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21st Century STEM Reasoning

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Real STEM

GEORGIA SOUTHERN UNIVERSITY

The Governor's Office of Student Achievement

Authentic Learning Through STEM Research Experiences

INSTITUTE *for* INTERDISCIPLINARY **STEM** EDUCATION

i²STEMe

SCIENCE TECHNOLOGY ENGINEERING MATH

GEORGIA SOUTHERN UNIVERSITY

Who's Who

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INSTITUTE *for* INTERDISCIPLINARY **STEM** EDUCATION

i²STEMe

SCIENCE
TECHNOLOGY
ENGINEERING
MATH

GEORGIA SOUTHERN UNIVERSITY

Partners

- Real STEM Scale Up – partners:
  - Bulloch County (SHS, LCMS)
  - Burke County (BCHS,BCMS)
  - Bryan County (RHHS, RHMS)
  - Fulton County (Tri-Cities HS, Paul D West MS)
  - Bibb County (Central HS, Miller MS)

Partner Activities

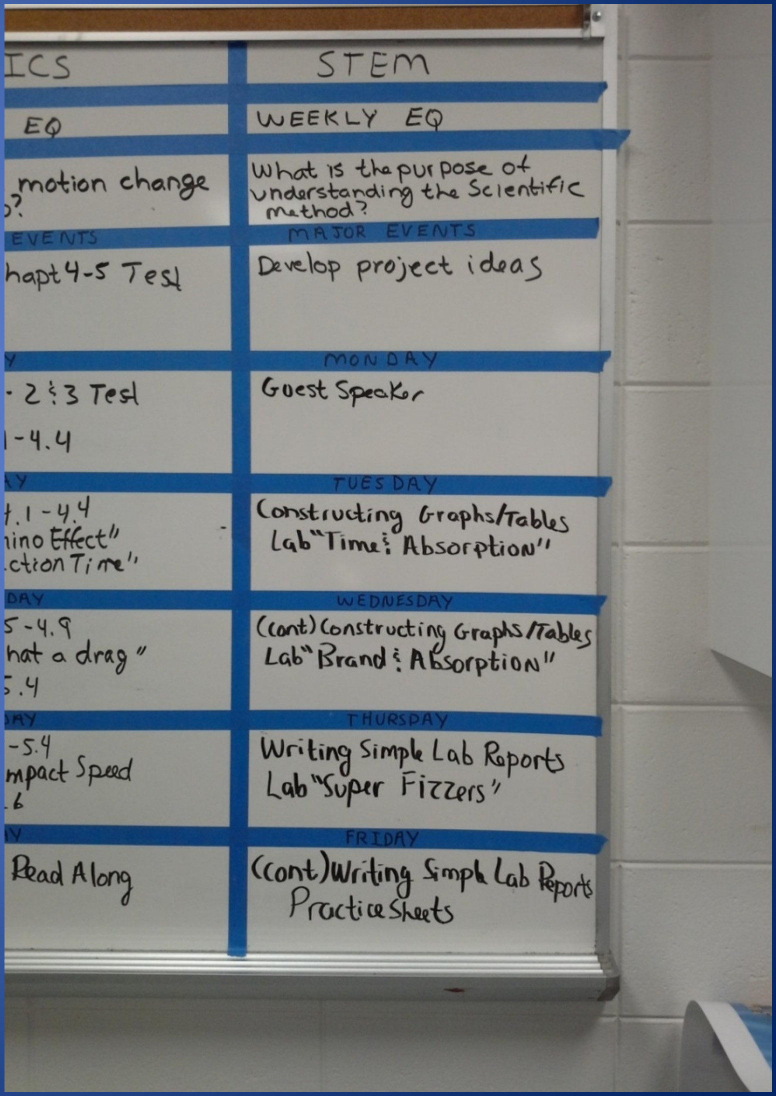
- Bulloch County
  - HS: Studying fish in local rivers, Constructing sustainable fish pond
  - MS: Future Cities Competition
- Burke County
  - HS: Speed boat contest, Designing apps, studying local pond
  - MS: Source to Sink Trash Stories, Solve Hunger games
- Bryan County
  - HS: Go-Kart electric conversion, Composting initiative
  - MS: Nasa Launch, Future Cities, Model rocket competition, Hydroponics
- Bibb County
  - HS: Forensic Science
  - MS: Bridge building competition, ISTEM Room
- Fulton
  - HS: Scientific Experiment Projects
  - MS: Using drones for good

What are our goals?

- Increase the STEM Career Pipeline
- Develop STEM Literate citizens
- Develop 21st Century Problem Solving/Reasoning Skills in students
- Increase student participation, engagement, and performance in STEM

Soooo…..What are we doing?

- STEM Module: Introduction through Middle and High School 1-3 week Modules/units
- STEM Courses: move to interdisciplinary STEM course at Middle and High School
- STEM Academic Pathway: extend to series of interdisciplinary STEM courses serving as student pathway

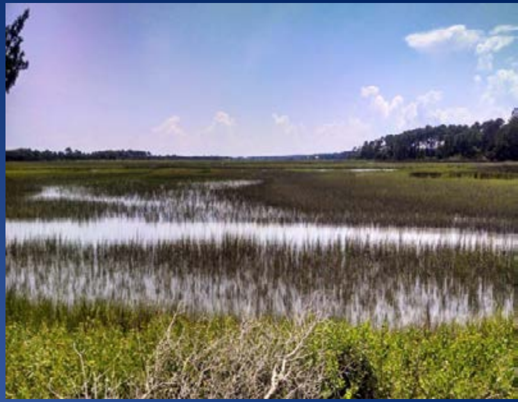


How do we get started? Tenets of the Grant

- Authentic Instruction:
  - Project Based Education
  - Problem Based Learning (PBL)
  - Place Based Education (PBE)
- Teaching for Understanding (UbD)
- Interdisciplinary STEM
- 21st Century Problem Solving/Reasoning Skills

Authentic Learning Design Elements	
Real-world relevance	Learning rises to the level of authenticity when it asks students to work actively with abstract concepts, facts, and formulae inside a realistic—and highly social—context mimicking “the ordinary practices of the [disciplinary] culture.”
Ill-defined problem	Challenges cannot be solved easily by the application of an existing algorithm; instead, activities are relatively undefined and open to multiple interpretations, requiring students to identify the tasks and subtasks needed to complete the major task.
Sustained investigation	Authentic activities comprise complex tasks to be investigated by students over a sustained period of time.
Multiple sources and perspectives	Authentic activities provide the opportunity for students to examine the task from a variety of theoretical and practical perspectives, using a variety of resources, which requires students to distinguish relevant information in the process.
Collaboration	Authentic activities make collaboration integral to the task, both within the course and in the real world.
Reflection (metacognition)	Authentic activities enable learners to make choices and reflect on their learning, both individually and as a team .
Interdisciplinary perspective	Instead, authentic activities have consequences that extend beyond a particular discipline, encouraging students to adopt diverse roles and think in interdisciplinary terms.
Integrated assessment	Assessment is not merely summative in authentic activities but is woven seamlessly into the major task in a manner that reflects real-world evaluation processes.
Polished products	Authentic activities culminate in the creation of a whole product, valuable in its own right.
Multiple interpretations and outcomes	Rather than yielding a single correct answer obtained by the application of rules and procedures, authentic activities allow for diverse interpretations and competing solutions.

Let’s start with our “Place”



“is learning that is rooted in what is local – the unique history, environment, culture, economy, literature, and art of a particular place. The community provides the context for learning, student work focuses on community needs and interests, and community members serve as resources and partners in every aspect of teaching and learning. This local focus has the power to engage students academically, pairing real-world relevance with intellectual rigor, while promoting genuine citizenship and preparing people to respect and live well in any community they choose.” (Rural School and Community Trust, 2005*)*

Why Problem-Based Education?”

- “learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem.” (Savery, 2006, p. 9)
- Long-term retention, skill development, and student and teacher satisfaction have been found to be benefits of problem-based learning when compared with traditional forms of instruction (Strobel & van Barneveld, 2009)

“Problems” in my “Place?”

Explore:

-**Growing Today For Tomorrow**

https://www.youtube.com/watch?v=ym6biFbr3GQ

-**One Hungry Planet**

https://www.youtube.com/watch?v=Jd-48Zw0Tr4&feature=youtu.be

-**Great Pacific Garbage Patch**

https://www.youtube.com/watch?v=2VrrxMliwgQ

Discuss:

Possible “Problem” topics

Source of Problems

Grand Challenges of Engineering:

- Make solar energy economical
- Provide energy from fusion
- Develop carbon sequestration methods
- Manage the nitrogen cycle
- Provide access to clean water
- Restore and improve urban infrastructure
- Advance health informatics
- Engineer better medicines
- Reverse-engineer the brain
- Prevent nuclear terror
- Secure cyberspace
- Enhance virtual reality
- Advance personalized learning engineer the tools of scientific discovery

National Academy of Engineering of the National Academies
www.engineeringchallenges.org

Source of Problems

GRAND CHALLENGES IN ENVIRONMENTAL SCIENCES

1. **Biogeochemical Cycles**
2. **Biological Diversity and Ecosystem Functioning**
3. **Climate Variability**
4. **Hydrologic Forecasting**
5. **Infectious Disease and the Environment**
6. **Institutions and Resource Use**
7. **Land-Use Dynamics**
8. **Reinventing the Use of Materials**

Businesses - Source of Problems

THE DUPONT CHALLENGE:

- **TOGETHER, WE CAN FEED THE WORLD.**
  Ensuring that enough healthy, nutritious food is available for people everywhere is one of the most critical challenges facing humanity.

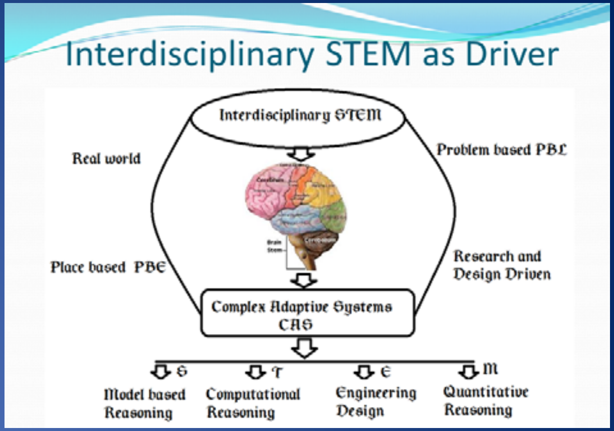
- **TOGETHER, WE CAN BUILD A SECURE ENERGY FUTURE.**
  With a growing population, we will need to use our existing resources as efficiently and effectively as possible and find better ways to harness renewable energy sources.

- **TOGETHER, WE CAN PROTECT PEOPLE AND THE ENVIRONMENT.**
  A growing global population places increased pressure on people and the environment, and as the world develops, humanity places greater value on both life and the earth we all share.

- **TOGETHER, WE CAN BE INNOVATIVE ANYWHERE.**
  Our passions for any topic in science, technology, engineering, and mathematics can lead to innovations that help to make the world a better place.

http://thechallenge.dupont.com/essay/challenges/

Expand Interdisciplinary STEM Reasoning

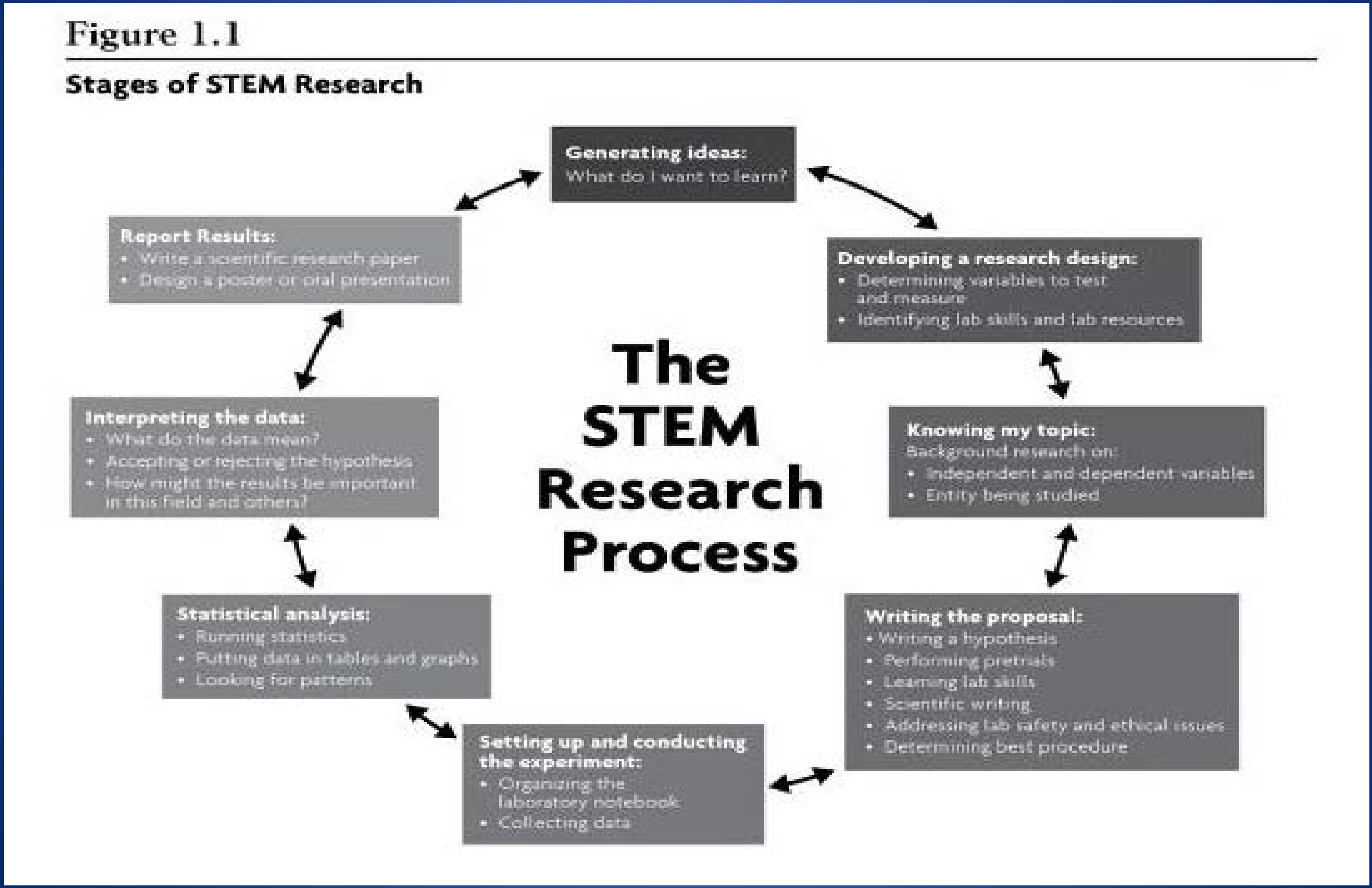


- Complex Adaptive Systems (CAS) –
  - study phenomena as system, not in isolation
- Scientific Reasoning: think like a scientist
  - Research Design
  - Model-Based Reasoning
- Technology: think like a computer scientist
  - Computational Reasoning– visualizations of data, simulations, thinking like a computer scientist
  - Data-intensive science – use of large data sets
- Engineering Design: think like an engineer
- Mathematical Reasoning: think like a mathematician
  - Quantitative Reasoning (QR) – mathematics and statistics applied to real-life

CAS Conceptual Element	Description of Element
Agent-based reasoning (bottom-up)	Reason from the properties and behavior of individual system elements (Berland & Wilensky, 2005), considering multiple agents and their interaction
Aggregate-based reasoning (top-down)	Reason about the properties and rates of change of populations and other macro level structures (Berland & Wilensky, 2005); often results in mathematical model of system level outcomes; use emergent exercises where students alternate between agent-based and aggregate-based reasoning (Wilensky, Hazzard, & Longenecker, 2000)
Complexity	Answer the question: How complex is it? What amount of information is necessary to describe the system? If a single component controls the collective behavior of a system, there is no emergent complexity.
Edge of chaos	It is the critical point in the system, which ranges from equilibrium to chaos within a system; it describes multiple stable states, small displacements or perturbations that lead to recovery while larger perturbations can lead to radical changes in properties (Bar-Yam, http://www.necsi.edu).
Emergence	Describes the relationship of the agents with environment, the overall function of the system, and the scales (micro and macro levels) in which patterns develop. The relationship of the agents refers to how agents interact in random ways to ultimately develop a pattern .The function of the system is what parts of a system do together that they would not do alone.
Feedback loops	A closed path that causes the output to transmit information back as input, which influences the entire system as a cause and effect cycle (Abrahamson & Wilensky, 2005; Burnes, 2005).
Interdependence	Refers to the connection and relationship of the agents that impact survival of the system. It is when the state/behavior of one of the system components depends on the state of each of the other components. There will be no more than seven degrees of separation between components (refers to the 7+/-2 probability rule).
Multi-scale hierarchical organization	Describes the magnitude of complexity. Multi-scale descriptions are needed to understand complex systems. Within a complex system, there are multiple levels of organization and smaller systems within larger systems (nested systems; Bar-Yam, 1997).
Nonlinear effects	It is a balance of chaos and order that allow unpredictable patterns to unfold; (Burnes, 2005); it is contrary to the linear cause and effect process where a small action has a small effect and large action has a large effect. In complex systems this may be flipped Jacobson & Wilensky, 2006).
Randomness-determinism confusions, Stochasm or random actions	Describes the random behavior involving chance or probability, random interaction between agents as component of model; it also recognizes that a system's whole cannot always be understood by reducing it to simpler parts because changes are often abrupt and discontinuous (Eidelson, 1997; Jacobson, 2001; Abrahamson & Wilensky, 2005),
Self-organization	Describes the bottom up process that is a spontaneous emergence; it is the system's ability to adapt to the environment in order to survive. The decentralized actions lead to an emergent final result, and there is no hierarchy that commands or controls the system. Instead, systems organize themselves based on cues in their environment (Kaisler & Madey, 2008).
Simple Rules	Complex systems are not complicated in that they have basic internal rules/behavior of the whole system that they abide by (Holladay, 2005).

SMB Conceptual Element	Description of Element
Scientific model	A scientific model is an idea or set of ideas that explains what causes a particular phenomenon in nature (Modeling for Understanding in Science Education – MUSE)
Observations	Scientists make observations and develop models to explain the observations.
Pattern identification	Scientists identify patterns in their observations and construct models to explain them.
Revision of model	Models are continually revised to probe new phenomena and account for new data.
Models are ideas	Models are ideas not physical objects.
Multiple representations	Models are communicated through drawings, graphs, equations, three dimensional structures or words. The representations are distinct form the underlying model they purport to explain.
Acceptability of model	Don't ask if a model is right, but if it is acceptable. Acceptability is based on model's ability to explain all the observations, predict the behavior of the system under a given manipulation, and be consistent with other knowledge about how the world works and with other models in science.
Uniqueness	Not always possible or even desirable to exclude all but one model. Different models may account for different aspects of a phenomena.
Development of model	An experiment and observations inform the development of a model.
Application of model	A model is applied to explain reality, make predictions, and assessed for how well it explains real-world phenomena.
Empirical or Theoretical Objects	Models are constituted by a set of objects which may be empirical (genes and alleles in meiotic model) or theoretical objects.
Processes	Models are constituted of processes in which objects participate (segregation and assortment in meiotic model).
Empirical Assessment	Scientists assess whether a model can explain all of the data at hand and predict the results of future experiments.
Conceptual Assessment	Scientists evaluate how well a model fits with other accepted models and knowledge.
Guide future work	Models influence and constrain the kinds of questions scientists ask about the natural world and the types of evidence they seek.

Scientific Reasoning



STEM Student Research Handbook, Pg. 3, Fig. 1.1

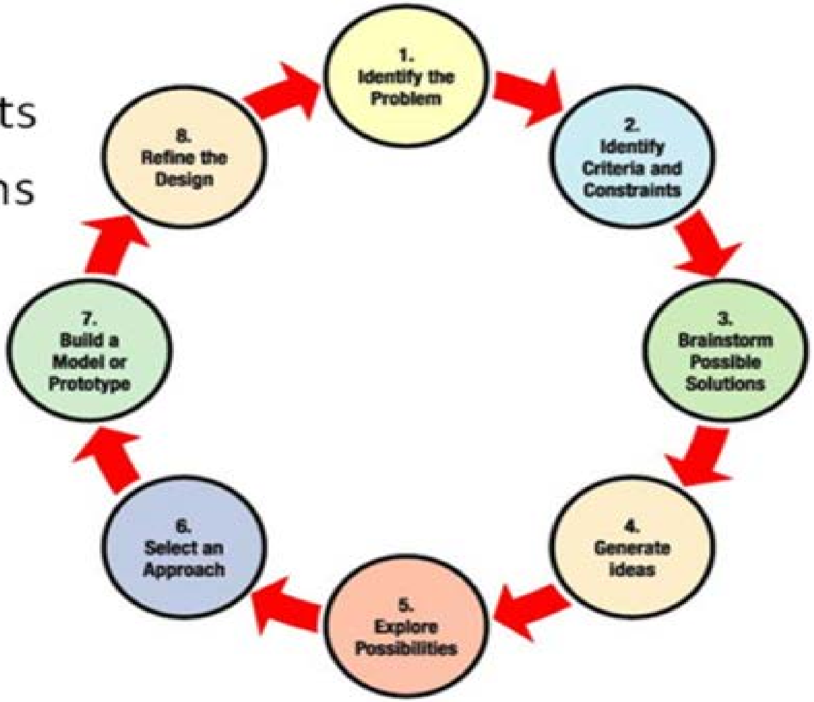
CR Conceptual Element	Description of Element
Abstraction	Stripping down a problem to bare essentials; capturing of common characteristics or actions that can be used to represent other problems; the ability to filter out information that is not necessary to solve a certain type of problem. It involves pattern generalization which is transferring the problem solving process to a wide variety of problems (interdisciplinary application).
Algorithm Design	Develop a set of instructions to solve similar problems and repeat the process
Analysis and Evaluation	Reflective practice of validating whether abstractions are correct, making judgments, in an objective and systematic way; statistical, numerical, or experimental analysis of data
Automation	Process of executing repetitive tasks quickly and efficiently; automating solutions through algorithmic thinking (series of ordered steps); modularization; a tool for explaining and representing complexity. Involves conceptualization through thinking at multiple levels of abstraction; formulates problems in a way that enables us to use a computer and other tools to solve the problem.
Decomposition	Systematically breaking a task or problem down into steps or parts; it is developing a plan of action of how to solve a problem
Parallelism	Sequences of instructions happening at the same time, parallel processing
Programming	Essential to computer science, but does not have to be the focus of teaching computational reasoning. It uses a language (a series of commands) to tell the computer how to carry out specific tasks.
Simulation and Modeling (CR & DIS)	Representation or model of a process. How we mine useful information from data and make inferences without seeing all the data.
Visualization (CR & DIS)	Representing data so you can determine trends and make predictions, using various data representations. How we fully comprehend large data sets and make human-computer interface more effective.
Capture (compressed sensing – DIS)	How we sensor networks to be used to capture geological or ecological data? How can nanotechnology devices be used to gather biomedical data at the individual level?
Curation (DIS)	Where and how do we store the data to make it useable?

EDB Conceptual Element	Description of Element
Identify Problem	Engineers solve real world problems. A customer presents a problem, then the engineer formalizes it as an engineering challenge. Research the problem, identifying prior knowledge, observations, and STEM principles that will aid in solving the problem.
Determine Criteria	Engineers need to know what outcomes are expected from their solutions. These are called criteria, which guide the engineer in designing a solution.
Determine Constraints	Engineers have limitations to the solutions they design. These are called constraints, for example cost of materials.
Brainstorm Solutions	Generate possible solutions to the problem based on criteria and constraints. Engineers will generate multiple solutions and collaborate on determining one to pursue. Time is spent generating ideas and exploring possibilities.
Select Approach	The most promising approach is selected and the team of engineers works together on developing a solution using this approach.
Build Model or Prototype	For the selected approach, the engineers build a prototype. A prototype is a working model of a design solution.
Test Solution	Test how well the design prototype solves the problem. Does it meet the criteria and constraints assigned for the problem? Collect data on the performance of the prototype and analyze it to determine if design solves the problem.
Refine Design	Use the prototype test data to make modifications to the prototype to improve performance. Collect data on the revised model's performance.
Analyze & Interpret Results	Report on how well the design solved the problem, improvements that could be made, and design concerns. How well did the design meet the criteria and constraints for the problem? What changes can be made to improve the success of the design?

Engineering Design

Engineering Design Process

1. Identify the Problem
2. Identify Criteria & Constraints
3. Brainstorm Possible Solutions
4. Generate Ideas
5. Explore Possibilities
6. Select an Approach
7. Build a Model or Prototype
8. Refine the Design

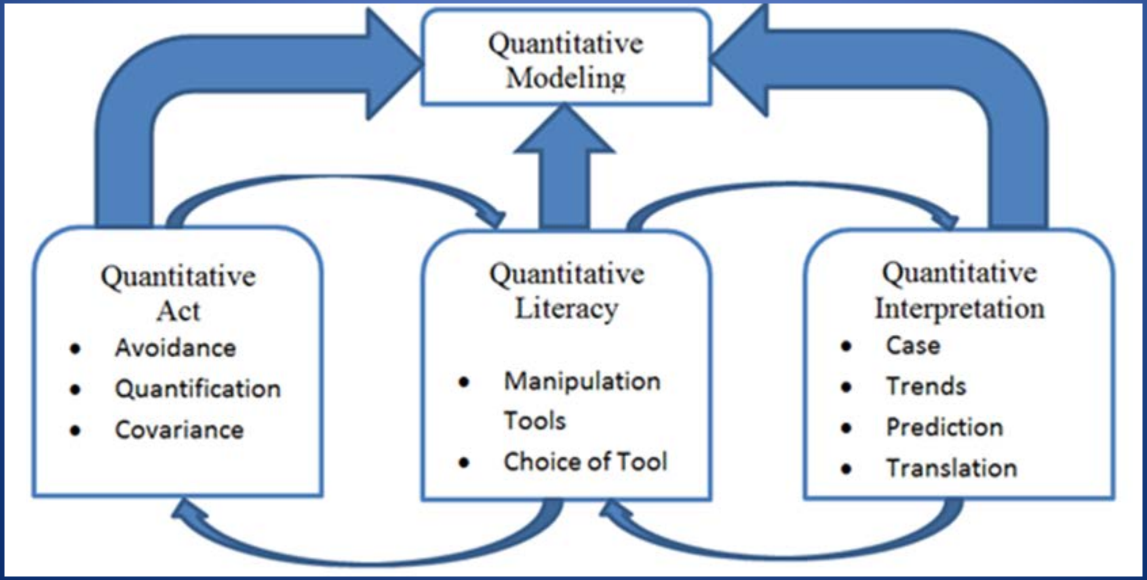


http://www.nasa.gov/audience/foreducators/plantgrowth/reference/index.html

QR Conceptual Element		Description of Element
Quantitative Act (QA)		The ability to mathematize a STEM context, moving from qualitative written accounts to quantitative mathematical accounts. QA includes four primary elements: Contextual view, Variable, Quantitative Literacy, and Variation
	Contextual View	Confidence with using mathematics within a context; cultural appreciation of mathematics within context; solve ill-defined problems within a socio-political context
	Variable	Construct for an object within the context which includes both attributes and measure; capacity to communicate quantitative account of solution, decision, and course of action within context
	Quantitative Literacy	Reason with quantities to explain relationships between variables; includes proportional reasoning and numerical reasoning
	Variation	Reason about covariation between two or more variables; comparing, contrasting, relating variables in context
Quantitative Interpretation (OI)		The ability to interpret a model represented as a table, graph, analytic equation, statistical or science model. QI includes four primary elements: Trends, Predictions, Translation, and Revision
	Trends	Interpret trends including linear, power, and exponential trends; recognize and provide quantitative explanations of trends in models with context
	Predictions	Make predictions from a model using covariation; provide a quantitative account applied within the context
	Translation	Translate between different models for the same context; challenge quantitative variation between models; identify best model for context
	Revision	Revise models theoretically without new data; evaluate competing models for possible combination
Quantitative Modeling (QM)	Create Model	Ability to create a model representing a context and apply it within context; use variety of quantitative modeling methods including least squares, linearization, logistic growth, multivariate, and simulation models
	Refine Model	Extend model to new situation; test and refine model for internal consistency and coherence to evaluate scientific evidence, explanations, and results
	Model Reasoning	Construct and use models spontaneously to assist own thinking; predict behavior in the real world, generate new questions about phenomena
	Statistical	Conduct statistical inference to test hypothesis

Quantitative Reasoning

- Quantitative Act (QA): extract from real world context variable, measure and attribute, then can use quantitative literacy skills to compare, contrast, and construct models
- Quantitative Interpretation (QI): variable and distribution type impact descriptive statistics and statistical display; interpret a model provided for trends, translation, and predictions
- Quantitative Modeling (QM): create model from data and test hypotheses using statistical methods



Examples From Schools in Real STEM

Richmond Hill Middle School: Hydroponics

& Aviation

Examples From Schools in Real STEM

Richmond Hill High: Model Based Reasoning

Examples From Schools in Real STEM

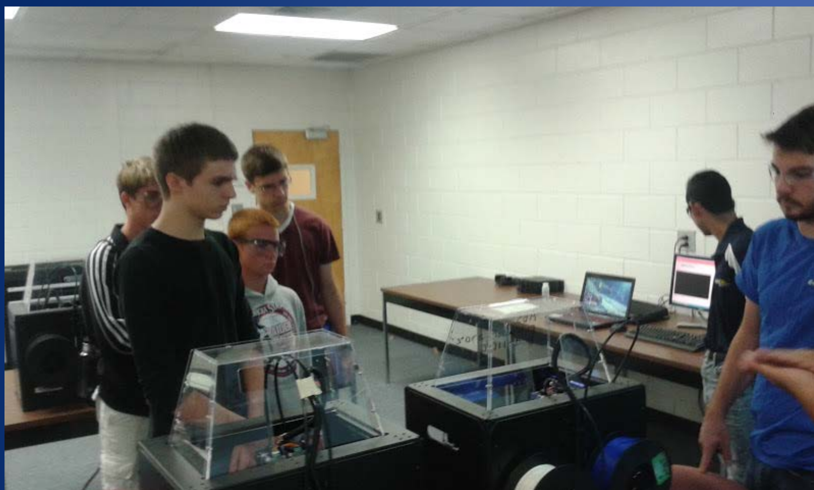
Burke County High: Boat Building Competition

Examples From Schools in Real STEM

Burke County High School:

- Trash tracking
  - Tracking source to sink paths of garbage
  - Analysis of tie into carbon cycle
  - Tracking Possible Intervention
- Lego Robotics Competition.

Field Trips to GA Southern



3D Printing Lab at
Eagle Motorsports

Thank you for coming!

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