

The background of the slide features a dense pattern of vibrant green leaves in the upper portion, transitioning into a blue-green water surface with white ripples in the lower portion. A large, semi-transparent white rounded rectangle is centered on the slide, containing the text.

Research Method

Dr. Jin Wen

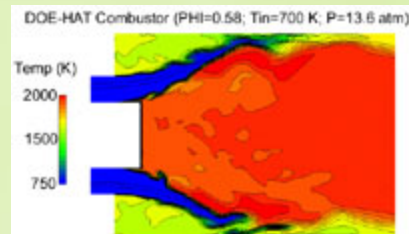
Department of Civil, Architectural, and Environmental Engineering

Drexel University

July, 2006

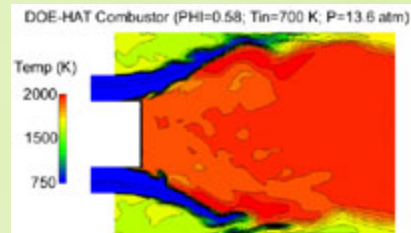
What is Research?

- “Research is often described as an active, diligent, and systematic process of inquiry aimed at discovering, interpreting and revising facts. This intellectual investigation produces a greater understanding of events, behaviors, or theories, and makes practical applications through laws and theories. The term research is also used to describe a collection of information about a particular subject, and is usually associated with science and the scientific method.” - Wikipedia



What is Research?

- “A scientist is a searcher after truth, but complete certainty is beyond his reach” – Peter Medawar
- Science must begin with a deep and clear understanding of the problem domain, followed by an hypothesis about a possible solution that must be tested impartially under carefully controlled conditions – Paracelsus (Phillippus Hohenheim)



Types of Research

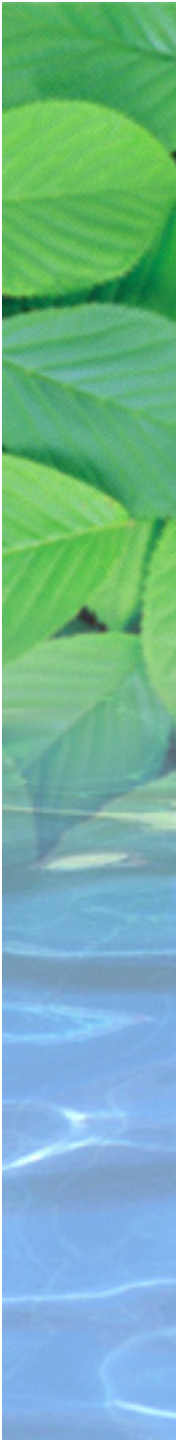
- Different categories exist
 - Pure, applied, and strategic research
 - Descriptive, explanatory, and evaluation research
 - Market and academic research
 - Exploratory, testing-out, and research
 - Covert, adversarial, and research
 - Basic, applied, instrumental, participatory, and action research

In Engineering areas:
Product development research and Pure research (lead only to knowledge findings)



Research (Scientific) Method

- The Scientific Method comprises four sequential phases – **Analysis, Hypothesis, Synthesis, and Validation** – which are applied to a task *iteratively* and *recursively* to achieve the objective of the task.



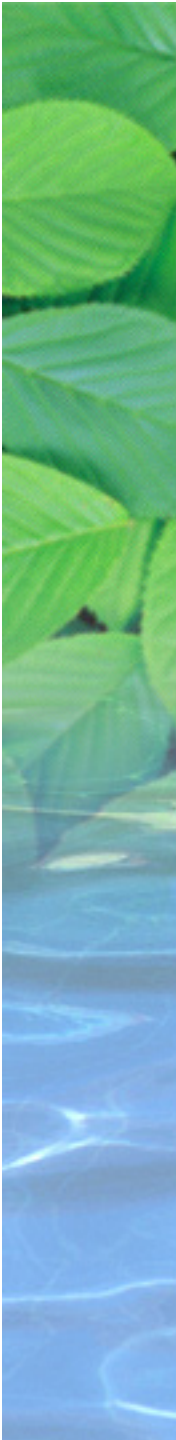
Analysis	Describe Problem
	Set Performance Criteria
	Investigate Related Work
	State Objective
Hypothesis	Specify Solution
	Set Goals
	Define Factors
	Postulate Performance Metrics
Synthesis	Implement Solution
	Design Experiments
	Conduct Experiments
	Reduce Results
Validation	Compute Performance
	Draw Conclusion
	Prepare Documentation
	Solicit Peer Review



Research (Scientific) Method

- ***Iterative Execution***

Analysis	Describe Problem
	Set Performance Criteria
	Investigate Related Work
	State Objective
Hypothesis	Specify Solution
	Set Goals
	Define Factors
	Postulate Performance Metrics
Synthesis	Implement Solution
	Design Experiments
	Conduct Experiments
	Reduce Results
Validation	Compute Performance
	Draw Conclusion
	Prepare Documentation
	Solicit Peer Review





Research (Scientific) Method

- ***Iterative Execution***
- ***Feasibility Pilot Task***
 - ***Smaller scale***
 - ***Quicker and cheaper***
 - ***Demonstrate the feasibility of the proposed solution***
 - ***Also need good planning and recording***
- ***Importance of Planning***

Research (Scientific) Method

- *Recursive Execution*

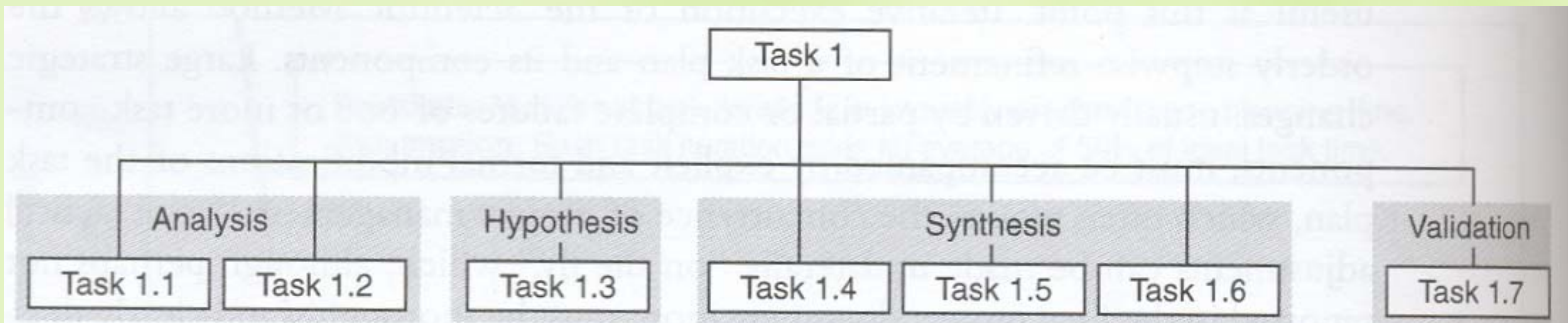
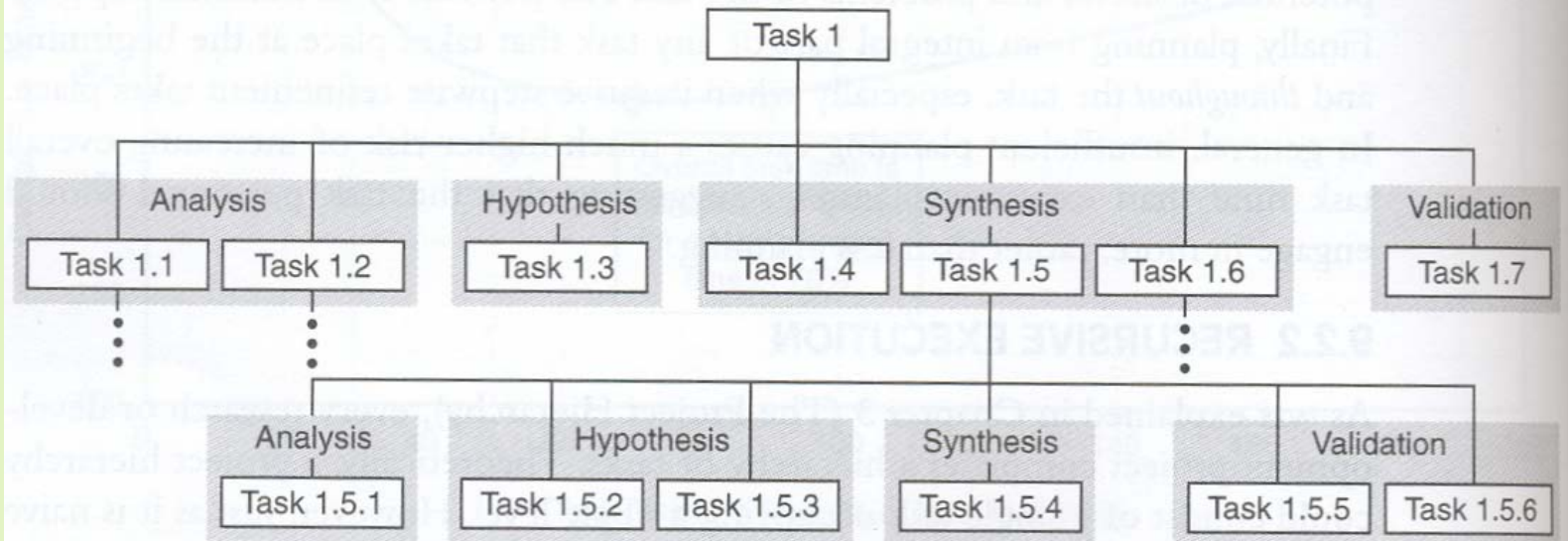


Figure 9.3 Illustration of a two-level project hierarchy



Analysis

- ***The Objective of the Analysis Phase is to gain a thorough understanding of the components of the problem domain, leading to the formulation of a single specific and reasonable task objective.***

Analysis

- ***Problem Statement***
 - ***an interrogative sentence, a declarative sentence, or an imperative sentence that summarizes a question, complaint, or requirement, respectively***
 - ***Example***

Table 10.1 Examples of problem statements

Complaint:	Customers complain that the battery in the portable drill (Part #156A-90) loses its charge very quickly when it is not being used.
Requirement:	Design a more effective and reliable windshield wiper.
Question:	How well can humans recognize the characters on license plates when the surfaces of the plates are severely degraded by dirt and debris?
Complaint:	The user interface for Model 902 is difficult to understand.
Requirement:	Design a speech recognition system for voice control of automobile appliances, such as entertainment and air conditioning equipment.
Question:	Why are red and green used for traffic lights to indicate “stop” and “go,” respectively?
Complaint:	My dog has fleas.
Requirement:	Land a team of astronauts on the Moon and bring them safely back.
Question:	Is the sample of vehicle speeds normally distributed?

Analysis

- ***Problem Statement***
 - *One problem per task*
 - *Need enough description*
 - *Don't need too much criteria/initial conditions*
 - *Exercise: Compose a reasonable and accurate primary problem statement for the project that you are currently undertaking*


Analysis

- *Problem Statement*
- *Performance Criteria*
 - *Requirements that any proposed solution to the problem must fulfill*
 - *Development project often tightly constrained by fixed conditions and parameters imposed by demands of the marketplace or application domain*
 - *Pure research project often has much less restrictions*
 - *Graduate student: originality and significant contribution*
 - *Need to be unbiased*

Analysis

- ***Problem Statement***
- ***Performance Criteria (Cont.)***
 - ***If too strict, may result in research failure***
 - ***Example:***
 - ***Can not violate First Law of Thermodynamics***
 - ***The final product should save 30 % more energy than market available products***
 - ***The new material should be able to support at least 50 lb load per square foot***
 - ***The level-of- effort for the research task team must not exceed one person-year over an elapsed time of six months.***
 - ***Exercise: State the primary performance criteria for the project you are currently undertaking***

Analysis

- *Problem Statement*
 - *Performance Criteria*
 - *Investigate Related Work – Literature Review*
 - *What has been done in this area*
 - *What existing knowledge/product can be used for this project*
 - *Check originality of the proposed solution*
 - *Identify new performance criteria*
 - *Source: Professional journals; Conference proceedings; Books and monographs; Professional studies and investigations; Newspaper and magazine reports; Manufacturer's technical specifications; Discussion with colleagues; Reverse engineering...*
- 

Analysis

- ***Investigate Related Work (Cont.)***
 - ***Often is not a one-time thing;***
 - ***Need to determine the validity of the information***
 - ***Unclear about the circumstances surrounding the generation of the knowledge by the source***
 - ***Report itself is a secondary source***

Analysis

- *Problem Statement*
- *Performance Criteria*
- *Investigate Related Work*
- **State Objective**
 - A statement of what the task is intended to achieve, expressed as an infinitive phrase
 - Realistic and highly specific
 - Each project can have multiple objectives but each task can only have one task objective
 - Example:
 - To reduce the level of water leakage in the basement by 50 %
 - To identify a methodology
 - Exercise: State the complete and detailed objective for the project that you are currently undertaking



Hypothesis

- ***The Objective of the Hypothesis Phase is to propose a solution to achieve the task objective, a set of goals and hypothesis for this solution, and the factors and performance metrics for testing the validity of the solution.***
- ***Specify Solution; Set Goals; Define Factors; and Postulate Performance Metrics***

Hypothesis

- ***Specify Solution***
 - *Hardest Part*
 - *Knowledge, literature, thinking...*
- ***Set Goals***
 - *How the response of the task unit will be determined when the solution is applied to it*
 - *Accomplished with a set of experiments designed and conducted in the Synthesis Phase*

Hypothesis

- **Set Goals**

- **Example**

- **Task: Measure Liquid Temperature Variation**

- Objective: To decide if the variation of the temperature of the liquid is greater than specified by the manufacturer**

- Goal: To measure the temperature of the liquid over time using the thermocouple**

- **Task: Find New Planet**

- Objective: To find a new planet of the required mass in the predicted solar orbit**

- Solution: Blink comparator to detect object motion**

- Goal: To use the blink comparator to detect movement of objects between successive plates**

Hypothesis

- **Set Goals**

- *Research Hypothesis is a declarative sentence that asserts a desired, expected, or possible conclusion of a goal*

- **Example:**

- *Task: Measure Liquid Temperature Variation*

- *Objective:* *To decide if the variation of the temperature of the liquid is greater than specified by the manufacturer*

- *Goal:* *To measure the temperature of the liquid over time using the thermocouple*

- *Hypothesis:* *The temperature of the liquid in the refrigerated vessel is stable over time*

Hypothesis

- ***Define Factors***
 - ***Factors are parameters or conditions that will be varied to observe their effects on the performance of the task unit during an experiment***
 - ***Start with a complete list***
 - ***May need pilot test to examine important ones***
 - ***Example***
 - ***Task: Measure Liquid Temperature Variation***
 - ***Task: Find New Planet***

Hypothesis

- ***Postulate Performance Metrics***
 - ***A performance metric is a postulate that transforms the results of the task into measures of performance for drawing conclusions about the task objective***
 - ***Start from task objective***
 - ***Task specific***
 - ***Used to draw conclusion***
 - ***Example***



Question?