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21st Century Reasoning Modalities In Interdisciplinary STEM Education

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S.T.E.M 21st Century Reasoning Modalities

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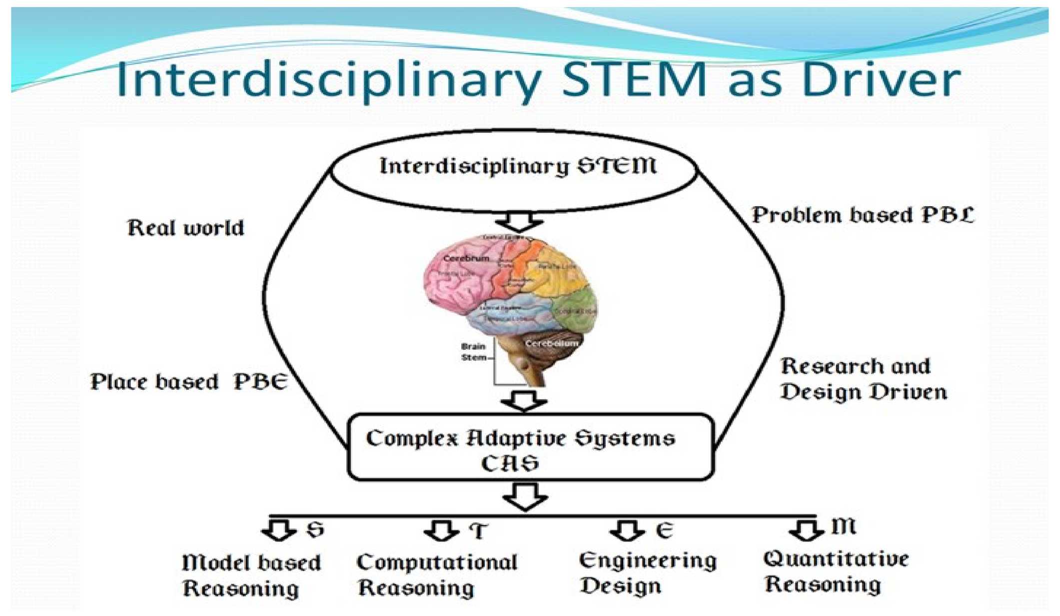
Introduction

An overarching goal of the Institute for Interdisciplinary STEM Education (i²STEMᵉ) at Georgia Southern University is to improve student engagement & learning outcomes in STEM courses through immersion in authentic, real-world, problem-based & place-based educational settings. To accomplish this goal, i²STEMᵉ has partnered with 10 middle & high schools located in Georgia to incorporate a series of reasoning modalities developed to meet the requirements of the *Next Generation Science Standards* (NGSS) to develop STEM literate citizens capable of making informed decisions, and to open up opportunities to fill the growing need for STEM professionals. Each reasoning modality reflects how STEM experts think, providing guidance for teacher practice and student learning. Each reasoning modality corresponds to a particular area of STEM (Science, Technology, Education, Math) while reframing student inquiry as an interdisciplinary exploration of complex real-world problems. Through the utilization of the developed reasoning modalities, i²STEMᵉ is examining the impact of interdisciplinary STEM on teacher practice and student ability to engage in 21st century reasoning practices. Currently, i²STEMᵉ is engaged in a mix of on-going literature reviews to continue developing and strengthening the theoretical underpinnings supporting each modality. Thus far, pre-post data collected through the ALSQ student assessment for the fall of 2015 shows positive growth in student engagement as well as growth in interest in STEM fields after exposure. These results align with i²STEMᵉ core mission to develop students' abilities to reason critically using STEM principles and the identified 21st century reasoning modalities while fostering a sense of confidence to make informed decisions and increase interest in STEM professions.

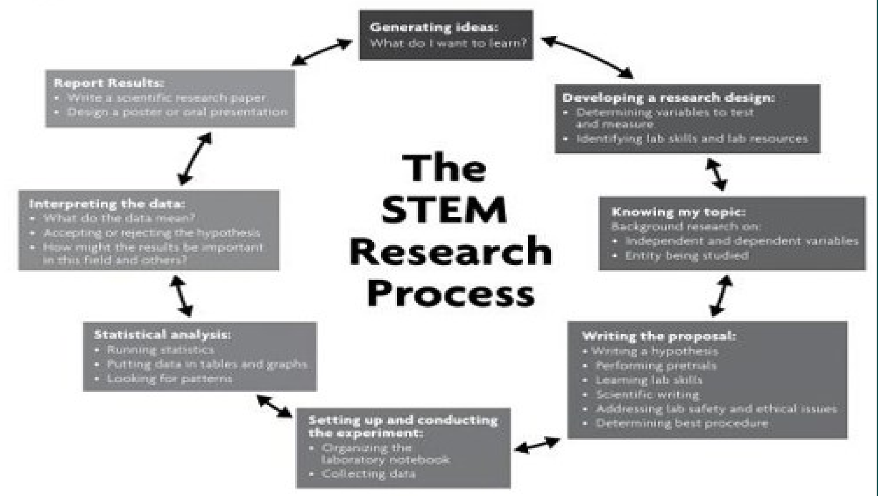
Complex Adaptive Systems

Complex adaptive systems (CAS) serve as an overarching i²STEMᵉ reasoning modality. CAS encourages students to reason within a larger system and to recognize how the interaction of separate parts creates a whole. CAS reasoning is intended to develop students who are capable of systematic thinking, can generate and evaluate alternative solutions, and can deal with the complexity and uncertainty that accompanies complex systems in the real world.



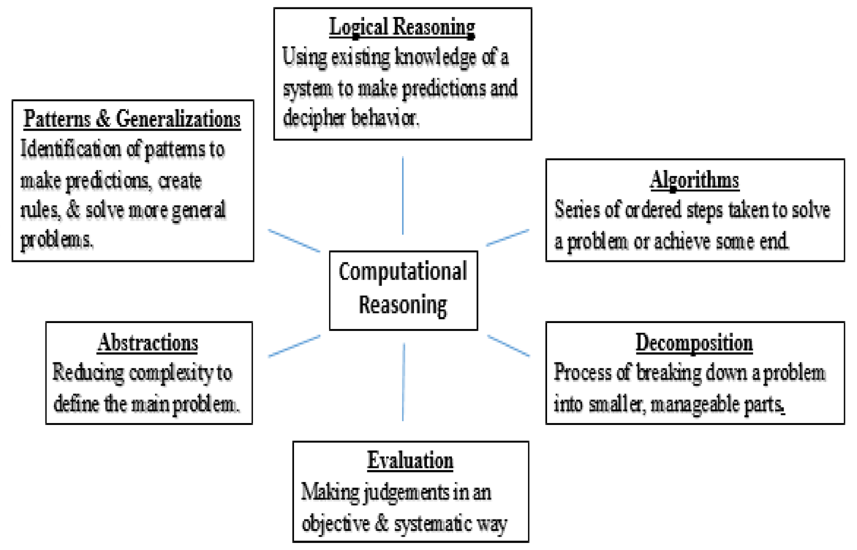
Scientific Model-Based Reasoning

The *Next Generation Science Standards* (NGSS) and the *Common Core Math Standards* (CCSS-M) identify *scientific modeling & model-based reasoning* as essential processes in STEM. Model-based reasoning involves the development & use of varying forms of representations and subsequent feedback and redesign. Modeling enhances science education by broadening processes beyond conducting experiments.



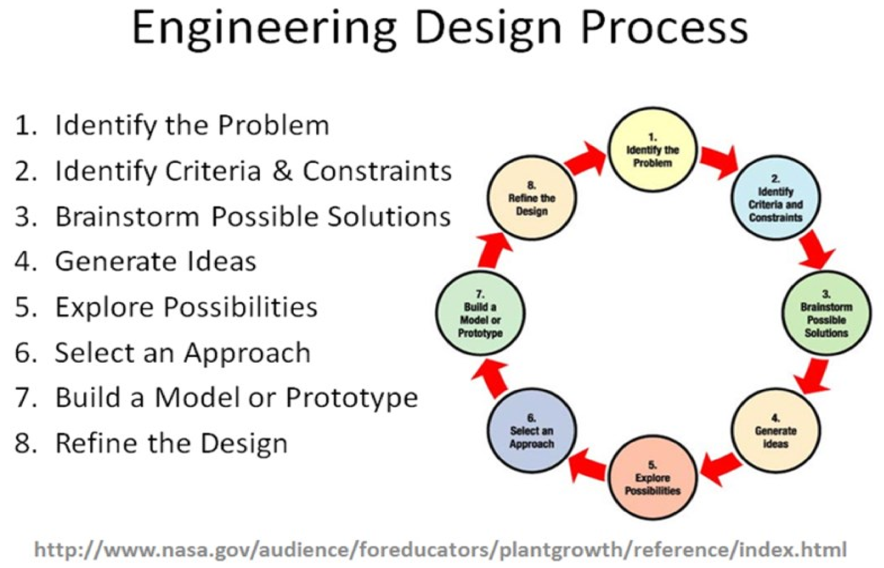
Computational Reasoning

Computational reasoning (CR) is the thought processes involved in formulating problems so their solutions can be represented as computational steps and algorithms (Grover & Pea, 2013). CR includes a broad range of mental tools and concepts from computer science that help solve problems, design systems, understand human behavior, & engage computers to assist in automating a wide range of intellectual processes.



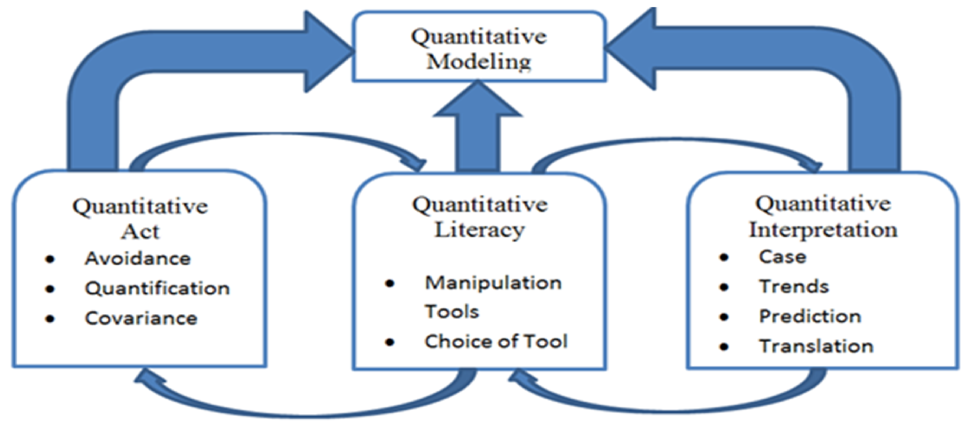
Engineering Design

Engineering design (EDR) involves the development of a new product or system with a specified performance design goal. Whereas the overarching goal is inherently large and complex in scope, the use of a step-by-step process breaks the project into a series of interconnected activities that highlight systems thinking, quantitative analysis, and the scientific process.



Quantitative Reasoning

Quantitative Reasoning (QR) is mathematics & statistics applied in real-life. QR problems are context dependent, interdisciplinary, open-ended tasks that require critical thinking and the capacity to communicate a course of action (Mayes, Peterson, & Bonilla, 2013). QR is considered a to be a defining characteristic of scientific model-based reasoning (Duschl & Bismack, 2013). As a core reasoning modality, QR is envisioned as transgressing contexts and disciplines, informing student comprehension in a multitude of place-based amd problem-based contexts.



Data Collection & Results

- Student feedback was collected using the ALSQ, a self-report questionnaire that includes 36 items to assess students' attitudes on *intrinsic motivation, self-management/self-regulation, intent to persist, problem-solving,* and *implementation activities*
- Students showed statistically significant increases in *Intrinsic Motivation, Self-Management/Self-Regulation skills, and Intent to Persist.*
- Largest gains were observed in *Intrinsic Motivation*, suggesting that the program was particularly effective in enhancing students' interests and motivation to learn & derive value from the STEM material.

Overall- Constructs

Constructs		n	Mean[1]	Paired Samples t-test[2]
Intrinsic Motivation	Before	271	3.77	$p<0.001^{**}$
	Now	268	4.19	
Self-Management/Self-Regulation	Before	271	4.02	$p<0.001^{**}$
	Now	270	4.18	
Intent to Persist	Before	271	3.54	$p<0.001^{**}$
	Now	271	3.74	
Problem Solving	Now	269	4.19	N/A
Implementation Activities	Now	266	4.10	N/A

Note. [1]Reference lines are set at 3.5 and 4. [2]Please note that only students with matched Pre and Post data were assessed for significance. Desired statistically significant changes are highlighted in green and undesired statistically significant changes are highlighted in red. $^{**}p<0.001$, $^{*}p<0.01$, $^{\dagger}p<0.05$. Negatively worded statements were reverse coded for mean computations.