NILE UNIVERSITY of NIGERIA

DEPARTMENT OF PETROLEUM & GAS ENGINEERING

GET 101 2021. 2nd Intake. Introduction to Engineering.
Presentation 4 - DESIGN & TEAMWORK

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1. INTRODUCTION

1. INTRODUCTION

Basic Concepts

- Regardless of your selected engineering discipline or career path, communication is critical for survival as an engineer.
- Due to the complexity of many analysis and design projects, it is necessary for all engineers to operate effectively on a team.
- The importance of design and teamwork cannot be over emphasised

2. DESIGN

Introduction to Design

- Design is a creative process that requires
    - problem definition,
    - idea generation and selection,
    - solution implementation and
    - testing, and evaluation.
- Design is inherently multifaceted, so any problem addressed will have multiple solutions.
- While a particular solution might address some objectives well, other objectives might not be met at all.
- The goal is to identify a design that meets the most important objectives.

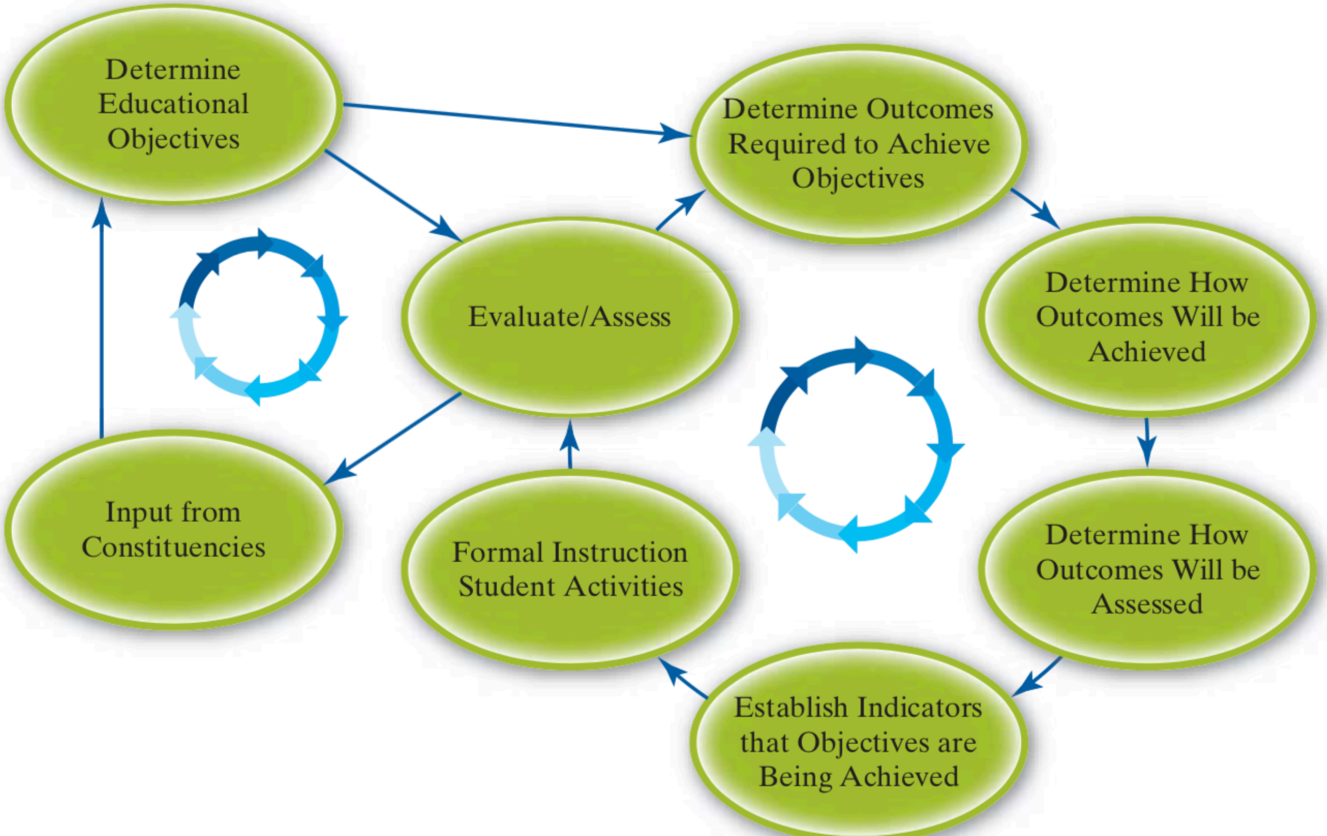
2. DESIGN

The Design Process

- To evaluate ideas and communicate them to others,
  - engineers commonly sketch possible solutions and
  - build models of their work
- It is common to draw a diagram of the design process to help others understand how process steps are connected.
- Example - The design process for Engineering Education Programs is madeup of two iterative processes, shown in Fig. 3-1 below.

2. DESIGN

The Design Process - Engineering Education Program



The ABET Design Approach

2. DESIGN

The Design Process - Engineering Education Program

- The iterative loop on the left comes first
    - because a new program would begin there; i
    - input from constituencies,
    - determining educational objectives, and
    - evaluating or assessing how well those objectives are being achieved.
- These steps might be called something like “problem definition.”
- “Constituencies” may also be called
    - users, clients, stakeholders, or other terms.

2. DESIGN

The Design Process - Engineering Education Program

- The process is iterative because
    - the constituencies should be pleased with the results,
    - adapt to changing needs, and to
    - achieve the continuous improvement expected by the engineering profession.
- With the problem identified (knowing our educational objectives), the iterative process on the right side of Figure 3-1 begins.
- This process occurs primarily in the designer's workspace, whatever that is.
- In the case of designing engineering curriculum,
    - the process takes place within the walls of the university or college.

2. DESIGN

The Design Process - Engineering Education Program

- Knowing the objectives,
    - the design team determines the outcomes that will accomplish those objectives,
    - how those outcomes will be achieved,
    - how they will be assessed, and
    - what indicators will demonstrate success before any students are actually taught.
- Once students have had learning experiences (including extracurricular experiences),
    - evaluation and assessment guide both processes into another cycle.

2. DESIGN

The Design Process - Engineering Education Program

- The step "determine outcomes required to achieve objectives"
    - is called "problem definition" or
    - "specification" in many other design processes.
    - critical step - shapes all the others.
- "Determine how the outcomes will be achieved"
    - creative step in the process
        - "generating ideas,"
        - "innovating,"
        - "developing possible solutions," or
        - something similar, and
        - might include "research."

2. DESIGN

The Design Process - Engineering Education Program

- “Determine how the outcomes will be assessed”
  - depends on how to measure the success of a design,
  - designers must think carefully
    - what will be measured and how,
    - determining indicators of success.
- These steps are commonly called “analysis”
  - breaking down the design
  - to examine its assumptions, benefits, and risks.
- The remaining part of the process is one of “prototyping,” “implementation,” and “testing.”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Coffee Break

3. DEFINING THE PROBLEM OR NEED

Introduction

- Understand the need to define problems
- Recognise that problems can actually be opportunities
- Determine the stakeholders in a design

3. DEFINING THE PROBLEM OR NEED

The Problem

- In school -
    - the problem or need is frequently identified and described by a teacher or professor.
- The "problem" might be
    - something to be calculated,
    - a topic for a term paper,
    - a position to debate, or
    - a subject to paint
    - but it is commonly chosen in advance and provided to the student.

3. DEFINING THE PROBLEM OR NEED

The Problem

- In the workplace
  - to make sales calls to a list of phone numbers,
  - to stock shelves,
  - to gather vital health data from a set of patients,
  - to make a series of deliveries, or
  - to serve vegetarian lasagna to the traveling engineer at table #8 after a long day of field work.

3. DEFINING THE PROBLEM OR NEED

Problem

- In engineering,
    - a problem or need may be provided by a client or by an employer
- At other times, engineers have much more latitude in defining (or redefining) the problem e.g.
    - “design a process by which the asbestos in a school boiler room can be removed”,
    - “design a process by which the school boiler room can be made safe from airborne asbestos”
    - the engineer could choose from multiple ways to define the problem

3. DEFINING THE PROBLEM OR NEED

Problem

- Problems and needs are best identified and defined with the help of stakeholders.


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4. DEFINING WHAT IS IMPORTANT

Introduction

- Understand the difference between “must” and “should” in design
- Consider how to handle a large number of criteria in design

4. DEFINING WHAT IS IMPORTANT

Criteria in Design

Starting with a problem definition, we can begin to generate an appropriate set of criteria to:

- provide some basic direction as we consider all the possible solutions.
- compare design options and narrow our choices objectively.
- assess cost, to check whether certain approaches become less attractive.
- check proposed solutions might be hazardous, thus further narrowing our options.

4. DEFINING WHAT IS IMPORTANT

Criteria in Design

- The criteria for evaluating potential solutions *should* be discussed
    - before you start thinking of solutions
    - to avoid choosing criteria that favour a popular solution.
- Criteria *must* be identified before evaluation begins
    - so that all ideas can be considered fairly
    - this helps avoid arguments based on hidden criteria
- Criteria range from
    - *must* criteria - any successful solution has to have
    - *should* criteria - desirable, distinguish one solution from another.
- Some solution parameters are preferences or options where there is no agreement on what is better.

4. DEFINING WHAT IS IMPORTANT

Criteria in Design

- "Must" criteria are commonly called constraints, and may be established legally at a regional level
    - California's automotive emission laws
    - Florida's building code provisions regarding wind-borne debris
    - Corporate Average Fuel Economy (CAFE) standards
    - American National Standards Institute (ANSI)
    - the International Organization for Standardization (ISO),
    - Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal
    - Nigeria National Building Code

4. DEFINING WHAT IS IMPORTANT

Criteria in Design

- Valid criteria must be clearly understood and measurable.
- For criteria to be considered *should* criteria,
    - usually called simply “criteria” as opposed to “constraints”,
    - it must also be clear what is better.
- The final type of criteria are preferences or options.
    - These are features that distinguish designs,
    - but that different people, groups, or applications indicate a different choice for what is better.


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5. GENERATING IDEAS

Brainstorming

- Define brainstorming within the design process
- Recognise the need for diverse perspectives in design

5. GENERATING IDEAS

Brainstorming

- **Brainstorming -** process by which ideas are generated.
- Idea generation follows common rules:
    - encourage a lot of ideas,
    - encourage a wide variety of ideas, and
    - do not criticize.
- The third rule is important if the first two are to be achieved.
- It has been said: “The best way to get a good idea is to get lots of ideas!”
- Where is quality in this process? “quality, not quantity.”

5. GENERATING IDEAS

Brainstorming

- The most common approach to solving a problem is to find out if it has been solved before.
    - "there is nothing new under the sun"
    - "phone a friend"
    - consult a comprehensive search of published material, including journals, patents, and product catalogs.
    - Contacting a colleague
    - An experienced engineer with a robust network may know just the person to go to when certain kinds of questions arise:

EXERCISE 1

We frequently express criteria in terms that are not clear and measurable. Write a clear criterion to replace each of these vague criteria for the products.

Product	Computer	Automobile	Bookshelf
Inexpensive	Less than $300		
Small			
Easy to assemble			Requires only a screwdriver
Aesthetically pleasing			
Lightweight			
Safe			
Durable			
Environmentally friendly		Has an estimated MPG of at least 50	


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6. COMPARING DESIGNS AND MAKING DECISIONS

Introduction

- Use pairwise comparison to narrow a set of design choices
- Conduct and analyse a weighted benefit analysis

6. COMPARING DESIGNS AND MAKING DECISIONS

Introduction

- The design criteria must also guide the process of choosing a solution.
- Each proposed solution must be evaluated against those criteria.
- Step 1 - eliminate any solutions that do not meet the minimum requirements
    - those solutions are out-of-bounds and
    - need not be considered further.
- mmmm

6. COMPARING DESIGNS AND MAKING DECISIONS

Introduction

- There are many ways of applying the remaining criteria to select a solution.
- Voting - reduce a large number of choices to a smaller number of choices,
    - voting processes - weighted voting, multi-voting, ranking, and more) can quickly eliminate many non-controversial options.
- Other approaches include **pairwise comparisons**.
    - use a table for each criterion to summarise how each of the solutions compares with others.
- A disadvantage of the pairwise comparisons approach is that all criteria have equal weight, whereas some criteria are likely to be more important than others.
- An alternative approach is to use **weighted benefit analysis**


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7. PROTOTYPING & TESTING

Introduction

- Define prototyping
- Define design testing
- Understand how the process of reevaluation fits into prototyping and testing

7. PROTOTYPING & TESTING

Evaluate the Solution

- When a solution has been identified as the best fit to the criteria, it is best to stop for a reality check before moving forward.
- After the evaluation process, some ideas will be left on the cutting room floor.
    - Do any of these merit further consideration?
    - Are there important elements of those ideas that can be incorporated into the chosen design?
    - If the reality check reveals that an idea really should not have been eliminated, then a change in the selection criteria may be appropriate.

7. PROTOTYPING & TESTING

Prototype

- Make sure a particular design will work in practice
  - to actually try it out
  - to build a sample, a scale model, or a *prototype* and
  - find out if it performs the way we think it will.
- Generating prototypes has been resource - intensive
  - materials and construction time
  - reduce the number of design options before considering making a prototype
- A prototype was only made to ensure that a chosen design would function correctly, and
  - no further design options were considered unless the prototype did not function as expected.

7. PROTOTYPING & TESTING

Testing

- Even when the selection of a particular design is considered "final," it will undergo testing.
- Intentional testing in laboratories and in user studies.
    - introduction of the design into a pilot installation or a test market,
    - yields information both about the performance of the design and about its marketability.
- Design tends to be iterative– design, build, test, redesign, and so on


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7. PROTOTYPING & TESTING

Evaluate the Solution

- Stopped Friday,16th Nov 2018

8. SUSTAINABILITY

Introduction

- Define sustainability
- Understand how sustainability fits within the design process
- Recognize how sustainability can also apply to topics aside from design

8. SUSTAINABILITY

Introduction

- Sustainability is "meeting the needs of the present without compromising the ability of future generations to do the same."
    - fundamentally about people.
    - includes future generations as well as present ones.
- Sustainability is not just an issue for our children and grandchildren,
    - it is an issue that is affecting all of us right now.

8. SUSTAINABILITY

Environmental & Sustainability

- "Environmental" and sustainability are often used interchangeably;
- Sustainability also has social and economic dimensions.
- All three of these dimensions must be balanced for truly sustainable engineering solutions.
- The figures show the relationships between these dimensions.
- Our society would not exist if our environment did not support human life.
- Our economy would not exist if we did not have a stable society (most people do not want to start businesses in failed states).
- As business leader Peter Senge points out: "the economy is the wholly owned subsidiary of nature, not the other way around."

8. SUSTAINABILITY

Environmental & Sustainability

- You can apply a basic understanding of sustainability to your own engineering solutions.
- Sustainability is not a stand-alone topic.
    - It cannot be bolted onto an engineering design at the end of the project.
- For example, in a new building project, one of the first sustainability considerations
    - whether this project is even necessary.
    - perhaps more efficient use of existing facilities is better.
    - This is quite an ethical dilemma!

8. SUSTAINABILITY

Teamwork & Communication

- Teamwork and communication in the process are vital
    - sustainable solutions require consideration of multiple issues.
- We must be able to work with engineers from different disciplines
    - non-engineers such as architects, contractors, and lawmakers.
- We must be able to communicate with the end users
- These basic ideas apply across disciplines, whether you are designing a building, an engine, or a new material.

8. SUSTAINABILITY

Teamwork & Communication

- How much is humanity currently considering sustainability?
- How do we use our critical resources?
    - such as energy and water,
    - shawarma and chocolate,
    - can they be sustained at current rates?
- Increasing population and affluence will stress these resources even more.

8. SUSTAINABILITY

Teamwork & Communication

- Allocation of resources for the present and future is a huge ethical question engineers must consider.
    - Should you build a reservoir that will provide water for an impoverished area, but restrict availability downstream?
    - Do the risks associated with nuclear energy outweigh the fact that it is a carbon-free source of energy?
    - Do you establish a coal fired power plant?

8. SUSTAINABILITY

Solutions for Sustainability Issues

- Creating solutions for sustainability issues
  - expanding the boundaries of single-discipline thinking,
  - recognise relationships between systems and the associated problems and opportunities.
- For example, our fossil-fuel based energy system has increased standards of living all over the world
  - contributes to climate change,
    - significant negative impacts, with more predicted for the future.
  - the system contributes to inequalities between those who have energy and those who do not,
    - which is a major source of poverty and conflict.

8. SUSTAINABILITY

Solutions for Sustainability Issues

- These complex relationships can make problems seem overwhelming;
  - however, these relationships also offer opportunities.
- Engineers creating sustainable energy solutions will have positive impacts in multiple areas,
  - such as helping to curb climate changing emissions,
  - reducing energy poverty and resource conflict.
  - You can make a conscious effort to build your skills in the broad, systems-thinking needed to identify these opportunities.


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9. WORKING IN TEAMS

Introduction

- Define ground rules for working in teams
- Resolve issues in communication or roles in teams
- Recognise the importance of personal participation within a team

9. WORKING IN TEAMS

Introduction

The ability to work in a team
is one of the most critical traits an
engineer needs.
Even if you are the greatest engineer in
the world,
you will not know all of the answers
or have all of the right ideas.
We can always learn something
from our peers.

9. WORKING IN TEAMS

Introduction

- Group: A number of people who come together at the same place, at the same time.
- Team: Individuals cooperating to accomplish a common goal.
- As a student and in the workplace, you will complete some assignments individually and complete some as part of a team.
- When you work independently, you are mostly free to choose when and how you will work.
- When you work as part of a team, make sure the team has ground rules for how it will operate.

9. WORKING IN TEAMS

Introduction

- Any time several people are asked to work closely together,
  - there is a potential for much good from a diversity of ideas and skills but
  - there is also a potential for conflict.
- Conflict can be both productive and unproductive,
  - you need to manage it.

9. WORKING IN TEAMS

Team Behaviour

- The most critical task for a team, particularly a new team,
  - establish its purpose,
  - process (its way of doing things), and
  - means of measuring team progress.
- Here are several topics regarding team behaviour that you may wish to consider.
- **Ground rules:**
  - Each team needs to come to a consensus about
  - acceptable and unacceptable
  - individuals as well as team behaviour.

9. WORKING IN TEAMS

Team Behaviour

- **Decision making:**
  - Teams by necessity make decisions.
  - Each team needs to decide how these decisions will be made.
    - will they be done through consensus,
    - majority vote (either secret or show of hands), or
    - by other methods?

9. WORKING IN TEAMS

Team Behaviour

- **Communication:**
  - This is often one of the hardest parts of working effectively as a team.
  - Team members need to recognize the value of real listening and constructive feedback.
  - During the course of team meetings, *every* team member needs to participate *and* listen.

9. WORKING IN TEAMS

Team Behaviour

- **Roles:**
  - You may adopt various roles on your team.
  - In a long-term project, roles should rotate so that everyone has a chance to learn each role.

- **Participation:**
  - Decide as a team how work will be distributed.
  - Your team should also consider how to handle shifts in workload when a team member is sick or otherwise unavailable.

9. WORKING IN TEAMS

Team Behaviour

- **Values:**
  - The team as a whole needs to acknowledge and accept the unique insights that each team member can contribute to their work.
- **Outcomes:**
  - Discuss and agree on what types of measures will be used to determine that the team has reached its final goal.

9. WORKING IN TEAMS

Teammate Evaluation - Practicing Accountability

- COREN requires that engineering students graduate with an ability to function on multidisciplinary teams.
- To ensure that each student achieves this outcome, individual accountability is needed.
- Much of the activity of a team happens when the team is meeting privately (without a professor),
    - an effective and increasingly common way of addressing this tenet is to have team members rate one another's performance.
- It is important to learn how to be an effective team member now,
    - because most engineering work is done in teams,
    - most engineering graduates will have supervisory responsibility (at least project management) within 5 years of graduation.
    - some team members are more effective than others.

9. WORKING IN TEAMS

Teammate Evaluation - Practicing Accountability

Consider these three snapshots of interactions with engineering students. All three are true stories.

Case 1

- Three team members approach the professor, concerned that they have not seen the fourth team member yet.
- The professor speaks with the student, who quickly becomes despondent, alerting the professor to a number of serious burdens the student is bearing.
- The professor alerts the Course Advisor and the student gets needed help.

9. WORKING IN TEAMS

Teammate Evaluation - Practicing Accountability

Case 2

- A student, acting as the team spokesperson, tells the professor that one team member never comes to meetings.
- The professor speaks to the nonparticipating student, who expects to be contacted about meetings by cell phone, not email.
- The professor explains that the student's expectations are unrealistic.

9. WORKING IN TEAMS

Teammate Evaluation - Practicing Accountability

Case 3

- A student is insecure about being able to contribute during team activities.
- After the team's ratings of that student are in, the professor talks to the class about the importance of participating and the different ways students can contribute to a team.
- In the next evaluation, the student receives the highest rating on the team.

9. WORKING IN TEAMS

Teammate Evaluation - Practicing Accountability

- Peer evaluations are a useful way for team members
    - to communicate to one another and
    - to communicate to their professor about how the members of a team are performing.
- Reviewing and evaluating job performance is a marketable skill
- useful to the employee seeking a job or a job advancement as it is to the supervisor.

9. WORKING IN TEAMS

Focus on What Your Teammates Do Rather Than What You Think of Them

- It is challenging to give a team member a single rating on their effectiveness as a teammate
    - because some team members will be helpful to the team in some ways,
    - but engage in some behaviours that hinder the team.
- Another difficulty is that each team member is likely to consider some ways of contributing more valuable than others,
    - so the evaluation of a particular teammate will be overly influenced by that teammate's performance in certain areas.
- The only way to be fair is to
    - focus on behaviours - what your teammates do
    - rather than opinions such as how you feel about them.

9. WORKING IN TEAMS

Focus on What Your Teammates Do Rather Than What You Think of Them

- One way to focus on behaviours
  - take an inventory of what behaviours your teammates demonstrate
  - how often do they demonstrate such behaviour
- The result would be that you might need to answer 50 or more questions about each member of the team.
  - It is difficult to stay focused on answering accurately when completing such a long survey.
- A better way to focus on behaviours is by using sample behaviours to anchor each point of a rating scale.

9. WORKING IN TEAMS

Focus on What Your Teammates Do Rather Than What You Think of Them - Comprehensive Assessment of Team-Member

- There is a peer evaluation instrument that is widely used in engineering education
- Comprehensive Assessment of Team-Member Effectiveness (CATME, see www .catme.org).
- CATME measures five different types of contributions to a team using such a behaviourally anchored rating scale.
- Each scale includes representative behaviours describing
    - exceptional,
    - acceptable, and
    - deficient performance in each area.

Focus on What Your Teammates Do Rather Than What You Think of Them - Comprehensive Assessment of Team-Member

- Recognising that an individual team member may exhibit a combination of behaviours,
    - the CATME instrument also includes "in-between" ratings.
- The five types of contributions are described below the associate behaviours.
- *Contributing to the Team's Work* describes a team member's commitment to the effort, quality, and timeliness of completing the team's assigned tasks.

9. WORKING IN TEAMS

Focus on What Your Teammates Do Rather Than What You Think of Them - Contributing to the Team's Work

- A student who is exceptional at contributing to the team's work
  - Does more or higher-quality work than expected
  - Makes important contributions that improve the team's work
  - Helps to complete the work of teammates who are having difficulty

- A student who does an acceptable job at contributing to the team's work
  - Completes a fair share of the team's work with acceptable quality
  - Keeps commitments and completes assignments on time
  - Fills in for teammates when it is easy or important

9. WORKING IN TEAMS

Focus on What Your Teammates Do Rather Than What You Think of Them - Contributing to the Team's Work

- A student who is deficient at contributing to the team's work
  - Does not do a fair share of the team's work.
    - Delivers sloppy or incomplete work
  - Misses deadlines.
    - Is late, unprepared, or absent for team meetings
  - Does not assist teammates.
    - Quits if the work becomes difficult

9. WORKING IN TEAMS

Focus on What Your Teammates Do Rather Than What You Think of Them - Interacting with Teammates

*M*easures how a team member values and seeks contributions from other team members.

- A student who is exceptional at interacting with teammates
    - Asks for and shows an interest in teammates' ideas and contributions
    - Improves communication among teammates. Provides encouragement or enthusiasm to the team
    - Asks teammates for feedback and uses their suggestions to improve
- A student who does an acceptable job at interacting with teammates
    - Listens to teammates and respects their contributions
    - Communicates clearly. Shares information with teammates. Participates fully in team activities
    - Respects and responds to feedback from teammates

9. WORKING IN TEAMS

Focus on What Your Teammates Do Rather Than What You Think of Them - Interacting with Teammates

- A student who does an acceptable job at interacting with teammates
    - Listens to teammates and respects their contributions
    - Communicates clearly. Shares information with teammates. Participates fully in team activities
    - Respects and responds to feedback from teammates
- A student who is deficient at interacting with teammates
    - Interrupts, ignores, bosses, or makes fun of teammates
    - Takes actions that affect teammates without their input. Does not share information
    - Complains, makes excuses, or does not interact with teammates. Accepts no help or advice

9. WORKING IN TEAMS

Focus on What Your Teammates Do Rather Than What You Think of Them - Keeping the Team on Track

Keeping the Team on Track describes how a team member monitors conditions that affect the team's progress and acts on that information as needed.

- A student who is exceptional at keeping the team on track
  - Watches conditions affecting the team and monitors the team's progress
  - Makes sure teammates are making appropriate progress
  - Gives teammates specific, timely, and constructive feedback

9. WORKING IN TEAMS

Focus on What Your Teammates Do Rather Than What You Think of Them - Keeping the Team on Track

- A student who does an acceptable job at keeping the team on track
  - Notices changes that influence the team's success
  - Knows what everyone on the team should be doing and notices problems
  - Alerts teammates or suggests solutions when the team's success is threatened
- A student who is deficient at keeping the team on track
  - Is unaware of whether the team is meeting its goals
  - Does not pay attention to teammates' progress
  - Avoids discussing team problems, even when they are obvious

9. WORKING IN TEAMS

Focus on What Your Teammates Do Rather Than What You Think of Them - Expecting Quality

Expecting Quality is about voicing expectations that the team can and should do high-quality work.

- A student who is exceptional at expecting quality
    - Motivates the team to do excellent work
    - Cares that the team does outstanding work, even if there is no additional reward
    - Believes that the team can do excellent work

9. WORKING IN TEAMS

Focus on What Your Teammates Do Rather Than What You Think of Them - Expecting Quality

- A student who does an acceptable job at expecting quality
  - Encourages the team to do good work that meets all requirements
  - Wants the team to perform well enough to earn all available rewards
  - Believes that the team can fully meet its responsibilities
- A student who is deficient at expecting quality
  - Is satisfied even if the team does not meet assigned standards
  - Wants the team to avoid work, even if it hurts the team
  - Doubts that the team can meet its requirements

9. WORKING IN TEAMS

Focus on What Your Teammates Do Rather Than What You Think of Them - Relevant Knowledge, Skills & Abilities

Relevant Knowledge, Skills, and Abilities accounts for both the talents a member brings to the team and those talents a member develops for the team's benefit.

- A student who has exceptional knowledge, skills, and abilities
    - Demonstrates the knowledge, skills, and abilities to do excellent work
    - Acquires new knowledge or skills to improve the team's performance
    - Is able to perform the role of any team member if necessary.

9. WORKING IN TEAMS

Focus on What Your Teammates Do Rather Than What You Think of Them - Relevant Knowledge, Skills & Abilities

- A student who has an acceptable level of knowledge, skills, and abilities
  - Has sufficient knowledge, skills, and abilities to contribute to the team’s work
  - Acquires knowledge or skills needed to meet requirements
  - Is able to perform some of the tasks normally done by other team members
- A student who has deficient knowledge, skills, and abilities is
  - Missing basic qualifications needed to be a member of the team
  - Unable or unwilling to develop knowledge or skills to contribute to the team
  - Unable to perform any of the duties of other team members


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Coffee Break

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

Introduction

- Discuss why experimental design is important
- Define the steps in the PERIOD analysis method
- Understand how many measurements might be necessary in an analysis
- Experiments enable engineers to come up with a creative solution to a problem and test the validity of the proposed idea.
- An experiment is a test of a proposed explanation of a problem.
- A good design of an experiment is a critical part of the scientific method.

What Constitutes the Scientific Method?

What Constitutes the Scientific Method?

1. Observation: Observe the problem and note items of interest.
2. Hypothesis: Search for a known explanation of the phenomenon or attempt to formulate a new explanation.
3. Prediction: Create a model or prediction of behavior based on that hypothesis.
4. Experiment: Test your predictions. If necessary, modify your hypothesis and retest.

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

Why Is Experimental Design Important?

- As you move through your University career, you will be inundated with many equations and theories.
- These are useful in solving a wide variety of problems.
- However, as you will see, often the equations are only really useful in solving the most basic type of problems.
- Example - consider the speed of a ball as it rolls across the floor after rolling down a ramp.
    - equations of motion for bodies moving under the influence of gravity.
    - If you are good, you can use these to examine rolling balls.
    - there are numerous complicating factors in the application the basic equations to obtain an adequate answer.

What are Experimental Measurements?

- What are Experimental Measurements?
- Most scientific experiments involve measuring the effect of variability of an attribute of an object.
- In an experiment, the **independent variable** is the variable that is controlled.
- The **dependent variable** is a variable that reacts to a change in the independent variable.

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What are Experimental Measurements?

- A **control variable** is part of the experiment that can vary
  - but is held constant
    - to let the experimenter observe the influence of the independent variable on the dependent variable.
  - Keeping control variables constant throughout an experiment
    - eliminates any confounding effects resulting from excess variability.
- Any measurement acquired in an experiment contains two important pieces of information.

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What are Experimental Measurements?

- First - the measurement contains the actual value measured from the instrument.
    - a measurement is some physical dimension that is acquired with some man-made data-collection instrument.
    - there may be some imperfection that can cause adverse effects during data collection.

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What are Experimental Measurements?

- Second - the piece of information that goes along with any measurement is the level of uncertainty.
    - Any uncertainty in measurement is not strictly by instrumentation error.
    - Systematic error is any error resulting from human or instrumentation malfunction.
    - Random error is caused by the limits of the precision of the data-collection device.
    - It is possible to minimise the systematic error
    - but random error cannot be completely eliminated.

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What are Experimental Measurements?

Do you know what these unique measurement instruments do?

- Durometer
- Dynamometer
- Euidometer
- Galvanometer
- Gyroscope
- Manometer
- Opisometer
- Pycnometer
- Tachymeter
- Thiele tube

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What Measurements do you Need to Make?

- You need to develop a coherent experimental program.
- You should make enough measurements to answer any anticipated questions,
    - but you do not usually have the time or money to test every possible condition.
- Points to consider:
    - What are the parameters of interest?
    - What is the range of these parameters—minimum values, maximum values?
    - What increments are reasonable for testing (every 10 degrees, every 30 seconds, etc.)?
    - What order is best to vary the parameters? Which should be tested first, next, etc.?

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What Measurements do you Need to Make?

- Here is an acronym (PERIOD) that can help you remember these important steps.

  P – Parameters of interest determined

  E – Establish the range of parameters

  R – Repetition of each test specified

  I – Increments of each parameter specified

  O – Order to vary the parameters determined

  D - Determine number of measurements needed and Do the experiment

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What Measurements do you Need to Make?

As an example, it is applied to the problem of the ramp and rolling balls, described below

- As an example, suppose you are interested in the speed of a ball as it rolls across the floor after rolling down a ramp. In physics, you will learn the equations of motion for bodies moving under the influence of gravity. If you are good, you can use these to examine rolling balls. What you will quickly find, however, is that numerous complicating factors make it difficult to apply the basic equations to obtain an adequate answer.
- Let us suppose you are interested in smooth balls (such as racquetballs), rough balls (tennis balls), heavy balls (bowling balls), and lightweight balls (ping-pong balls). The simplified equations of motion predict that all these will behave in essentially the same way. You will discover, however, that the drag of the air affects the ping-pong ball, the fuzz affects the tennis ball, and the flexible nature of the racquetball will allow it to bounce at steep ramp angles. It is difficult to predict the behaviour analytically. Often, one of the quickest ways to learn about the performance of such complex situations is to conduct experiments.

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What Measurements do you Need to Make?

P – Parameters of interest determined

- Parameter 1 is the ramp angle.
- Parameter 2 is the distance up the ramp that we release the ball.
- Parameter 3 is the type of ball.

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What Measurements do you Need to Make?

E – Establish the range of parameters

- Ramp angle can vary between 0 and 90 degrees in theory, but in reality can only vary between 10 degrees (if too shallow, ball would not move) and 45 degrees (if too steep, ball will bounce).
- The distance we release the ball up the ramp can vary between 0 and 3 feet in theory, assuming that the ramp is 3 feet long. We cannot release the ball too close to the bottom of the ramp or it would not move. In reality, we can only vary between 0.5 and 3 feet.
- We will test as many types of balls as we have interest in

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What Measurements do you Need to Make?

R – Repetition of each test specified

- The ramp angle will be set according to the height of the ramp from the floor, so there is not much room for error in this measurement; only one measurement is needed for such geometry.
- Each placement of the ball before release will vary slightly and may cause the ball to roll slightly differently down the ramp; this is probably the most important factor in determining the speed, so three measurements at each location are needed.
- We will assume that every ball is the same, and the actual ball used will not change the outcome of the experiment; only one ball of each type is needed.

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What Measurements do you Need to Make?

I – Increments of each parameter specified

- We will test every 10 degrees of ramp angle, starting at 10 degrees and ending at 40 degrees.
- We will release the balls at a height of 0.5, 1, 1.5, 2, 2.5, and 3 feet up the ramp.
- We will test five types of balls: racquetball, baseball, tennis ball, ping-pong ball, and
bowling ball.

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What Measurements do you Need to Make?

O – Order to vary the parameters determined

- We will set the ramp angle and then test one ball type by releasing it at each of the four different distances up the ramp.
- We will repeat this process three times for each ball.
- We will then repeat this process for each type of ball.
- We will then change the ramp angle by 10 degrees and repeat the process.
- This process is repeated until all conditions have been tested.

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What Measurements do you Need to Make?

D - Determine number of measurements needed and Do the experiment

- It is always important to determine before you start to know how many measurements you need to make.
- Sometimes you can be too ambitious and end up developing an experimental program that will take too much effort or cost too much money.
- If this is the case, then you need to decide which increments can be relaxed, to reduce the number of overall measurements.

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What Measurements do you Need to Make?

- The number of measurements (*N*) you will need to make can be easily calculated by the following equation for a total of *n* parameters:

N = (# increments parameter 1 * number of repetitions for parameter 1) * (# increments parameter 2 * number of repetitions for parameter 2) * . . . (# increments parameter *n* & number of repetitions for parameter *n*)

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What Measurements do you Need to Make?

- Continuing the examples given above, the number of actual measurements that we need to make is calculated as

N = 14 angles2 * 16 distances * 3 repetitions2 * 15 types of balls2

= 360 measurements

- In this example, 360 measurements may be extreme.
- If we examine our plan, we can probably make the following changes without losing experimental information:

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What Measurements do you Need to Make?

- We decide to test every 10 degrees of ramp angle, starting at 20 degrees and ending at 40 degrees.
  - This will lower the angle testing from four to three angles.
- We will release the balls at a height of 1, 2, 2.5, and 3 ft up the ramp.
  - This will lower the distances from six to four.
- We will test three types of balls: racquetball, ping-pong ball, and bowling ball.
  - This will lower the type of balls from five to three.
  - The number of actual measurements that we now need to make is calculated as:

10. EXPERIMENTAL DESIGN - PERIOD ANALYSIS

What Measurements do you Need to Make?

- The number of actual measurements that we now need to make is calculated as

N = 13 angles2 *14 distances * 3 repetitions2 * 13 types of balls2

=108 measurements

This result seems much more manageable to complete than 360!


ZUCCHERO
Coffee Break

11. PROJECT TIMELINE

Introduction

- Create a project timeline
- Define and use a responsibility matrix
- Recognise the importance of team dynamics within a project timeline
- To complete a project successfully, on schedule and satisfying all constraints, careful planning is required.
- The following steps should help your team plan the completion of project work.

11. PROJECT TIMELINE

Step 1 - Create a Project Timeline

- The first consideration is the project's due date.
    - All team members need to note this on a calendar.
    - Examine the due date within the context of other assignments and classes.
    - For example, is there a calculus test in the fourth week?
    - When is the first English paper due?

11. PROJECT TIMELINE

Step 1 - Create a Project Timeline

- Look at the project itself and break into individual tasks and subtasks.
  - Create a list, making it as specific, detailed and thorough as possible.
  - Your list should include:
    - All tasks needed to complete the project
    - Decisions that need to be made at various times
    - Any supplies/equipment that will need to be obtained

11. PROJECT TIMELINE

Step 1 - Create a Project Timeline

- Carefully consider the order in which the tasks should be completed.
    - Does one task depend on the results of another?
    - *Then, working backwards from the project due date,*
    - *assign each task, decision, or purchase its own due date on the calendar.*

11. PROJECT TIMELINE

Step 1 - Create a Project Timeline

- Finally, your team should consider meeting at least once a week
    - at a consistent time and location for the duration of the semester.
    - More meetings will be necessary,
    - but there should be at least once per week when the entire team can get together and review the project status.
    - A standing meeting time will prevent issues of
        - "I did not know we were going to meet" or
        - "I did not get the message."

11. PROJECT TIMELINE

Step 2 - Create a Responsibility Matrix

- List the project's tasks and subtasks one by one down the left side of the paper.
- Then, create columns beneath each team member's name, written side by side across the top.
- Put a check mark in the column beneath the name of the member who agrees to perform each task.
- It then becomes the responsibility of that team member to successfully perform the task by the due date that was agreed upon in Step 1.
- An alternate grid is shown in Table 4-4.

11. PROJECT TIMELINE

Step 2 - Create a Responsibility Matrix

Table 4-4 - Sample Responsibility Matrix

Task	Completed by	Checked by
Purchase supplies	Pat and Chris by 9/15 team mtg	
Write initial proposal	Terry—Email to Robin by 9/22	Robin by 9/25 team mtg
Conduct preliminary calculations on height	Robin—Email to Pat by 9/22	Pat by 9/25 team mtg
Build prototype in lab	All—Lab: 7–9 p.m., 9/28	

11. PROJECT TIMELINE

Step 2 - Create a Responsibility Matrix

- In assigning the tasks, consider the complexity and time required for the job.
- One team member may have five small tasks while another may have one major task, with the goal being an equal distribution of effort.
- A second team member should be assigned to each task to assist or check the work completed by the first team member.
- Be sure all team members are comfortable with the assignments.

11. PROJECT TIMELINE

Step 3 - Consider Team Dynamics

Communication:

- The success of any project depends to a great extent on how well the team members communicate.
- Do not hesitate to share ideas and suggestions with the group and consider each member's input carefully.
- Do not be afraid to admit that you are having difficulties with a task or that the task is taking longer than expected.
- Be ready and willing to help one another.

11. PROJECT TIMELINE

Step 3 - Consider Team Dynamics

Trust and Respect:

- Remember the team is working toward a shared objective.
- Therefore, you must choose to trust and respect one another.
- Treat fellow team members with simple courtesy and consideration.
- Follow through with promises of completed tasks,
    - remembering the team is counting on your individual contributions.
- Try to deal honestly and openly with disagreements.
- However, do not hesitate to ask for help from faculty if problems begin to escalate.

11. PROJECT TIMELINE

Step 3 - Consider Team Dynamics

Nothing is carved in stone:

- It is important to plan the project as carefully as possible; however, unforeseen problems can still occur.
- Treat both the Project Timeline and Responsibility Matrix as working documents.
- Realise they were created to serve as guides, not as inflexible standards.
- Watch the project progress relative to the timeline, and do not hesitate to redesign, reallocate, or reschedule should the need arise.
- Review your matrix each week and adjust as needed.

11. PROJECT TIMELINE

Step 3 - Consider Team Dynamics

- Finally, do not forget to have fun!

ANY QUESTION?


Thank You!

NEXT TOPIC

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