Philosophy of Engineering

Unit - 3

Epistemology of Engineering

Relations between Science, Technology, and Engineering - Questions on Philosophy of Engineering - Four Dimensions of Engineering - RIASEC Model - Epistemology of Engineering Design - Rigour, Creativity, and Change in Engineering

Practice 7: Analyze the nature, contents, and complexity of the knowledge base in engineering

Practice 8: Case Study on RIASEC Theory of Career Choice

Practice 9: Analyze Distinctive Features of Epistemology of Engineering Design

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Epistemology of Engineering

foundational branch of philosophy

Theory/Study of knowledge

It seeks to understand the nature, scope, and limits of human knowledge, as well as the processes through which we acquire, justify, and evaluate knowledge.

Addresses questions such as

1. What is knowledge?
2. How do we acquire knowledge?
3. What are the limits of knowledge?
4. What is the role of belief, evidence, and justification?
5. Skepticism
6. Epistemic justification
7. Reliability of knowledge sources
8. The Gettier problem

What is knowledge?

- Epistemologists aim to define knowledge and distinguish it from mere belief or opinion.
- One common definition of knowledge is justified true belief, meaning that for something to be considered knowledge, it must be true; the person believing it must be justified in believing it.

How do we acquire knowledge?

- This question delves into the ways in which humans gain information and beliefs.
- Epistemologists examine processes like perception, reason, memory, and testimony as sources of knowledge.

What are the limits of knowledge?

- Epistemology explores the boundaries of what we can know.
- For instance, can we ever be certain about anything? Are there questions that are beyond the reach of human knowledge?

What is the role of belief, evidence, and justification?

- Epistemologists examine how our beliefs are formed, how evidence plays a role in shaping those beliefs, and
- What counts as sufficient justification for holding a belief as knowledge?

Skepticism

- Epistemology also considers various forms of skepticism, which challenge the certainty and reliability of knowledge.
- Philosophical skepticism, for example, questions whether we can have any certain knowledge at all.

Epistemic justification

- This involves exploring how and to what extent our beliefs can be justified.
- Do we have to have strong evidence for all our beliefs, or are some beliefs justified in other ways?

Reliability of knowledge sources

- Epistemologists study the reliability of different sources of knowledge, such as sense perception, introspection, and testimony.
- They investigate under what conditions these sources can be trusted.

The Gettier problem

- This is a famous problem in epistemology that challenges the traditional definition of knowledge as justified true belief.
- It's exemplified by cases where someone has a justified true belief but still doesn't seem to have genuine knowledge.

To Sum up,

Epistemology

It helps us understand how we come to know the world, how we justify our beliefs, and the extent to which we can trust our understanding of reality.

Relations between Science, Technology, and Engineering

> **"Scientists study the world as it is; engineers create the world that has never been."**
>
> **—Theodore von Kármán**

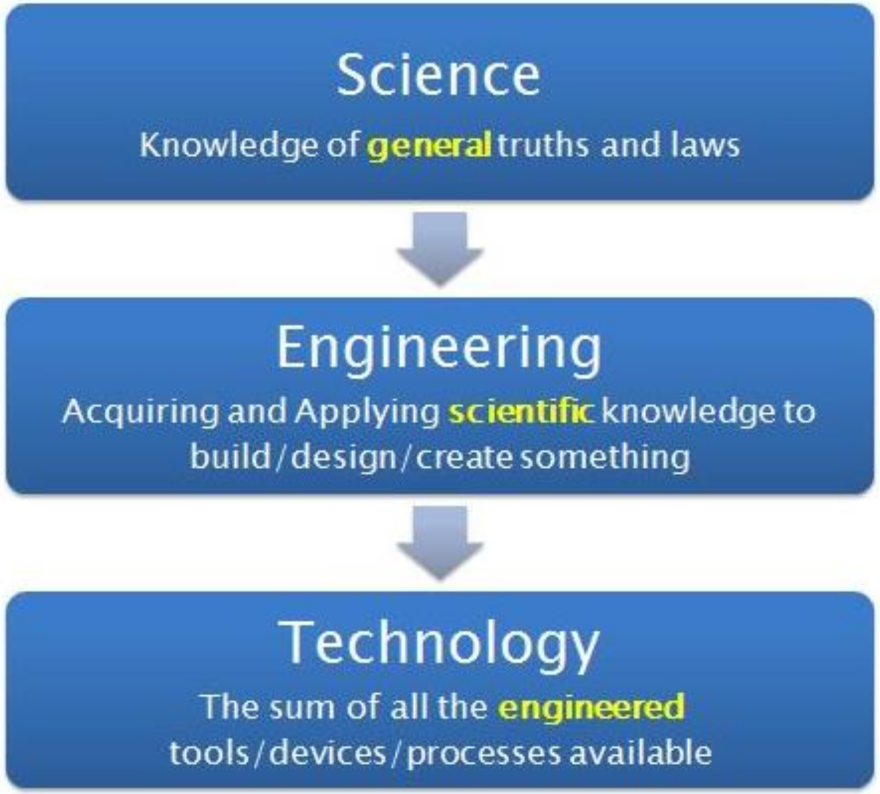
Science is a **study** of the **natural** world, while **Engineering** is **creating new things** based on that study.

To bring out a comparison between science, engineering, and technology:

"**Science** is the study of the natural world as it is;

Engineering is creating new tools, devices, and processes based on *scientific* knowledge;

Technology is the sum total of all the ***engineered*** tools, devices, and processes available."



Comparison between Science, Technology, and Engineering

Science	Engineering	Technology
Knowledge of the natural world put together	Creation based on the scientific knowledge put together	Set of engineered creations put together.
Comes from observation of the world	Comes from acquiring and applying knowledge,	Comes from repeated application and approval of the engineered tools.
Creating meaning of natural phenomenon	Creating new devices, tools and processes,	Creating a collection of engineered and tested tools for the mankind.

Key relationships between Science, Technology, and Engineering:

Science and Technology:

1. Science as a Basis for Technology:

- Science provides the foundational knowledge and understanding of the natural world.
- Technological advancements often rely on scientific discoveries.
- For example, breakthroughs in physics led to the development of nuclear technology and the transistor, which revolutionized electronics.

2. Applied Science:

- Technology is the practical application of scientific knowledge.
- Scientists often collaborate with engineers and technologists to translate theoretical knowledge into real-world applications.
- This can include fields like materials science, where discoveries in the properties of materials lead to the development of new technologies.

Science and technology have a feedback loop. Scientific research can lead to the creation of new technologies, and these technologies, in turn, enable scientists to conduct experiments and gather data more efficiently. For instance, advanced instruments and computational tools aid scientific research.

Key relationships between Science, Technology, and Engineering:

Technology and Engineering:

1. **Engineering as Applied Technology:**
   - Engineering is the application of scientific and mathematical principles to design and build practical systems, structures, and devices.
   - It relies heavily on existing technologies and often leads to the creation of new ones.

2. **Innovation:**
   - Engineers are responsible for innovating and improving upon existing technologies.
   - They design, develop, and optimize technological solutions to meet specific goals and solve practical problems.
   - For instance, civil engineers design and construct bridges and buildings using the latest construction technologies.

3. **Interdisciplinary Collaboration:**
   - Engineers often work closely with technologists and scientists.
   - For example, in the field of biomedical engineering, engineers collaborate with medical researchers and scientists to develop new medical devices and technologies.

Key relationships between Science, Technology, and Engineering:

Science, Technology, and Society:

1. **Impact on Society:**
   - Advances in science, technology, and engineering have profound effects on society.
   - They can improve the quality of life, enhance communication, and solve complex problems.
   - Conversely, they can also raise ethical, environmental, and social issues that need to be addressed.

2. **Ethical and Moral Considerations:**
   - As technology and engineering create new possibilities, ethical questions arise.
   - For instance, the development of genetic engineering raises ethical questions about altering human genes, and the use of artificial intelligence raises concerns about privacy and bias.

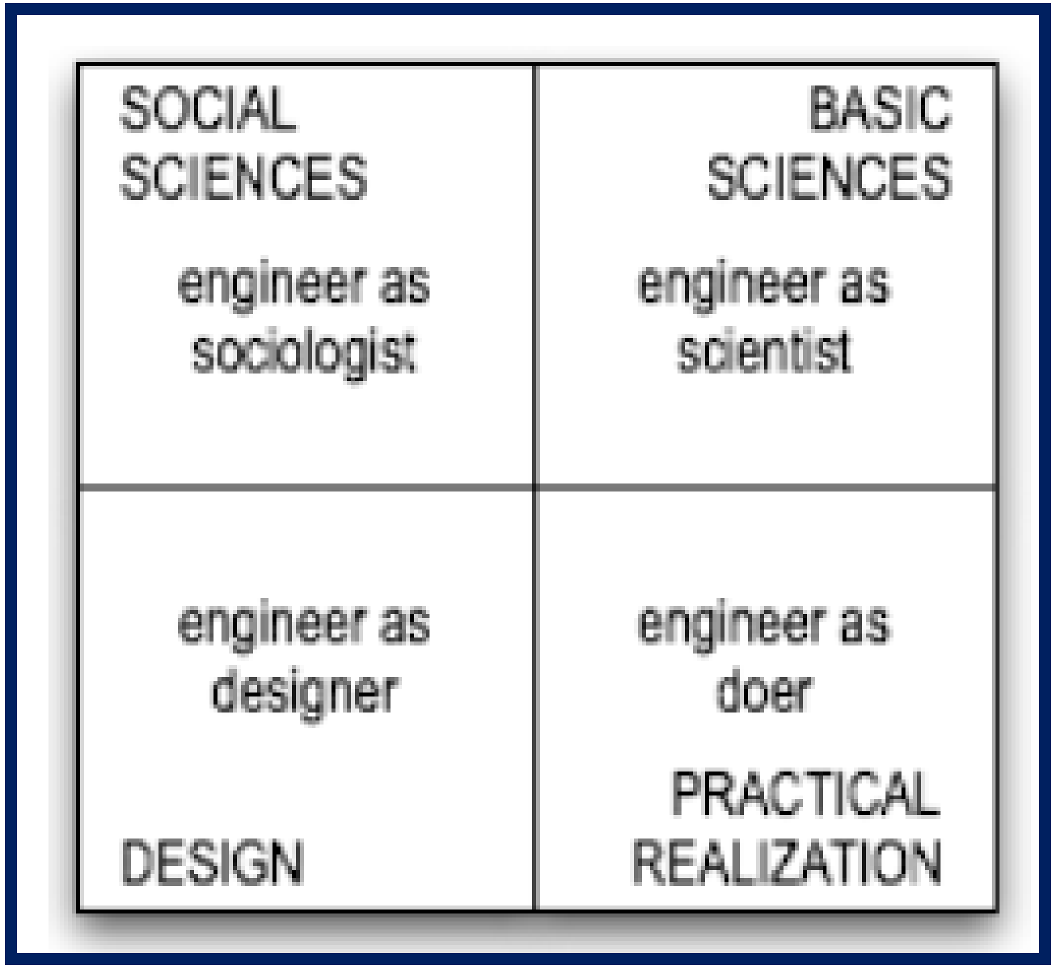
3. **Policy and Regulation:**
   - Governments and organizations play a role in regulating and shaping the development and use of technology and engineering.
   - Regulations and policies often aim to balance innovation with safety, ethics, and public interest.

Four Dimensions of Engineering:

Engineering has four main dimensions:

- ❖ Fundamental sciences,
- ❖ Social sciences,
- ❖ Design, and
- ❖ Practical accomplishment.

This enables us to consider **an engineer as a specialist** who combines several skills in varying ratios. **a scientist's, a sociologist's, a designer's, and a doer's traits.**



Basic Sciences

- The component influenced by the basic sciences emphasizes the importance of logic and rigor while viewing engineering as the application of the natural and exact sciences.
- It also considers knowledge as being created via analysis and experimentation.
- This dimension prefers research above other methods of operation because it views the discovery of initial principles as an activity that will earn it more respect.

Social Sciences

- The capacity to perceive the essentially social nature of the world they act in and the social complexity of the teams they belong to allows engineers to be seen as social specialists as well as technologists in the social component of engineering.
- In this aspect of engineering, the developments of social and economic value, as well as the belief in the happiness of end users, emerge as core values.

Design

- According to the design perspective, engineering is a form of design.
- It places a higher weight on systems thinking than on the analytical reasoning that distinguishes traditional science.
- In contrast to fragmentary visions, it bases its practice on comprehensive, contextual, and integrated views of the world. This dimension typically emphasizes compromise and exploring options.
- The important choices in this dimension, which commonly uses non-scientific ways of thinking, are frequently based on partial knowledge and intuition, as well as on individual and group experiences.

Practical Realization

- The fourth mode views engineering as the art of getting things done, valuing the ability to change the world, and overcoming complexity with flexibility and perseverance.
- It corresponds to the art of the homo faber, in its purest expression, and to the ability to tuck up one’s sleeves and get down to the nitty-gritty.
- In this dimension, the completed job, which stands before the world, leads to higher recognition.

RAISEC Model:

- In the 1950s, John Holland theorized that personality and work environment are measurable and that the two should be matched in order to find a satisfying career.
- Holland's theory describes six basic personality types
- The goal is to match an individual's code, or personality type, with his or her career.

Realistic - R (Doers)

- Like to work with their hands and focus on things in the physical world and use physical skills.
- Like to repair and work with tools, machines, or animals; outdoor work is often preferred.
- Prefer problems that are concrete rather than abstract; want practical solutions that can be acted out.
- Characteristics include stability, assertive, physical strength, and practical.

Holland typology:

- **Realistic, practical, frank, nature lover, curious, concrete, self-controlled, ambitious, persistent, athletic, mechanical thrifty, stable, reserved, independent, systematic.**

Investigative - I (Thinkers)

- Tend to focus on ideas.
- Like to collect and analyze data and information of all kinds. Curious and tend to be creative and original.
- Task-oriented and motivated by analysing and researching.
- Tend to prefer loosely structured situations with minimal rules or regulations.
- Prefer to think through rather than act out problems.
- Characteristics include reserved, independent, analytical, and logical.

Holland typology:

- **Investigative, inquisitive, scientific, precise, cautious, self-confident, reserved, independent, analytical, observant, scholarly, curious, introspective, broad-minded, logical.**

Artistic - A (Creators)

- Creative and tend to focus on self-expression through all kinds of mediums: materials, music, and words, as well as systems and programs.
- Able to see possibilities in various settings and are not afraid to experiment with their ideas.
- Like variety and tend to feel cramped in structured situations.
- Deal with problems in intuitive, expressive, and independent ways.
- Tend to be adverse to rules.
- Characteristics include intuitive, creative, expressive, and unconventional.

Holland typology:

- **Artistic, creative, imaginative, unconventional, independent, original, impulsive, courageous, complicated, nonconforming, intuitive, innovative, emotional, expressive, introspective, sensitive, open, idealistic.**

Social - S (Helpers)

- Concerned with people and their welfare.
- Tend to have well-developed communication skills and like to help, encourage, counsel, guide, train, or facilitate others.
- Enjoy working with groups or individuals, using empathy and an ability to identify and solve problems.
- Value cooperation and consensus.
- Deal with problems through feelings.
- Flexible approach to problems.
- Characteristics include humanistic, verbal, interpersonal, and responsible.

Holland typology:

- **Social, friendly, idealistic, outgoing, cooperative, responsible, kind, persuasive, patient, helpful, insightful, understanding, generous, forgiving, empathetic.**

Enterprising - E (Persuaders)

- Work with and through people, providing leadership and delegating responsibilities for organizational and/or financial gain.
- Goal-oriented and want to see results.
- Tend to function with a high degree of energy.
- Prefer business settings, and often want social events to have a purpose beyond socializing.
- Attack problems with leadership skills.
- Decision-Maker.
- Characteristics include persuasive, confident, demonstrate leadership, interest in power/status.

Holland typology:

- **Enterprising, self-confident, sociable, enthusiastic, adventurous, impulsive, inquisitive, talkative, spontaneous, assertive, persuasive, energetic, popular, ambitious, optimistic, extroverted.**

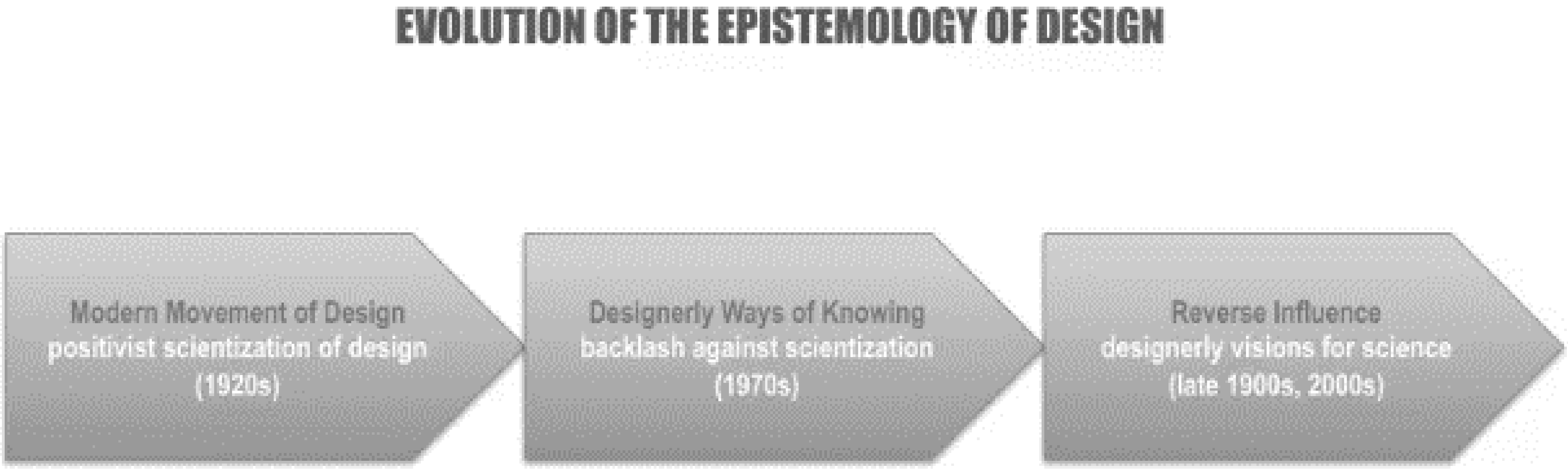
Conventional - C (Organizers)

- Like to pay a lot of attention to detail and organization, and prefer to work with data, particularly in the numerical, statistical, and record-keeping realm.
- Have a high sense of responsibility, follow the rules, and want to know precisely what is expected.
- Prefer clearly defined, practical problems and to solve problems by applying rules.
- Oriented to carrying out tasks initiated by others.
- Characteristics include conscientious, efficient, concern for rules and regulation, orderly.

Holland typology:

- **Conventional, well-organized, accurate, numerically-inclined, methodical, efficient, orderly, thrifty, structured, ambitious, persistent, conscientious, conforming, practical, systematic, polite, obedient.**

Epistemology of Engineering Design



SOME DISTINCTIVE FEATURES OF THE EPISTEMOLOGY OF DESIGN

PROBLEM FORMULATION

- Good acceptance of ill-defined problems
- Preference to gradually formulate problems as they are solved
- Reluctance to formulate problems rigorously until they are solved
- Attraction for exploratory changes of goals and constraints

REQUIREMENTS ANALYSIS

- Orientation toward the solution, rather than the problem
- Permanent generation of intermediary tasks and redefinition of requirements and constraints
- Tolerance of error and chance

SOME DISTINCTIVE FEATURES OF THE EPISTEMOLOGY OF DESIGN

FOCUS ON THE SOLUTION

- Conjectural approach to the problems as a function of potential solutions.
- Simultaneous tackling of problem and solution
- Generative, rather than deductive reasoning

EXPLORATORY PROGRESS

- The *sketch* as a metaphor to exploratory progression
- Importance of ambiguity, reinterpretation and analogy
- Dialectical progression
- Dialogue between *seeing that* and *seeing as*

- Design as Functional Analysis
- Design as Problem Solving
- Design as Problem Setting
- Design as Emergent Evolutionary Learning

DESIGN AS FUNCTIONAL ANALYSIS

- Requirements fully available a the outset
- Designer just needs to analyse the problem and deductively proceed to the solution
- Inspired by the positivist perspective of traditional basic sciences

DESIGN AS PROBLEM-SOLVING

- Specially for complex, organizational, problems
- Simplifies problems until a rational solution is possible ("bounded rationality")
- Epistemologically close to some popular visions of the social sciences

DESIGN AS PROBLEM SETTING

- Discovery and negotiation of unstated goals, implications, and criteria before a problem can be formulated and, subsequently, solved
- This vision of design takes a phenomenological approach that expresses a constructivist epistemology

DESIGN AS EMERGENT LEARNING

- Convergence of problem and solution
- Emergent process of learning while planning short-term partial goals, as the process progresses
- Design, emerging in circular references, linking problem formulation and problem solution, emphasizes a constructivist vision

THE FOUR QUESTIONS OF THE PHILOSOPHY OF SCIENCE

The main streams of the Philosophy of Science can be described by how they answer the four key questions of the Philosophy of Science:

1. ONTOLOGICAL QUESTION	*What is the nature of reality?* *What can be known?*
2. EPISTEMOLOGICAL QUESTION	*What is knowledge?* *What knowledge can we get?*
3. METHODOLOGICAL QUESTION	*How can knowledge be developed?* *What methods to build knowledge?*
4. AXIOLOGICAL QUESTION	*What is the value of knowledge?* *What is the ethics of knowledge?*

ONTOLOGICAL QUESTION

What reality can engineering know?

scientists, doers ⟷ designers, social experts

realist principle ⟷ **phenomenological principle**

We can know the reality that is external to us, independent from us, and driven by immutable laws

We know the world by interacting with it in an emergent process that changes knowledge as we keep interacting

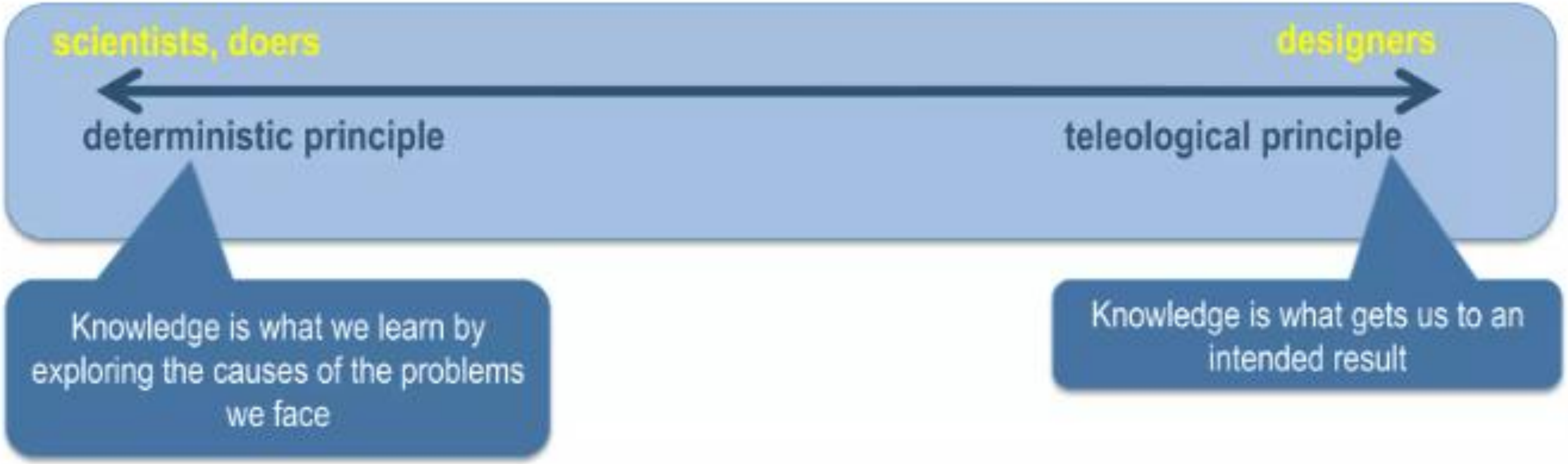
Engineers construct their knowledge along this whole continuum

As **scientists** and **doers**, they value the realist principle, but, as **designers** and **social experts** they are able to reconcile it with the phenomenological principle

[Figueiredo & Cunha (2006)]

EPISTEMOLOGICAL QUESTION

What is engineering knowledge?



Engineers construct their knowledge along this whole continuum

As **scientists** and **doers**, they value the deterministic principle, but, as **designers** they are able to reconcile it with the teleological principle

[Figueiredo & Cunha (2006)]

METHODOLOGICAL QUESTION

How can engineering knowledge be built?

scientists, doers ⟷ **designers, social experts**

scientists, doers

1. principle of analytical modeling
2. principle of sufficient reason

To explain reality we must divide each difficulty into as many parts as possible and necessary to resolve it better

There is no effect without a cause and no change without a reason for change

designers, social experts

1. principle of complexity
2. principle of intelligent action

We build knowledge by seeing the world as complex and embodying stability and change, chaos and order, with the parts interacting in the emergent and largely unpredictable construction of reality

Human reason can react to the dissonances to which it is confronted by producing "intelligent actions" adapted to reduce these dissonances

Engineers construct their knowledge along this whole continuum

[Figueiredo & Cunha (2006)]

AXIOLOGICAL QUESTION

What is the value of engineering knowledge?

scientists ⟷ designers, doers

principle of intrinsic rigour — principle of extrinsic relevance

The value of knowledge is determined by its demonstrated truth, expressed in generalised principles

The value of knowledge is determined by its practical results

Engineers construct their knowledge along this whole continuum

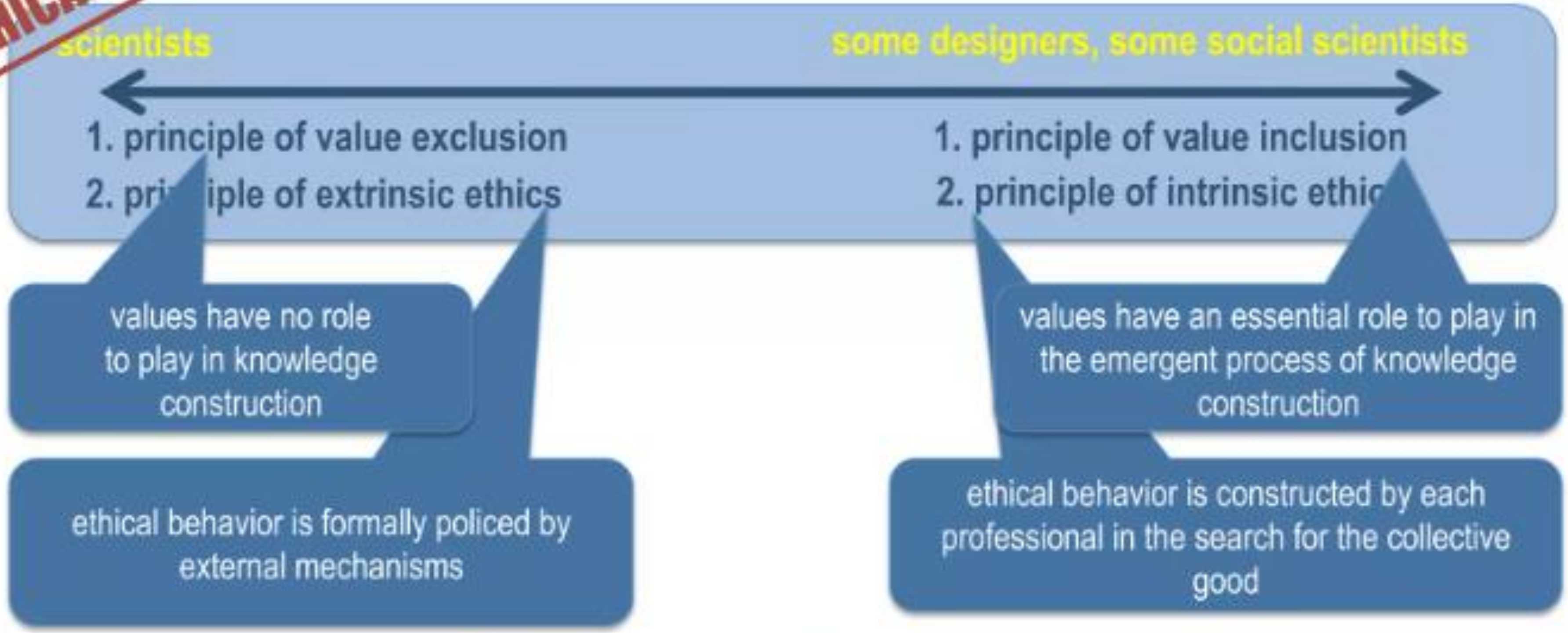
The issues relating to the esthetical dimension have been left out, to simplify

[Figueiredo & Cunha (2006)]

ETHICAL DIMENSION

AXIOLOGICAL QUESTION

What is the value of engineering knowledge?



Engineers construct their knowledge along this whole continuum

[Figueiredo & Cunha (2006)]

Summary

Ontology (***Reality***)	**Epistemology** (***Knowledge and Kowing***)	**Logic** (***Reasoning***)	**Axiology** (***Value or Worth***)
- study of being, becoming and existence and the esssence of things (their intrinsic nature)	- study of knowing, understanding, and justifying what counts as knowledge	- study of thoughts, inferences and judgements and perceptions that lead to truth	- study of evaluating situations and making value claims about worth or merit

Epistemology of engineering design refers to the philosophical study of knowledge and its acquisition within the context of engineering design processes.

- It explores questions related to how engineers come to know what they know, how they make decisions during the design process, and what constitutes valid and reliable knowledge in engineering design.

In summary, the epistemology of engineering design explores how knowledge is generated, applied, and validated in the context of designing practical solutions to complex problems. It combines empirical, scientific, mathematical, experiential, and ethical dimensions to inform the decision-making process in engineering design.

Epistemology of Engineering design

Empirical Knowledge: *Engineering design relies heavily on empirical knowledge gained through experiments, testing, and observation.*
Engineers gather data to understand the behavior of materials, systems, and processes. This empirical knowledge is fundamental to making informed design decisions.

Scientific Foundations: *Engineering design is often built upon a foundation of scientific principles and theories.*
Engineers draw upon the laws of physics, chemistry, and other sciences to understand the behavior of natural phenomena and use this knowledge to inform their designs.

Mathematical Modeling: *Mathematics plays a crucial role in engineering design. Engineers use mathematical models to simulate and predict the behavior of systems and structures.*
These models can help identify potential problems, optimize designs, and make informed decisions.

Experience and Expertise: *Experienced engineers often rely on their accumulated knowledge and expertise when making design decisions.*
This tacit knowledge, gained through years of practice, is not always explicitly articulated but plays a significant role in the design process.

Design Thinking:
Design thinking is an approach that emphasizes empathy, creativity, and iteration in the design process.
It acknowledges that knowledge is not static but evolves as designers engage with the problem and iterate on solutions.

Validation and Testing:
Engineers must validate their designs through testing and experimentation to ensure that they meet specified requirements and standards.
This process of validation contributes to the epistemological foundation of engineering design.

Design Heuristics: : *Engineers frequently use heuristics, or rules of thumb, to guide their design decisions.*
These heuristics are based on past experiences and can be valuable shortcuts for making design choices efficiently.

Uncertainty and Risk: *Engineering design often involves dealing with uncertainty and risk.*
Engineers must assess the reliability of their knowledge and make decisions under conditions of uncertainty, considering potential failures and safety concerns.

Multidisciplinary Nature: *Many engineering design problems are multidisciplinary, requiring knowledge from various fields.*
Engineers must integrate knowledge from different domains, which can present epistemological challenges in terms of reconciling conflicting information or methodologies.

Ethical Considerations: *The epistemology of engineering design also encompasses ethical considerations related to knowledge and decision-making.*
Engineers must consider the ethical implications of their designs, including potential harm to society and the environment.

Rigour, Creativity, and Change in Engineering

- Engineers' drive for innovation can be significantly curtailed by the "bottom line" finances available.
- Obtaining parts for experimentation in practically zero time can require very resourceful effort because the rigid systems in place for parts procurement too often have been established primarily for production and "just-in-time" receipt.
- One partial solution is obtaining "samples," but these are sometimes unreliable parts—and a single failure can result in a quick dismissal of a project by management.
- Rigorous design rules, such as parts derating, design reviews (Preliminary Design Reviews, Critical Design Reviews, and Final Design Reviews), are important.
- But with tight constraints on schedules and finances they often severely limit time for experimentation.

Thank you