# Using Video to Tie Fundamental Concepts to Engineering Themes

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# The Context

- MIT collaboration to establish Singapore University of Technology and Design (SUTD)
  - Undergraduate degrees in Engineering and Architecture
  - Emphasis on Design
  - Integrated, multi-disciplinary curriculum

- MIT's Teaching and Learning Lab asked to develop educational videos to supplement the **first three semesters** of the curriculum

# The SUTD Curriculum

| Semester 1 | Semester 3 |
| --- | --- |
| Single-Variable Calculus | Differential Equations |
| Classical Mechanics | Linear Algebra |
| Chemistry | Thermodynamics |
| **Semester 2** | Numerical Methods |
| Multi-Variable Calculus | Biology |
| Electricity and Magnetism | |
| Intro to Design | |

# Defining the Project

How do we choose concepts or skills to develop in a small number of videos?

- Establish the main goal of the SUTD curriculum
- Identify the "pivotal concepts" from the first 3 semesters of the curriculum
- Determine how and why these "pivotal concepts" support the main goal

# Identifying Pivotal Concepts

## Course Description

An introduction to Newtonian Mechanics. Topics will include: One dimensional Motion: kinematics with non-constant acceleration; Two Dimensional Motion: vector analysis, motion in a plane, relative inertial frames; Newton's Laws of Motion: forces, linear motion, circular motion. Energy: work-energy theorem, potential energy, conservation of energy, and vibrational motion (simple harmonic oscillator); Systems of Particles: particle dynamics, momentum, center of mass, impulse, and conservation of momentum, continuous mass transfer, kinetic theory and the ideal gas; Two Dimensional Rotational Motion: rigid bodies, moment of inertia, rotational energy, torque, angular momentum, rotational statics and dynamics, conservation of angular momentum; Central force Motions; Fluid Mechanics.

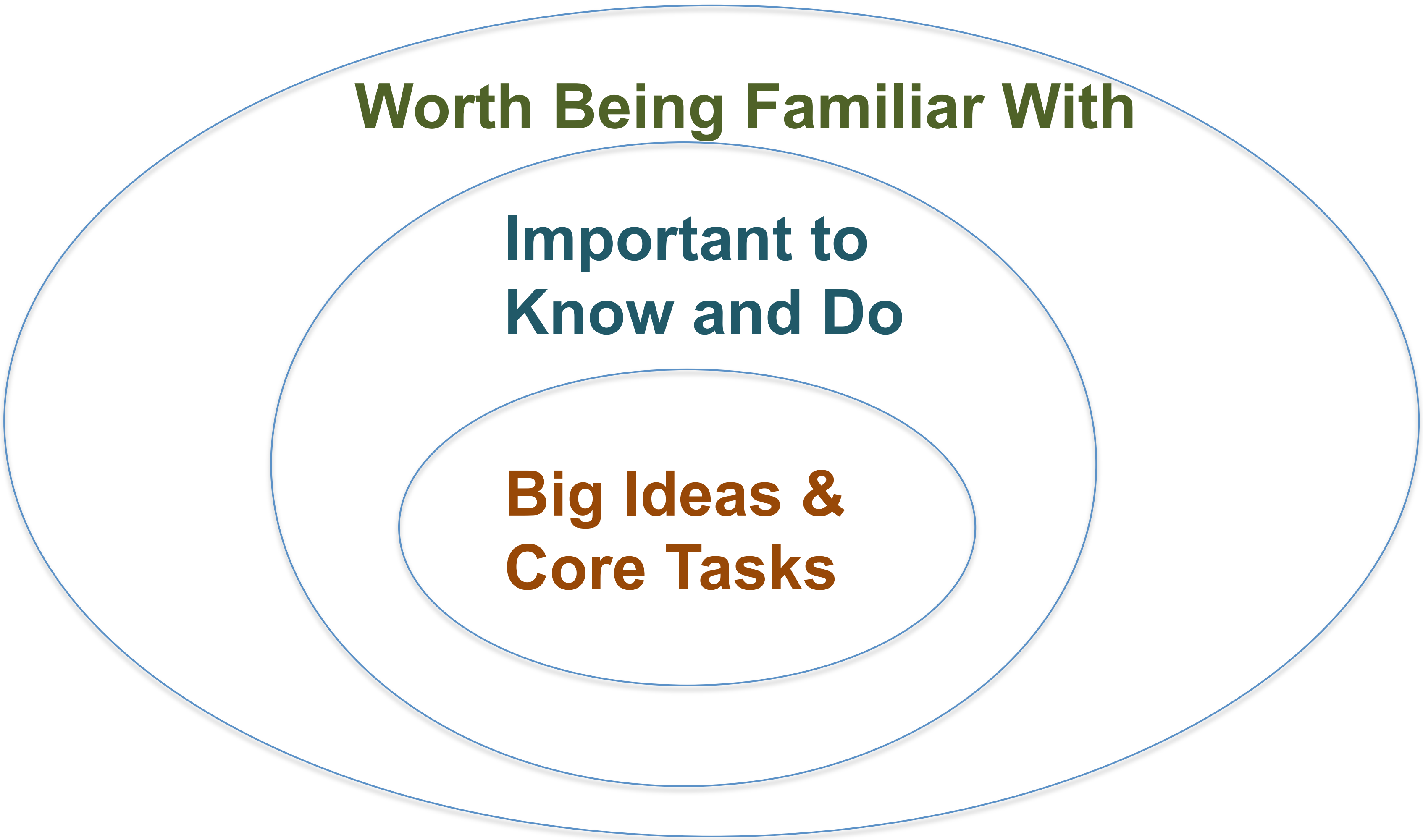
## Learning Objectives

•Students will have a basic understanding of kinematics and the use of vector analysis.
•Students will have an understanding of Newton's law of motion.
•Students will have an understanding of energy conservation.
•Students will have an understanding of momentum conservation.
•Students will have an understanding of two-dimensional rotational motion and angular momentum conservation.
•Students will be familiar with kinetic theory and how it relates to the ideal gas model.

## Measurable Outcomes

1. Solve kinematic problems of motion in one and two dimensions (homework, quizzes and tests, concept questions in class).
2. Solve simple dynamic problems using Newton's laws of motion to determine forces and subsequent motion of particles and rigid bodies in one and two dimensions. (Homework, quizzes and tests, concept questions in class).
3. Describe kinetic theory and how it leads to the ideal gas model (homework, quizzes and tests, concept questions in class).
4. Use energy conservation concepts to solve dynamical problems (homework, quizzes and tests, concept questions in class).
5. Use momentum conservation concepts to solve dynamical problems (homework, quizzes and tests, concept questions in class).
6. Use angular momentum conservation concepts to solve dynamical problems (homework, quizzes and tests, concept questions in class).

# Identifying Pivotal Concepts




Wiggins, G. & McTighe, J., *Understanding by Design*. 2nd edition. Alexandria, VA: Association for Supervision and Curriculum Development pp. 70-73 (2005).

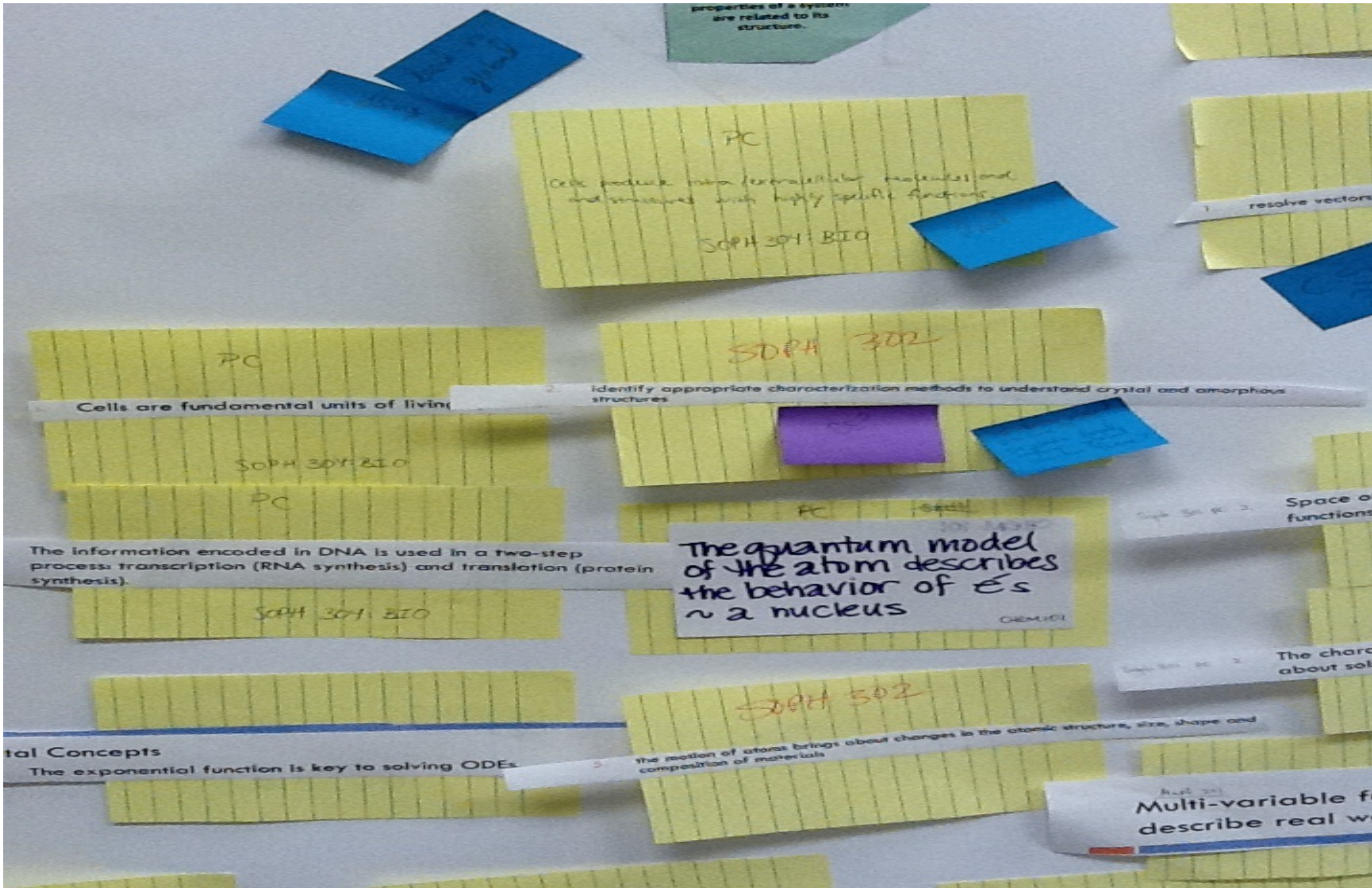
# Identifying Pivotal Concepts

Other sources:

- Literature on misconceptions and misunderstandings
- Literature on integrated curricula

- What concepts are interdisciplinary?
- What concepts have broad scaffolding potential?
- What concepts reappear in upper-level courses?

# Looking for Common Themes



# Creating an Engineering Curriculum Map

**Students will be able to describe the nature and behavior of engineering, physical, information, and social systems in order to design, modify, and adapt them.**

## Students will be able to analyze a system's parts and the interactions among those parts.

**Governing Rules**

Students will be able to describe and predict physical interactions between objects using a small number of governing rules.

**Representations**

Students will be able to utilize representations to understand a system's structure, properties, and function.

**Structure-Function-Properties**

Students will be able to describe the interrelationships among the structures, functions and properties of a system.

## Students will identify the changing and unchanging components of a system and utilize this knowledge to solve problems.

**Conservation**

Students will be able to predict system behavior by identifying conserved properties.

**Equilibrium**

Students will be able to determine properties of a system at equilibrium.

**Information Systems**

Students will be able to describe how a system is shaped and changed by the nature and flow of information into, within, and out of the system.

## Students will describe systems mathematically.

**Linear Systems**

Students will be able to identify and apply the properties of linear systems to simplify and describe engineering systems.

**Derivatives & Integrals**

Students will be able to understand and apply derivatives and integrals to solve engineering problems.

**Differential Equations**

Students will be able to explain how differential equations model changing properties.

## Students will design a product to solve a problem or to fulfill a need.

**Communication**

Students will be able to write, present, and communicate interpersonally in a professional setting based on communication strategies they develop.

**Modeling**

Through modeling, students will create representations of real processes, systems, or objects.

**Problem Solving**

Students will devise solutions to open-ended problems with technical and non-technical components.

**Teamwork**

Students will be able to work in teams.

# Drawing on Best Practices

1. Mayer’s Theory of Multimedia Learning

2. Gagné’s Nine Events of Instruction

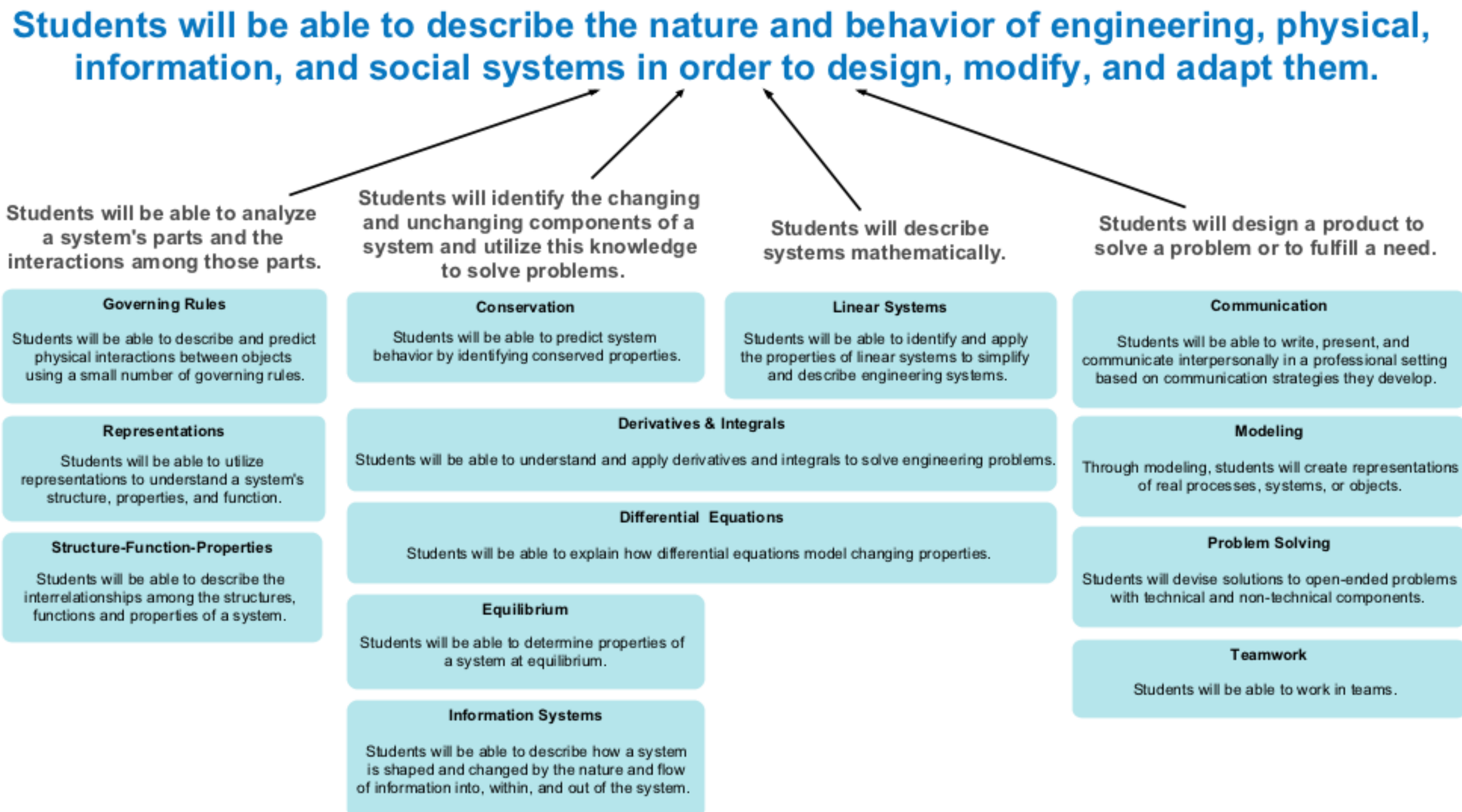
# Mayer's Theory of Multimedia Learning

1. Multimedia Principle
2. Contiguity Principle
3. Coherence Principle
4. Modality Principle
5. Redundancy Principle
6. Personalization Principle
7. Interactivity Principle
8. Signaling Principle

# Gagné's Nine Events of Instruction

1. Gaining Learner Attention
2. Informing Learner of Objectives
3. Stimulating Recall of Prior Knowledge
4. Presenting Stimulus Material
5. Providing Learner Guidance
6. Eliciting Performance
7. Providing feedback
8. Assessing performance
9. Enhancing retention and transfer

# Enhancing retention and transfer



# Instructor’s Guides

Provide context for video within curriculum

Provide Pre-Video questions/activities about prior knowledge required for video

- Opportunities for feedback and assessment of student proficiency with required prior knowledge

Provide Post-Video questions/activities about video content

- Opportunities for feedback and assessment of student proficiency with desired learning outcomes

References and suggestions for going further

# First Year Videos by Theme

| Communication | Differential Equations | Problem Solving |
|---|---|---|
| Communication Strategy | Divergence, Gradient, and Curl | The Problem Solving Process |
| **Conservation** | Enzyme Kinetics | Unit Analysis |
| Conservation of Mass | **Governing Rules** | **Representations** |
| Latent Heat | Entropy | Free Body Diagrams |
| **Derivatives & Integrals** | Kinetic Theory | Torque |
| Electric Potential | Maxwell’s Equations | Vectors |
| Flux & Gauss’ Law | Newton’s Laws | Vector Fields |
| Motion | **Linearity** | VSEPR |
| | Linear Approximations | Light |

| **Communication** | **Equilibrium** | **Differential Equations** |
|---|---|---|
| Interpretation of Texts | Kinetics and Thermodynamics of Reactions | An Ode to ODEs |
| **Representations** | Equilibrium vs Steady State | Contaminant Fate Modeling |
| Rotating Frames of Reference | **Linearity** | **Probability and Statistics** |
| Fourier Transform | Linear Algebra of Gear Trains | Conditional Probability |
| **Information Flow** | Rigid Body Kinematics | Distributions and Moments |
| Algorithms | Stability Analysis | Genetics and Statistics |
| Feedback Loops | Random Walks and Diffusion | **Structure-Function-Properties** |
| Radio Receivers | **Problem Solving** | Buffers |
| Recursion | Art of Approximation | Polyelectrolyte Multilayers |
| **Conservation** | Dimensional Analysis | Chirality |
| Energy and Polymers | Scientific Process: Biology | |

# Acknowledgements

Link to first year videos: tll.mit.edu/help/sutd-concept-vignettes-0

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