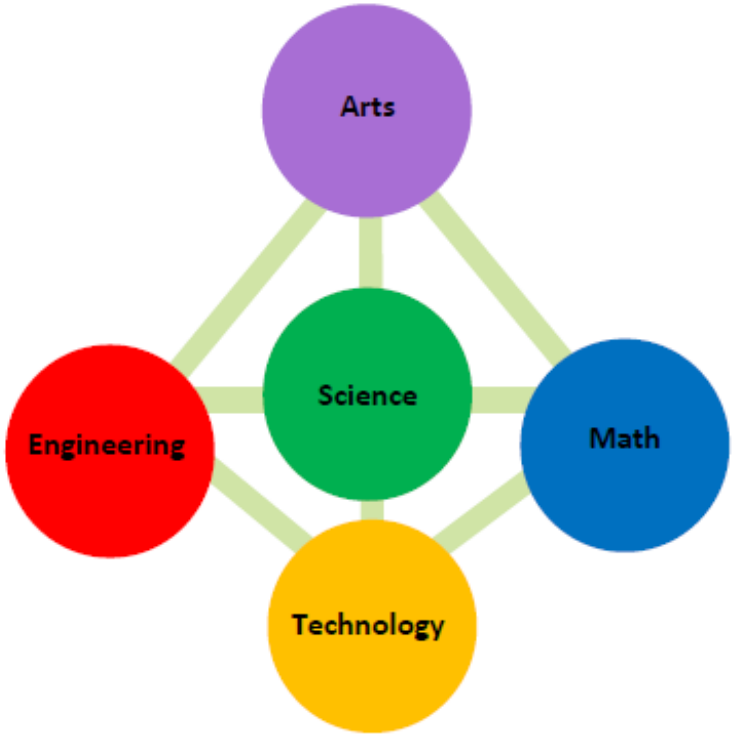


What is the “A” in STEAM?

Arts include

- performing arts such as dance, theater, music
- fine arts such as painting, sculpture
- linguistics and liberal arts such as sociology, education, philosophy

The inclusion of the Arts aims at enhancing the creative, critical and divergent thinking of learners



What is STEAM?

Arts ≠ Crafts
Arts = Creativity
Arts=Open-ended

“The arts and sciences are avatars of human creativity” - Mae Jemison

“Open-ended activities promote “the problem solving, the fearlessness, and the critical thinking and making skills” - John Maeda



STEAM ACTIVITY

What is a STEAM activity for you?

https://www.menti.com/alev77mcb6zy

- A smoothie;

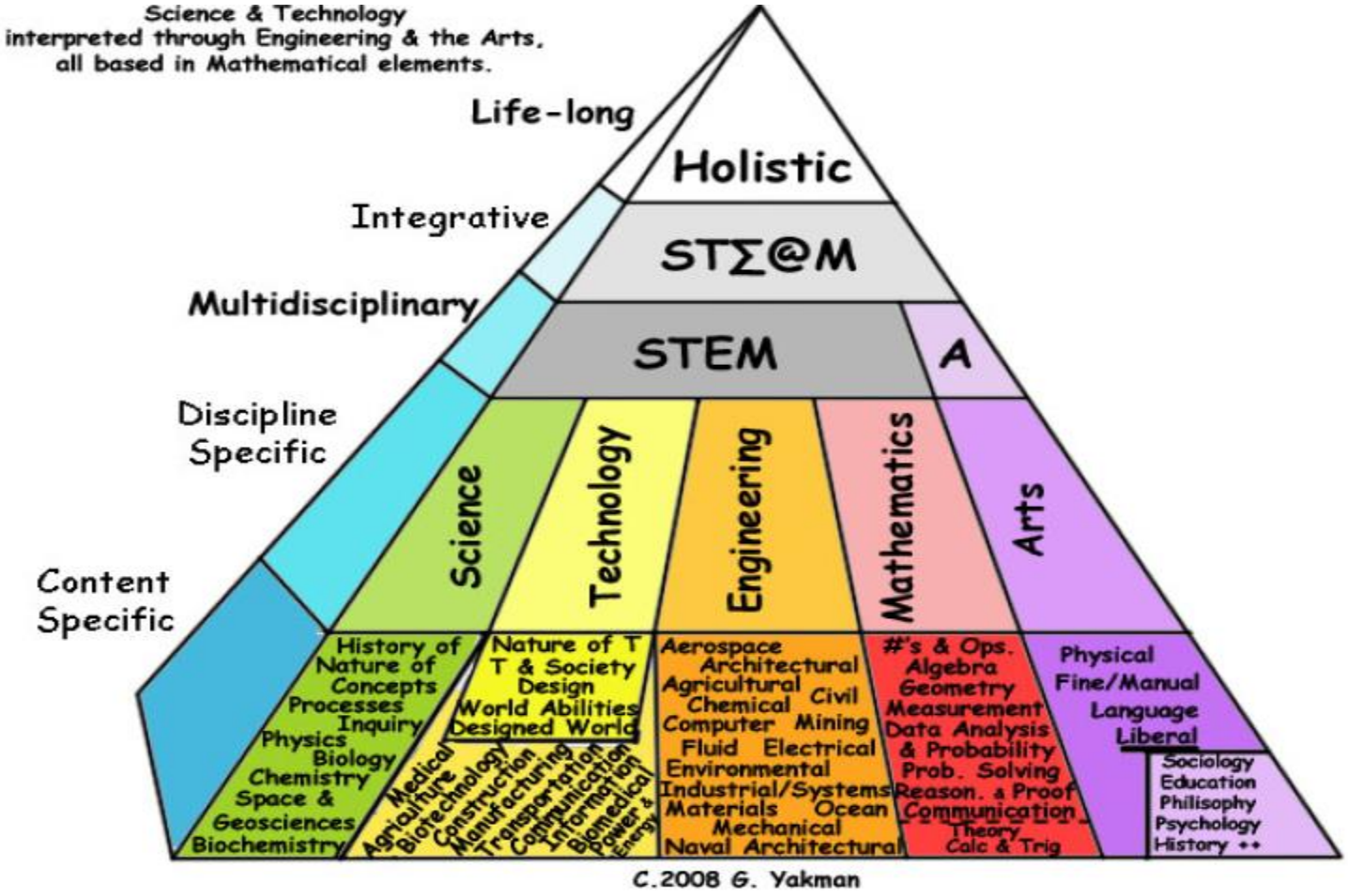


or

- A fruit salad;



STEAM Education: A Framework for Teaching Across the Disciplines

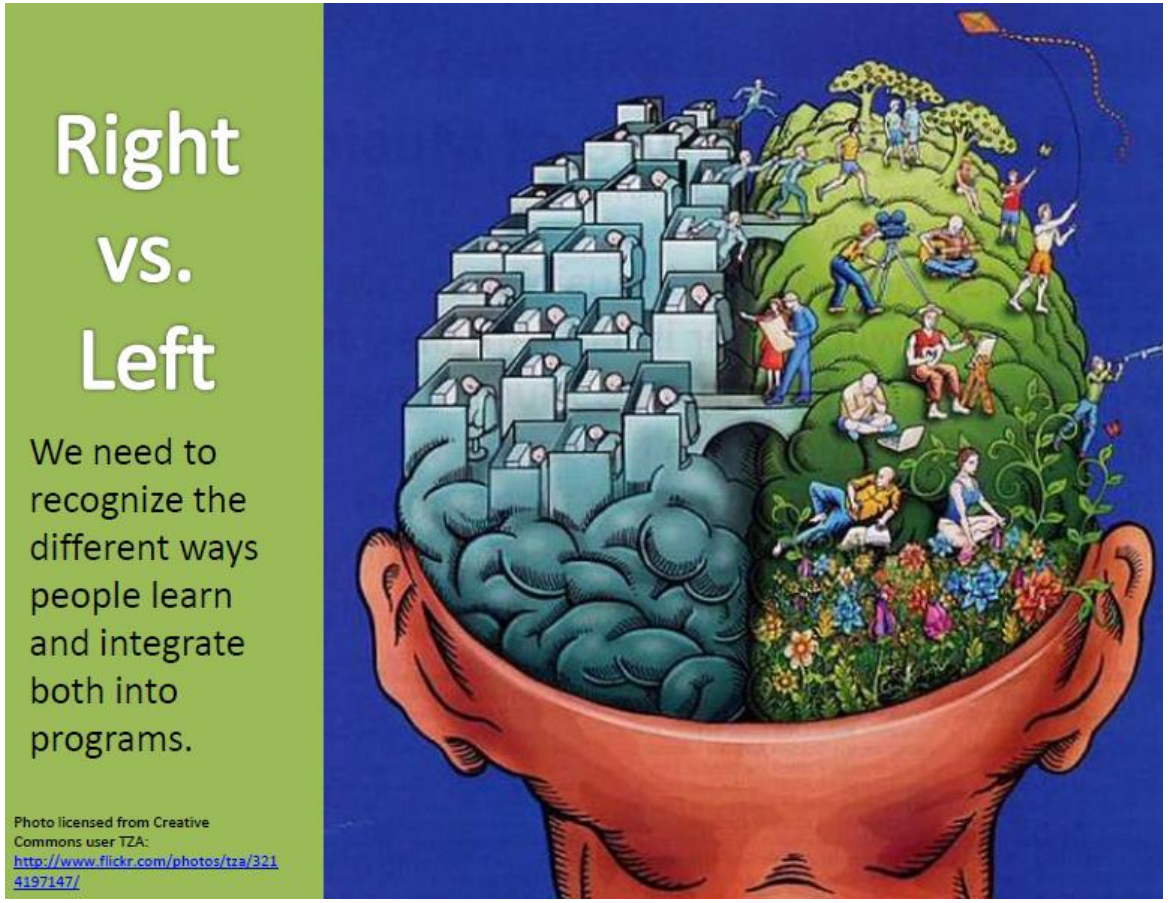


Connection between the Arts and STEAM fields

Root-Bernstein, a biochemist and MacArthur prizewinner did a study of 150 biographies of eminent scientists, from Pasteur to Einstein, in the early 1990's. It dealt with the relationship between the two sides of the brain

He found that nearly all of the great inventors and scientists were also musicians, artists, writers or poets. Galileo, was a poet and literary critic; Einstein was a passionate student of the violin; Samuel Morse, was a portrait painter, etc.

The Neuroeducation Study in 2009, led by John Hopkins and the Dana Foundation, showed that Arts education improves student cognition, memory and attention skills in the classroom as well as a range of life & academic skills



Importance of STEAM Education

- Innovative companies like Nike and tech giants like Intel rely on employees with a mind for science, but an eye for design
- It is imperative that our education system focuses on a curriculum that includes, uses and develops, all the tools and skills that are available to support creativity and innovation
  - *"It is the tension between creativity and skepticism that has produced the stunning unexpected findings of science."* - Carl Sagan
- STEAM Promotes Holistic Learning:
  - Supports whole learner
  - Stimulates senses
  - Deeper, more meaningful learning
  - Multiple Intelligences—addresses diverse learning styles
  - Integrated—allows many entry points for the learner
  - Learner reflects on experiences and interactions with environment to build complex, systematic understanding of world

STEAM for diversity and inclusion

- Cross-national studies of students' achievement (e.g. TIMSS, PISA) indicate lack of scientific (and literacy) competence for a considerable proportion of students
- Well-documented evidence of declining interest in key STEM topics and careers for students in the EU and internationally (Panorama, 2016; OECD, 2016)
- Socio-economic factors *(*gender, race, socioeconomic status, ethnicity, ability status etc.) continue to influence students' performance and/or participation in STEM
- The situation calls for urgent action, since skills in STEM/STEAM are among key competencies all individuals need in a knowledge-based society for employment, inclusion, subsequent learning, personal fulfillment and development (EU Commission, 2016)
- *EU Digital Education Action Plan, 2021-2027:* Calls schools and HE institutions to adopt the STEAM approach, in order to encourage women's and other underrepresented groups' participation in STEM/STEAM studies and careers

What Schools Need to increase underrepresented populations' participation in STEAM

STEAM content integrated in all courses

More engaged learning/less lecture

More ill-structured problem solving

More strategies that cause students to seek STEAM content answers

More collaborative learning experiences

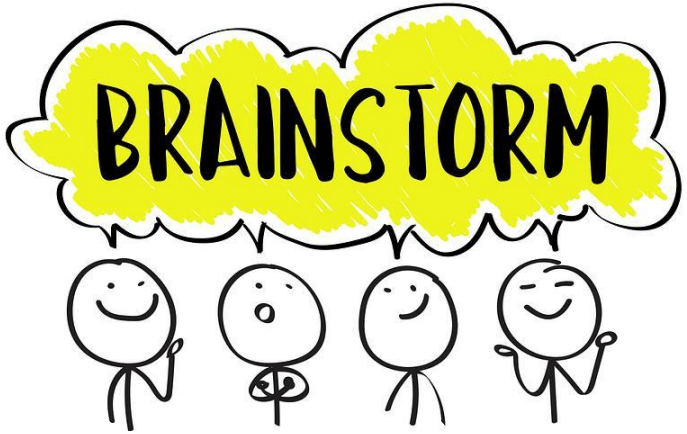
The STEAM educational model

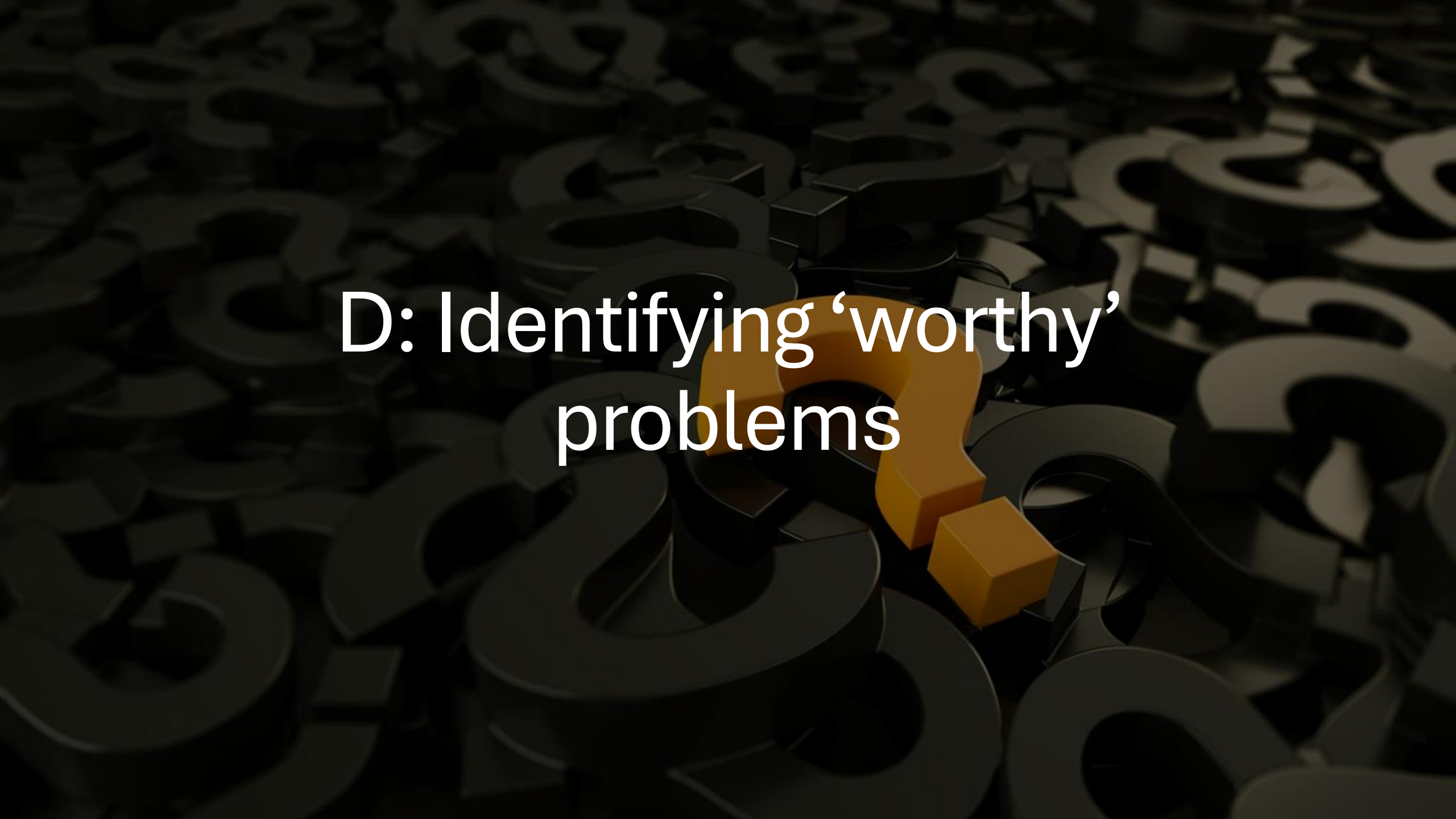
- Is based on contemporary learning theories
- Offers an active and participatory learning environment that takes place in authentic, transdisciplinary contexts, enhancing student motivation
- Enables students to explore, invent, and discover collaboratively, using real-world problems and situations, helping them develop 21st century skills
- Requires:
  - ✓ Revision of existing school curricula
  - ✓ Adoption of innovative teaching practices and technologies
  - ✓ Provision of high quality pre-service and in-service teacher training

Discuss how STEAM was represented in the STEAM-Ed reading.

What STEM did children engage in? What was the nature of the STEAM emphasis?

Think back to the video, what disciplines were the researchers from?





D: Identifying ‘worthy’ problems

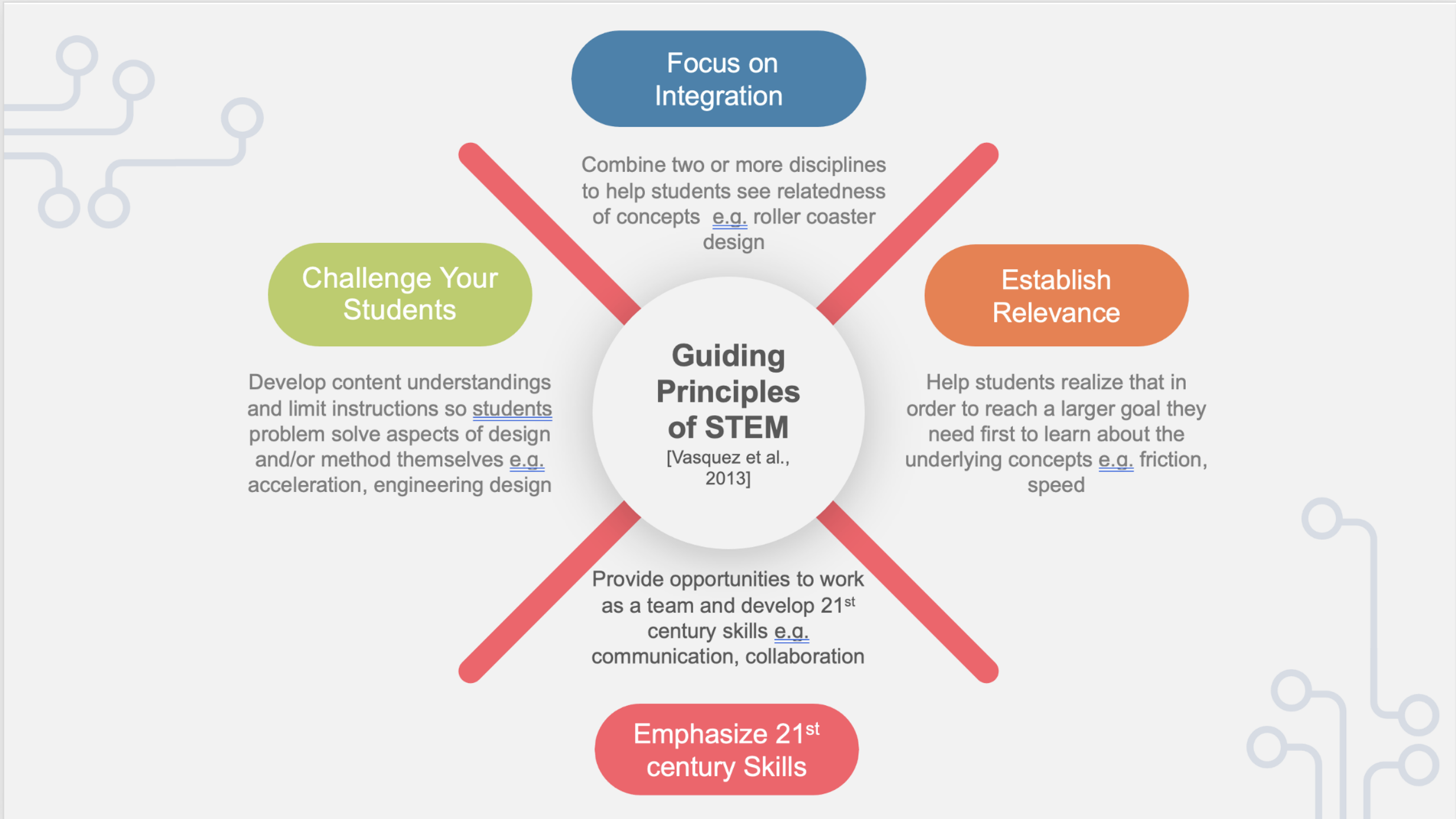
Worthy problems draw on **integrated STEAM contexts** and require the use of **data science** to solve/explore them.

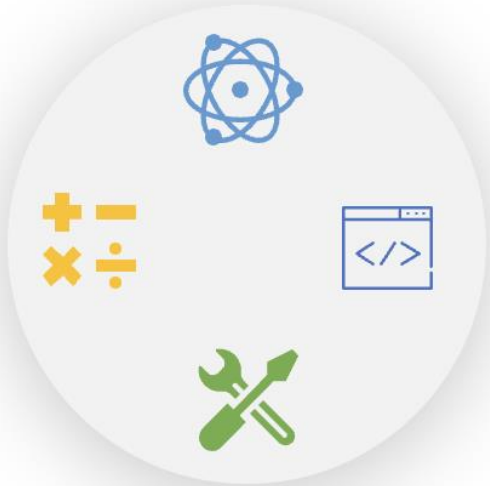
Four approaches to Integrated STEM

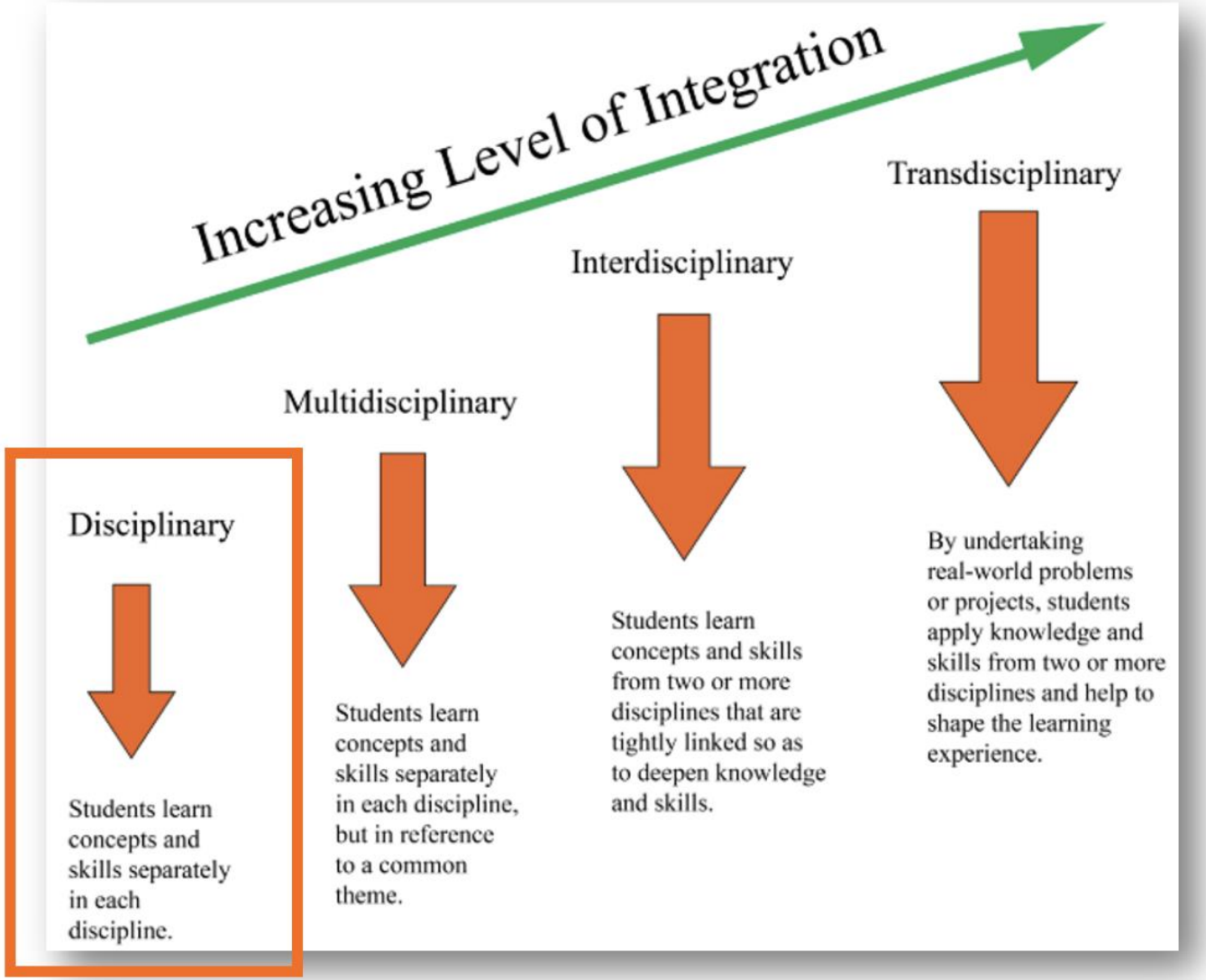
STEM education is an interdisciplinary approach to learning which removes the traditional barriers separating the four disciplines of science, technology, engineering and mathematics and integrates them into meaningful experiences for students

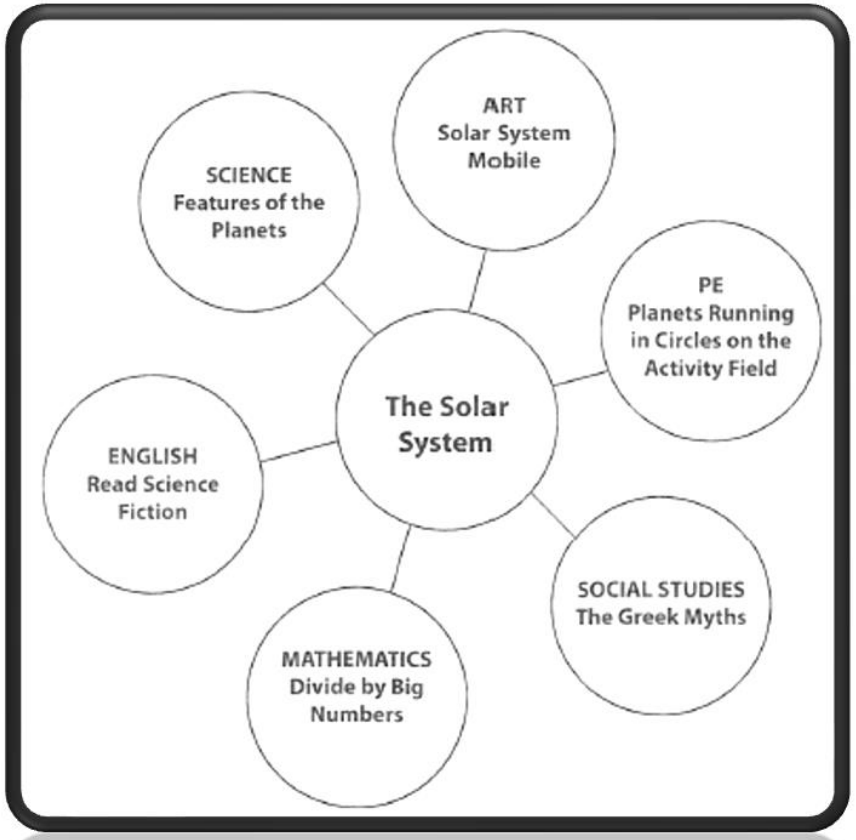
Vasquez et al., (2013)

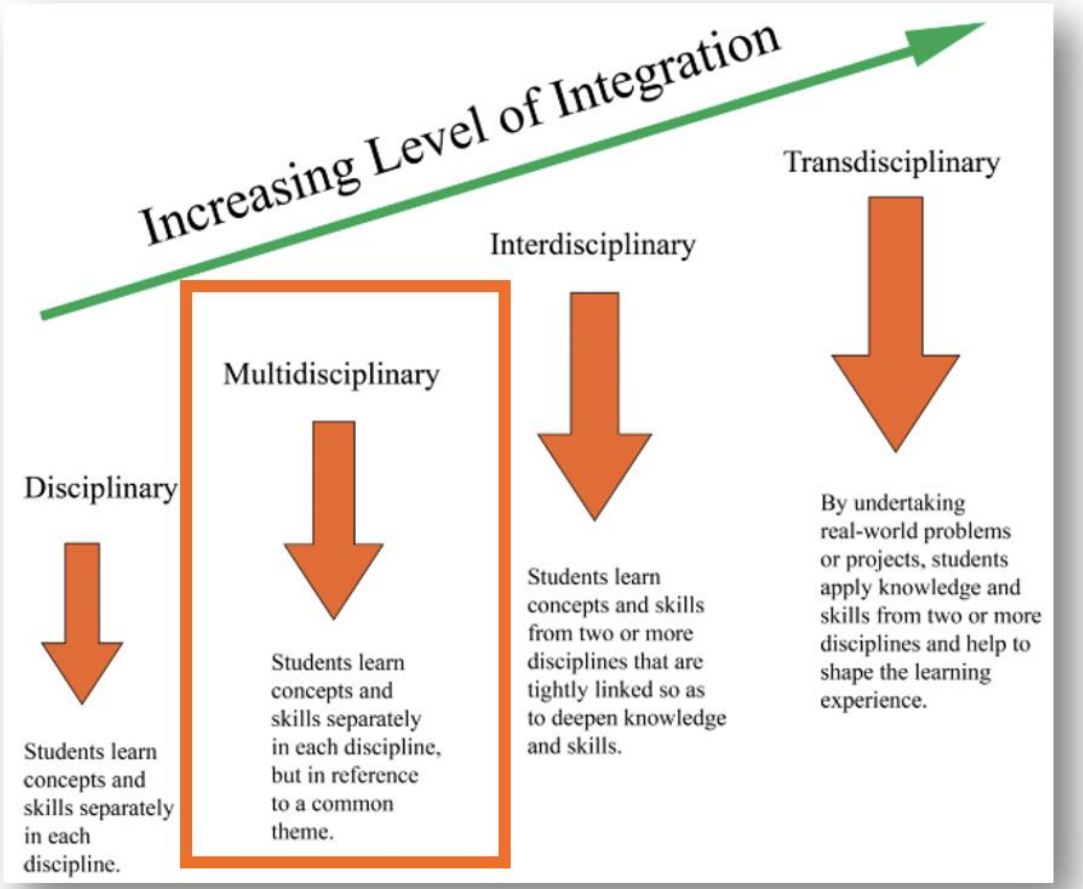



Focus on Integration
Combine two or more disciplines to help students see relatedness of concepts e.g. roller coaster design
Challenge Your Students
Develop content understandings and limit instructions so students problem solve aspects of design and/or method themselves e.g. acceleration, engineering design
Guiding Principles of STEM
[Vasquez et al., 2013]
Establish Relevance
Help students realize that in order to reach a larger goal they need first to learn about the underlying concepts e.g. friction, speed
Provide opportunities to work as a team and develop 21st century skills e.g. communication, collaboration
Emphasize 21st century Skills




Increasing Level of Integration
Disciplinary
Students learn concepts and skills separately in each discipline.
Multidisciplinary
Students learn concepts and skills separately in each discipline, but in reference to a common theme.
Interdisciplinary
Students learn concepts and skills from two or more disciplines that are tightly linked so as to deepen knowledge and skills.
Transdisciplinary
By undertaking real-world problems or projects, students apply knowledge and skills from two or more disciplines and help to shape the learning experience.


The Solar System
ART
Solar System Mobile
SCIENCE
Features of the Planets
PE
Planets Running in Circles on the Activity Field
ENGLISH
Read Science Fiction
SOCIAL STUDIES
The Greek Myths
MATHEMATICS
Divide by Big Numbers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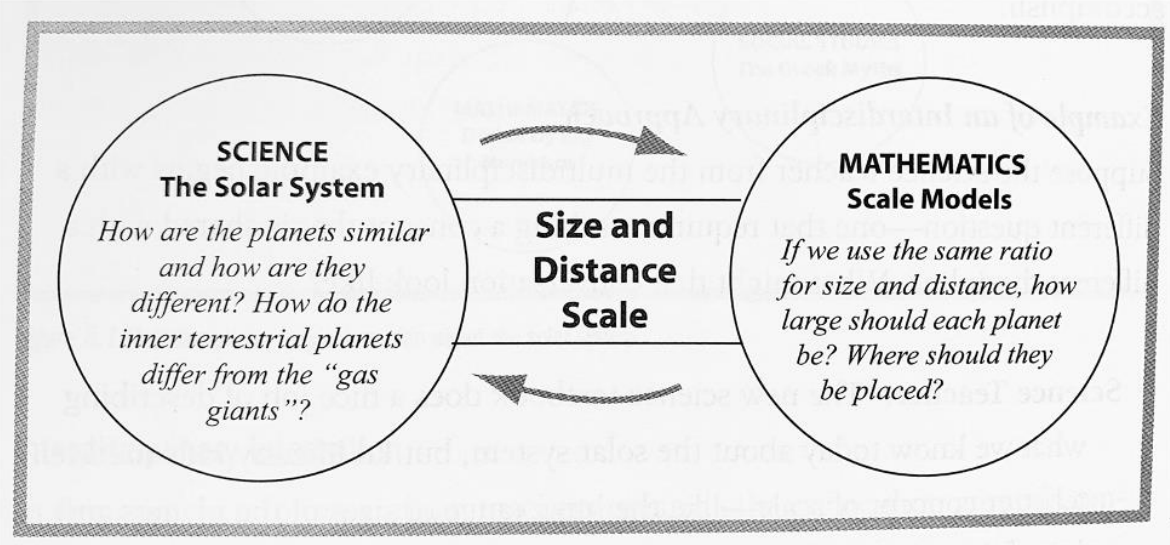
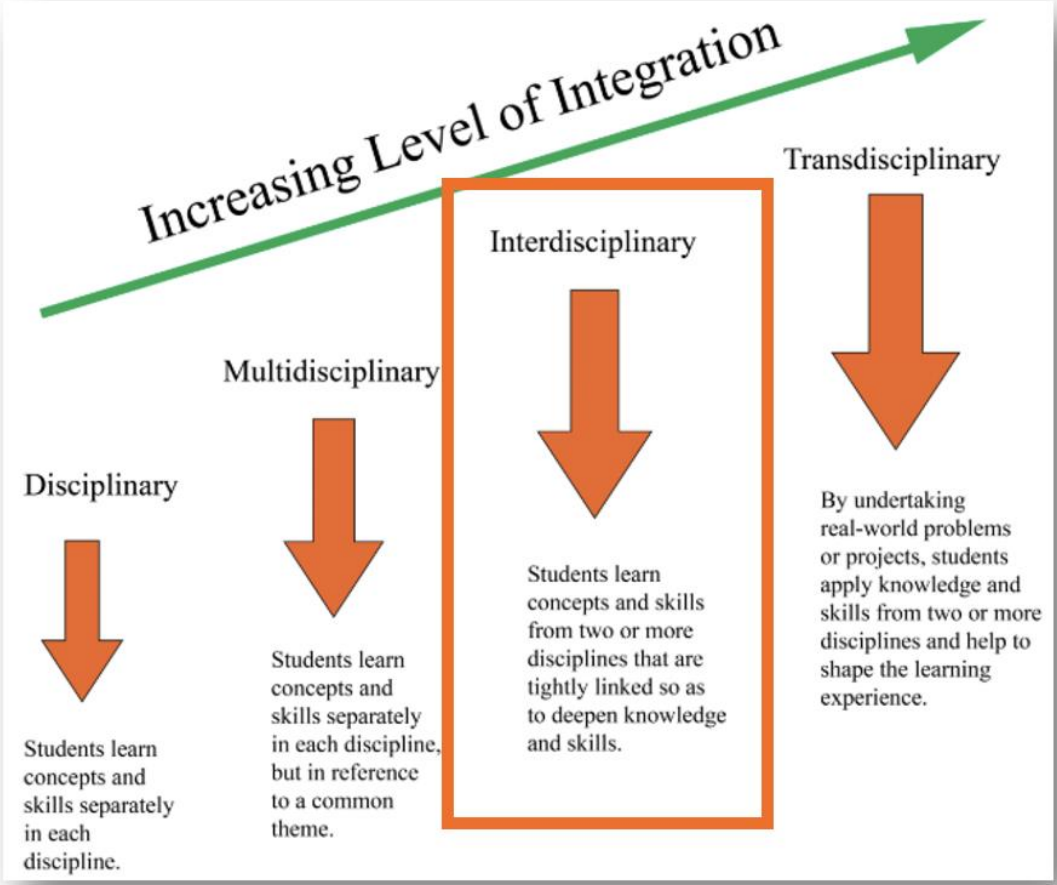
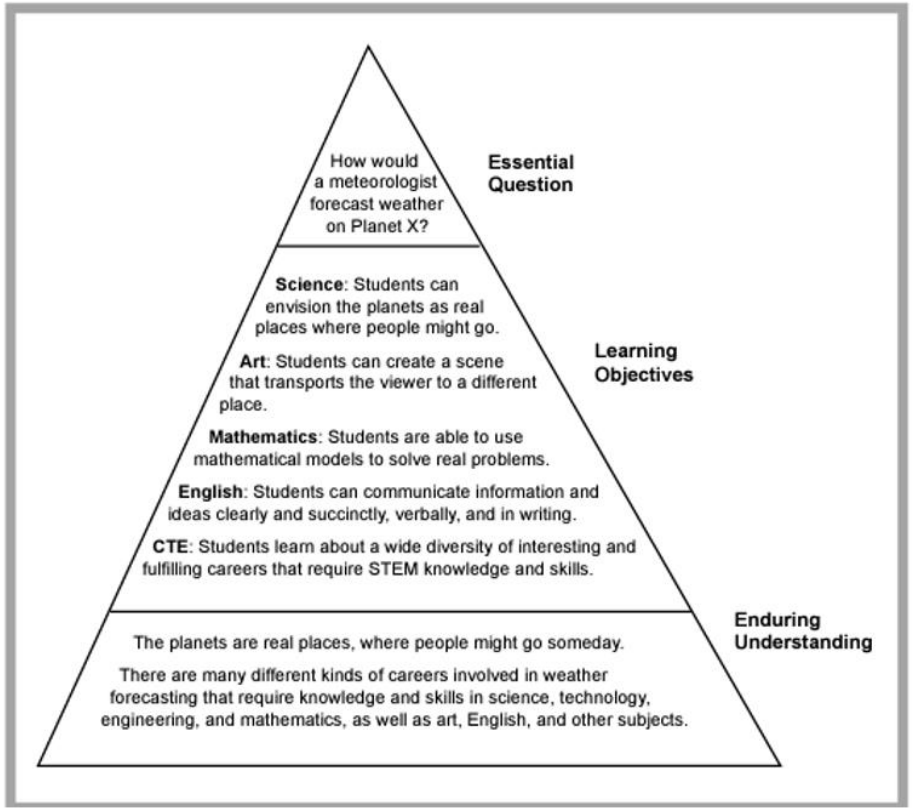
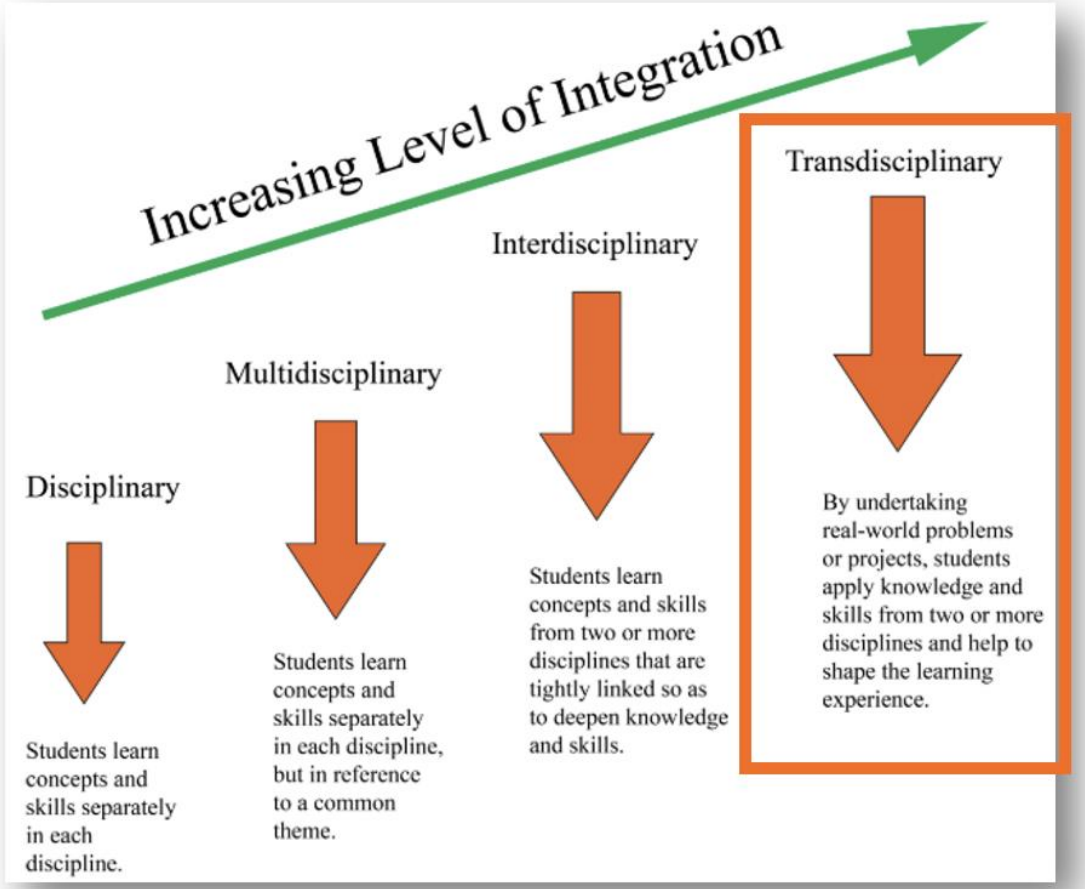


Two subject integration




How would a meteorologist forecast weather on Planet X?
Essential Question
Science: Students can envision the planets as real places where people might go.
Art: Students can create a scene that transports the viewer to a different place.
Mathematics: Students are able to use mathematical models to solve real problems.
English: Students can communicate information and ideas clearly and succinctly, verbally, and in writing.
CTE: Students learn about a wide diversity of interesting and fulfilling careers that require STEM knowledge and skills.
Learning Objectives
The planets are real places, where people might go someday.
There are many different kinds of careers involved in weather forecasting that require knowledge and skills in science, technology, engineering, and mathematics, as well as art, English, and other subjects.
Enduring Understanding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Trans-disciplinary Approach to STEM

Topic Specific Situations

Driving Questions

Table 6.1 Criteria for identifying and composing situations and driving questions

Situations and Driving Questions	
Will this situation and driving question—	
1	Pose a *specific* real-life problem/challenge?
2	Connect to student interest, school, home, and/or community?
3	Stimulate students' ongoing thinking and inquiry?
4	Spark high-order thinking (see Bloom's Top 3 levels)?
5	Invite students to raise questions?
6	Generate discussion and debate among students?
7	Prove appropriate throughout the project?
8	Require science, technology, engineering, and math for a solution?
9	Call for designing and building a product (prototype) to help solve the problem?
10	Call for open-ended consideration of various options both initially and throughout?
11	Call for evidence, reasoning, and justification of understanding?
12	Require students to report to audiences other than the teacher and fellow students?

Cianca, Sherri. *Teaching Elementary STEM Education : Unpacking Standards and Implementing Practice-Based Pedagogy*, Taylor & Francis Group, 2020. *ProQuest Ebook Central*, https://ebookcentral.proquest.com/lib/mic-ebooks/detail.action?docID=5835410.

REFLECT! The case study …..





Children examining the photos of places in the school and how they felt in those places.
They identified the school foyer as a dull and boring place. They want it to feel more exciting and interesting.

To what extent was the STEAM-Ed study a transdisciplinary investigation?





E. Doing Data Science?

- The International Data Science in Schools Project (IDSSP) framework for data science curriculum which provides a guide for a data science curriculum aimed at upper secondary level.
- It presents a cycle of learning from data, that incorporates many of the features prevalent in statistical inquiry cycles and other statistical inquiry cycle.

This cycle is the **process for doing data science.**

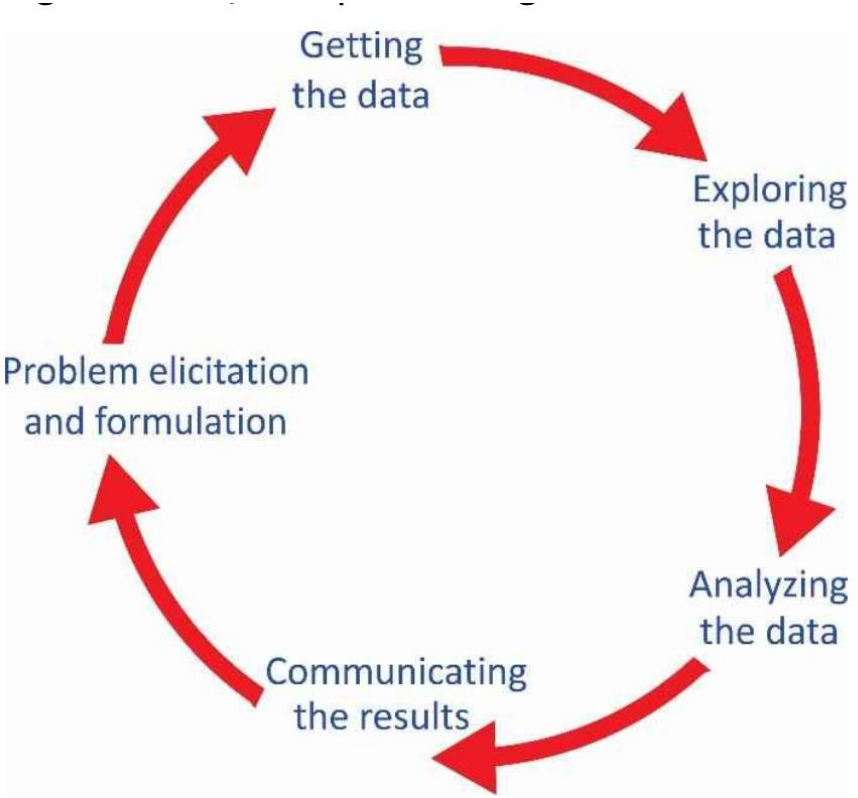


Figure 1 The basic cycle of learning from data

- At each step of the process, there are associated **data science practices**.

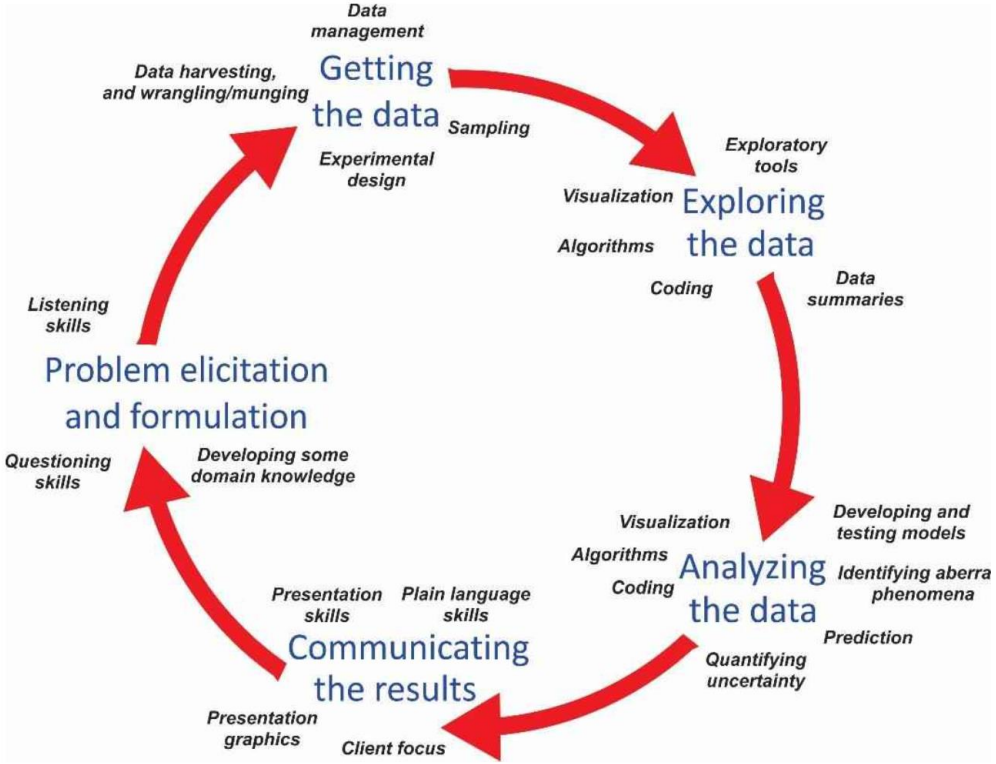
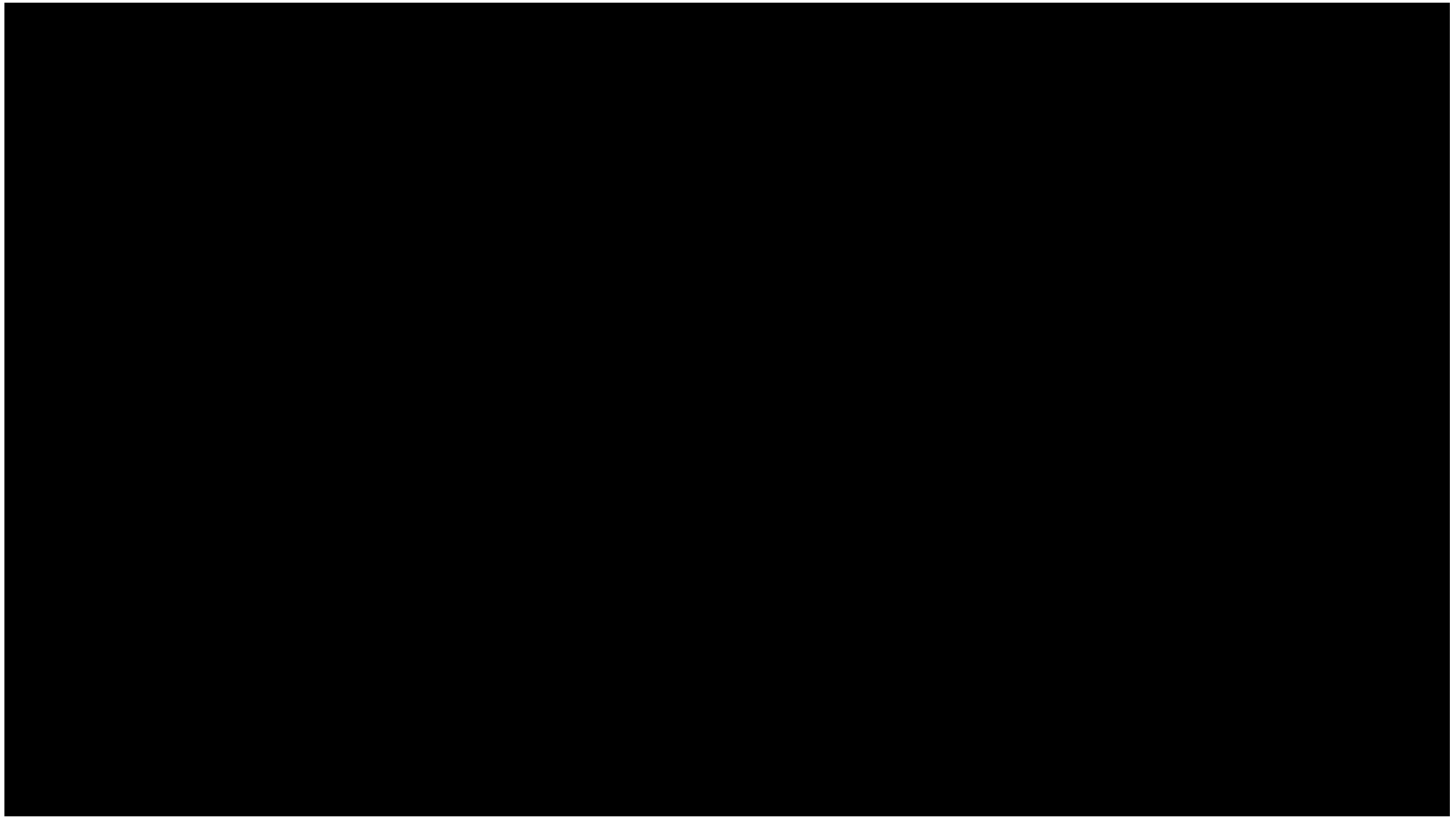


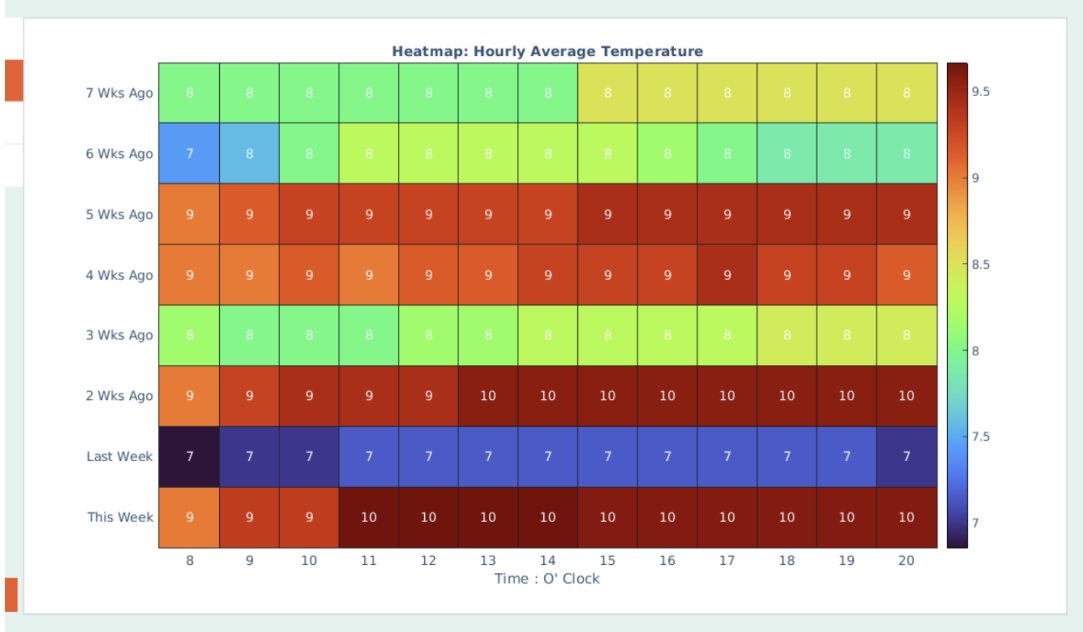
Figure 2 The varying activities involved in learning from data.

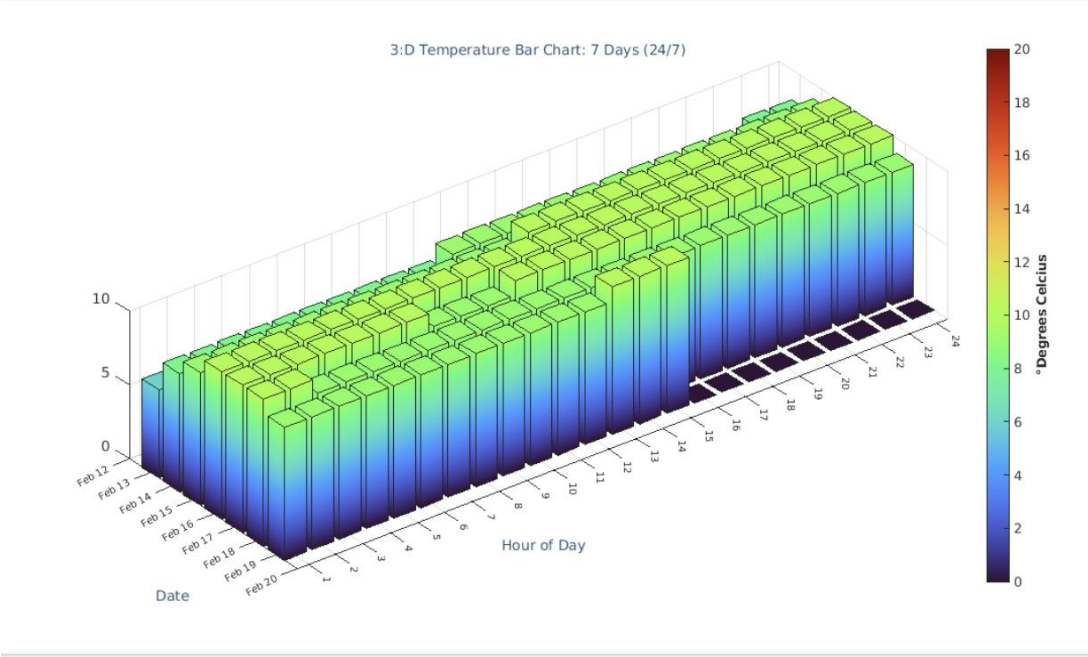
The sensors in this video show how the students ***get the data*** in the STEAM-Ed project

The sounds you hear are how the ***results are communicated*** via music (STEAM emphasis)

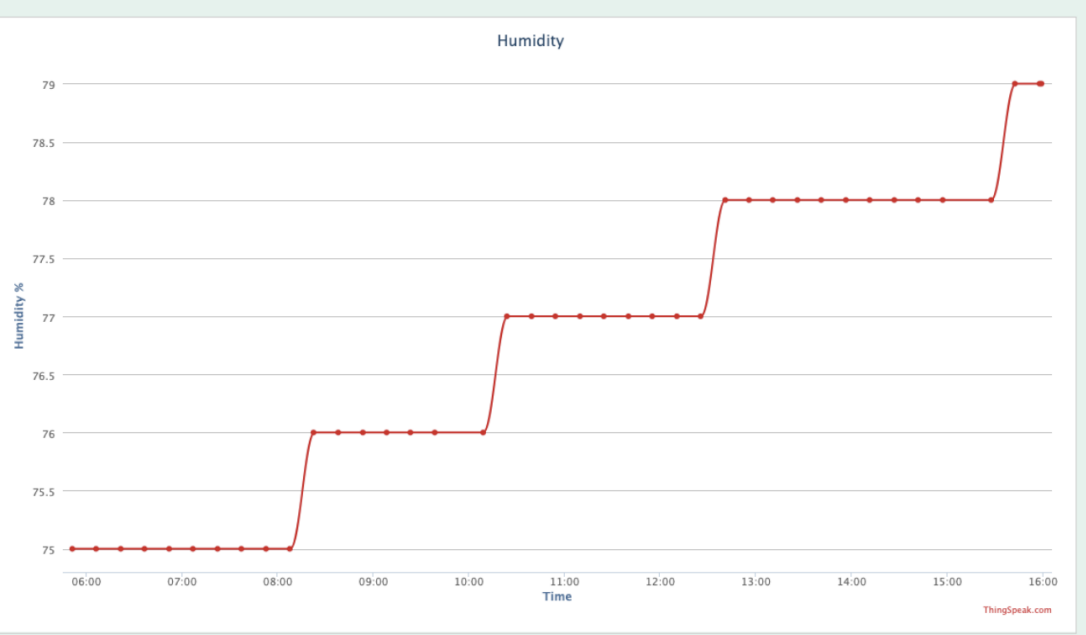


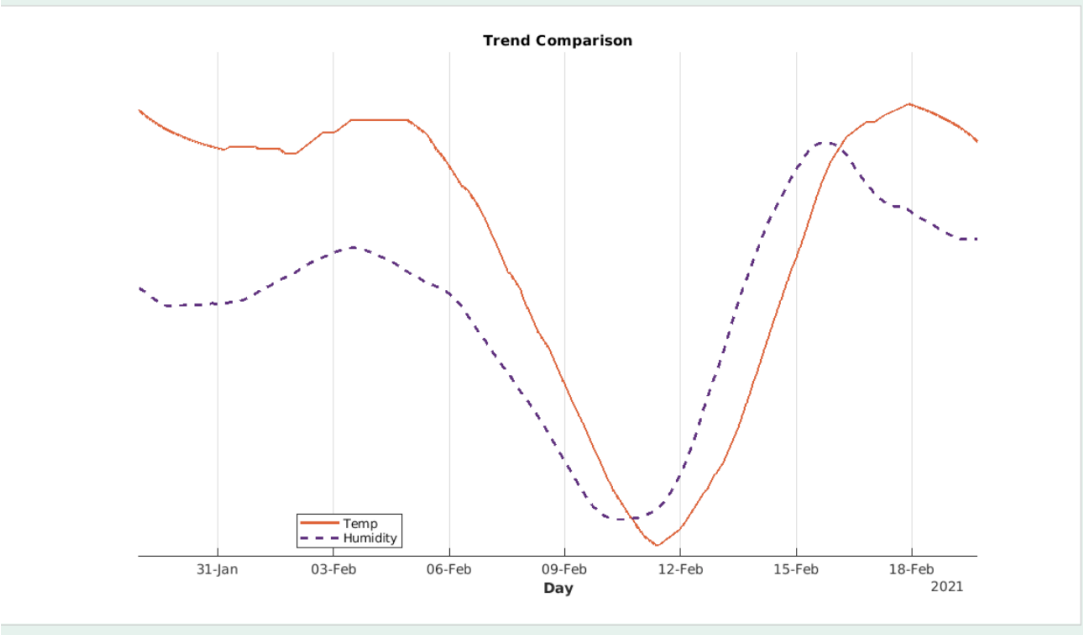
The graphs generated to **analyse temperature data**



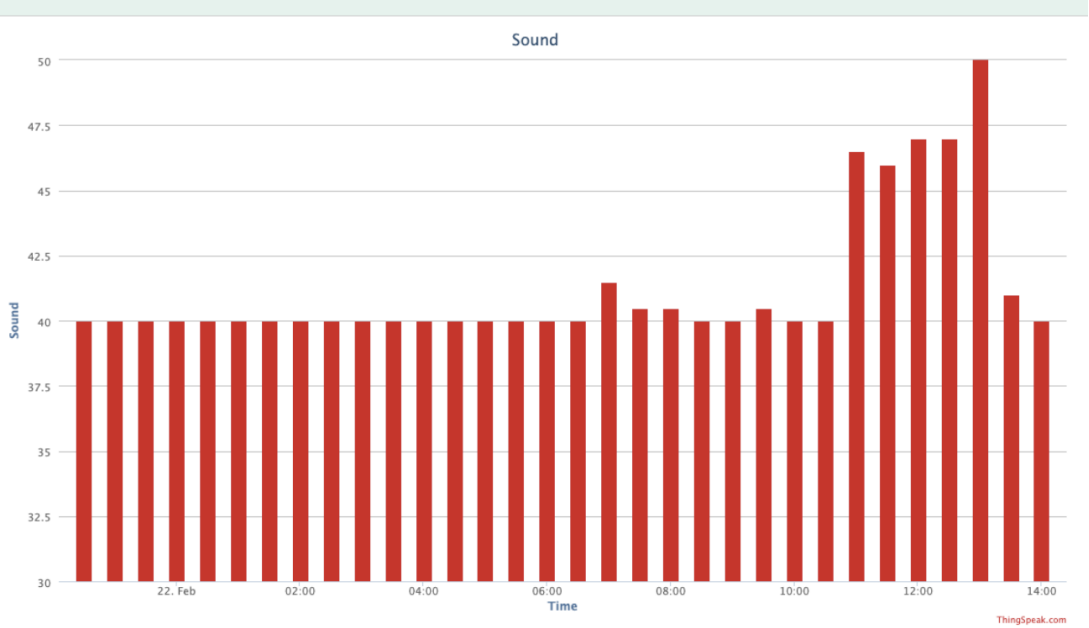


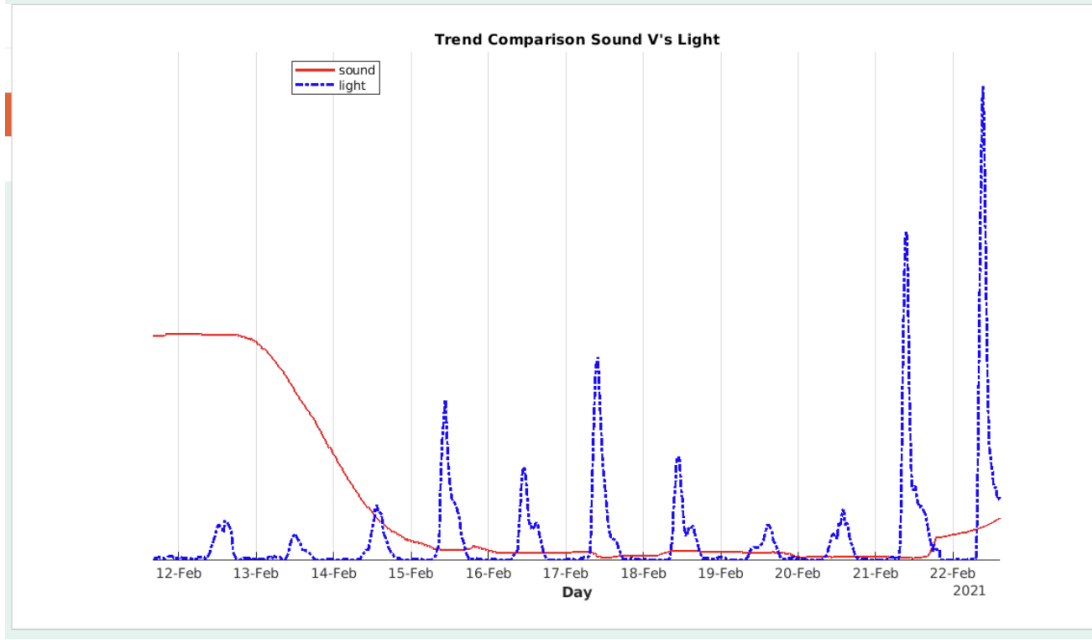
The graphs generated to **analyse humidity data**





The graphs generated to **analyse sound data**



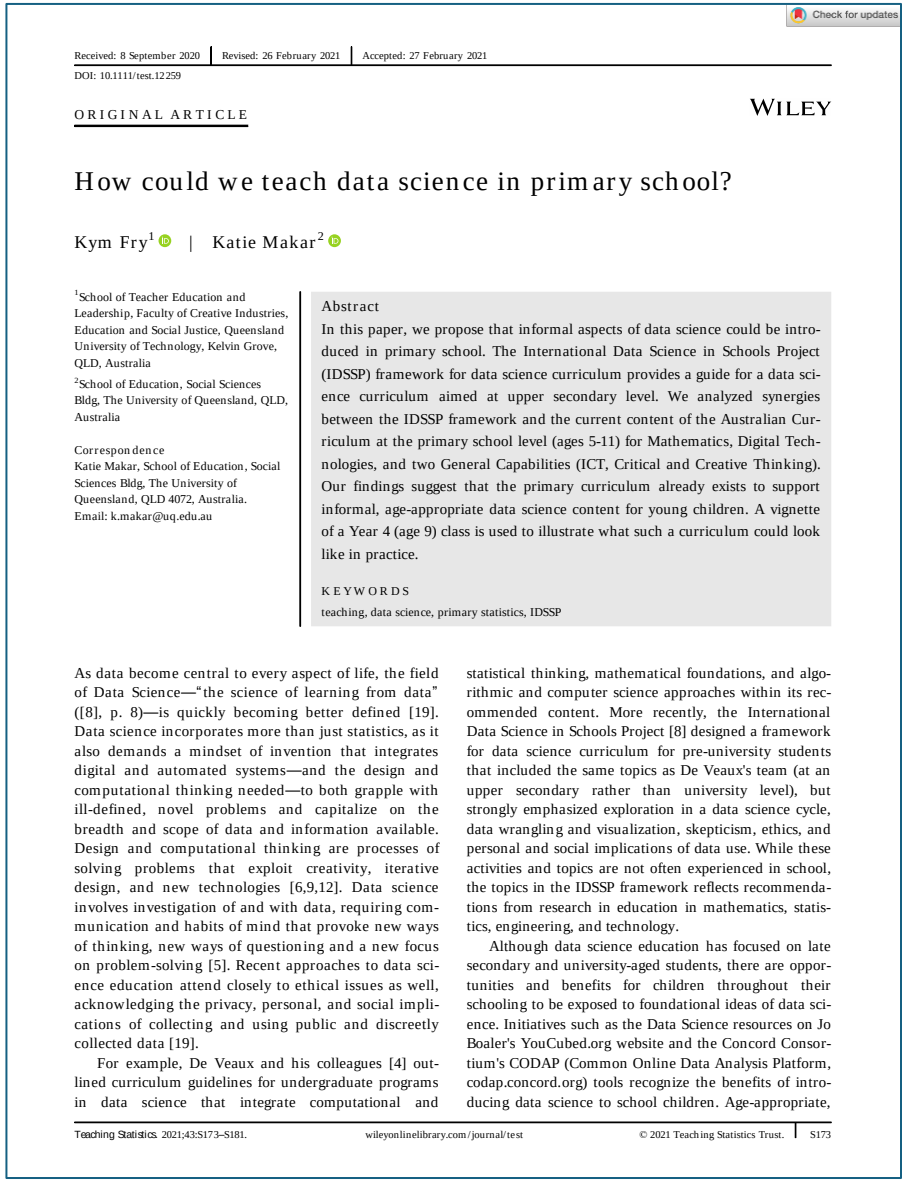




F. Considering Civic Engagement and Social Justice

F. Considering civic engagement and social justice

This study of Australian primary children illustrates how data science education can provide opportunities to develop primary children's learning and make authentic connections to their own citizenship. The paper draws on a series of six lessons where children generated and analysed non-standard data and debated social, well-being and privacy issues as they considered their activities in cyberspace.



Check for updates

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ORIGINAL ARTICLE

WILEY

How could we teach data science in primary school?

Kym Fry[1] | Katie Makar[2]

[1]School of Teacher Education and Leadership, Faculty of Creative Industries, Education and Social Justice, Queensland University of Technology, Kelvin Grove, QLD, Australia

[2]School of Education, Social Sciences Bldg, The University of Queensland, QLD, Australia

Correspondence
Katie Makar, School of Education, Social Sciences Bldg, The University of Queensland, QLD 4072, Australia.
Email: k.makar@uq.edu.au

Abstract
In this paper, we propose that informal aspects of data science could be introduced in primary school. The International Data Science in Schools Project (IDSSP) framework for data science curriculum provides a guide for a data science curriculum aimed at upper secondary level. We analyzed synergies between the IDSSP framework and the current content of the Australian Curriculum at the primary school level (ages 5-11) for Mathematics, Digital Technologies, and two General Capabilities (ICT, Critical and Creative Thinking). Our findings suggest that the primary curriculum already exists to support informal, age-appropriate data science content for young children. A vignette of a Year 4 (age 9) class is used to illustrate what such a curriculum could look like in practice.

KEYWORDS
teaching, data science, primary statistics, IDSSP

As data become central to every aspect of life, the field of Data Science—"the science of learning from data" ([8], p. 8)—is quickly becoming better defined [19]. Data science incorporates more than just statistics, as it also demands a mindset of invention that integrates digital and automated systems—and the design and computational thinking needed—to both grapple with ill-defined, novel problems and capitalize on the breadth and scope of data and information available. Design and computational thinking are processes of solving problems that exploit creativity, iterative design, and new technologies [6,9,12]. Data science involves investigation of and with data, requiring communication and habits of mind that provoke new ways of thinking, new ways of questioning and a new focus on problem-solving [5]. Recent approaches to data science education attend closely to ethical issues as well, acknowledging the privacy, personal, and social implications of collecting and using public and discreetly collected data [19].

For example, De Veaux and his colleagues [4] outlined curriculum guidelines for undergraduate programs in data science that integrate computational and statistical thinking, mathematical foundations, and algorithmic and computer science approaches within its recommended content. More recently, the International Data Science in Schools Project [8] designed a framework for data science curriculum for pre-university students that included the same topics as De Veaux's team (at an upper secondary rather than university level), but strongly emphasized exploration in a data science cycle, data wrangling and visualization, skepticism, ethics, and personal and social implications of data use. While these activities and topics are not often experienced in school, the topics in the IDSSP framework reflects recommendations from research in education in mathematics, statistics, engineering, and technology.

Although data science education has focused on late secondary and university-aged students, there are opportunities and benefits for children throughout their schooling to be exposed to foundational ideas of data science. Initiatives such as the Data Science resources on Jo Boaler's YouCubed.org website and the Concord Consortium's CODAP (Common Online Data Analysis Platform, codap.concord.org) tools recognize the benefits of introducing data science to school children. Age-appropriate,

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- In the reading, Makar et al. (2023) used a critical citizenship education lens to consider the dimensions that the children expressed when talking about their interactions online.

  politics (e.g., knowledge of how broad systems can be unjust),

  social (e.g., awareness of how data are used in society),

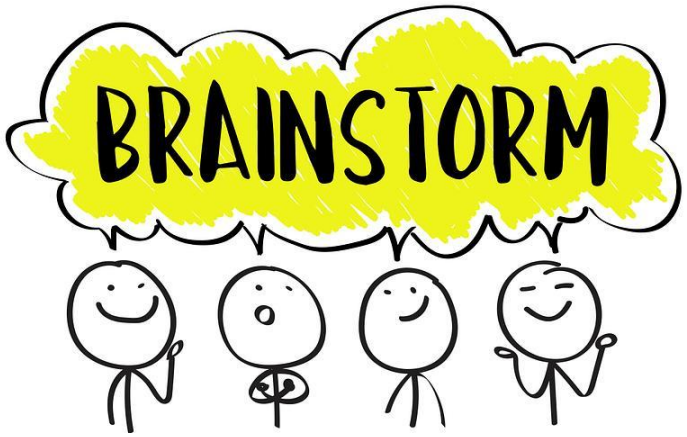
  self (e.g., personal online digital footprint and identity) and

  praxis (personal agency and action).

Examine .....

- The teacher projected a collection of images of primary children engaging in cyberspace to initiate a class discussion
- Read the children's dialogue on pages 972-974.
- Identify how the authors of the paper interpret what the children say through the ***political, social, self*** and ***praxis*** lenses.





Identify a critical and relevant context from your own students' lives that may lead to discussion incorporating reference to the four dimensions of politics, social, self and praxis.

Share a brief description of this context by referring to common examples (e.g. environment, sustainability etc.)

