Definition of Engineering Design

Engineering design may be defined in simple terms as the process of developing workable plans for the construction or manufacture of devices, processes, machinery or structures to satisfy some identified need. CEAB (accreditation board) formally defines it as:

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Update and course progress and end-game plan:

There are 9 lectures left. The plan is to do the following:

Discuss Engineering Design best practices	2 lectures
Engineers and Business	1 lecture
Intellectual Property (IP) Basics	1 lecture
Safety and Risk Discussion	1 lecture
Appropriate technology and sustainability	1 lecture guest
The Profession and Duty	1 lecture guest
Ethics and nanotechnology	1 lecture guest
Contingency	1 lecture
TOTAL	9 lectures

Remaining 10% of class Q and A value will be assigned to questions related to the three guest speaker lectures highlighted in red above. These questions will be administered on the final exam paper.

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The Design Process:

Needs Assessment

What is the problem? What are the existing solutions? Whome does it affect? What does the solution need to do? What is desirable? What are the constraints?

Synthesis

What ideas are there for solving the problem.

Design Analysis

Is the design idea feasible? Best practices used? Priorities given?

Implementation

How will the solution be built? Model or simulation required? Prototype required for testing?

Testing and validation

How will we evaluate solution and measure results or outcomes?

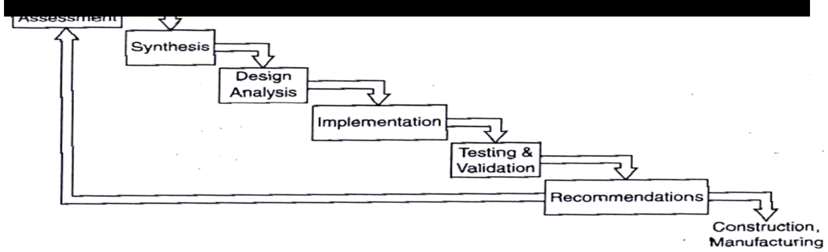
Recommendations

Are we ready to clearly state the design specifications for construction

So you should all know this off-by heart by NOW **!!!!**

FOR EXAMPLE!!!!!

over



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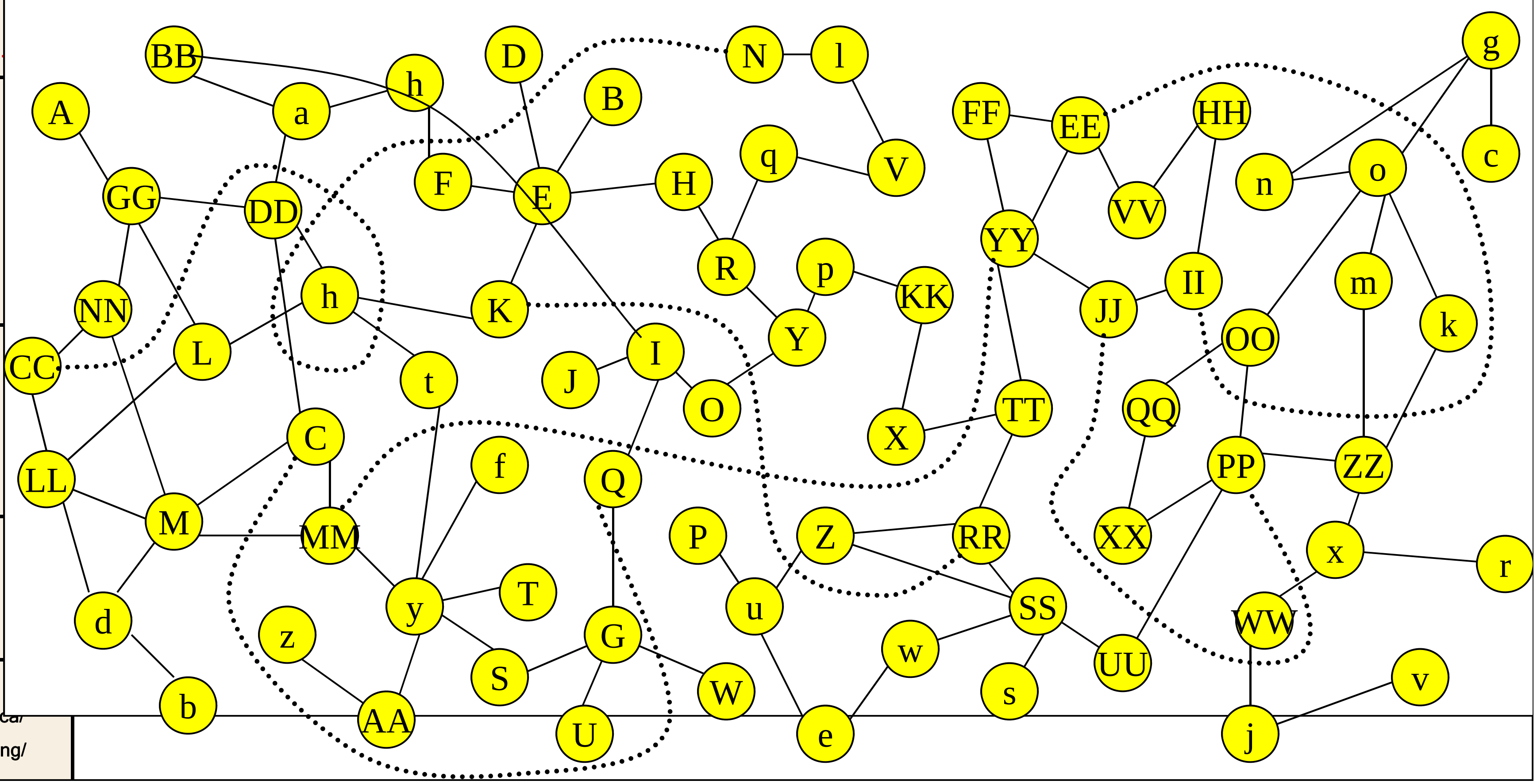
NEEDS IDENTIFIED HERE

In basic formulation

$$
\begin{aligned}
X' &= A * B \\
&= (A - (2^p - 1)) * (B - (2^q - 1)) \\
&= AB - B(2^p - 1) - A(2^q - 1) + (2^p - 1)(2^q - 1) \\
X'' &= (A - E_p)(B + Eq) \\
&= AB + AE_q - BE_p - E_pE_q \\
&= AB + AE_q - (BE_p + E_pE_q) \\
&= AB + AE_q - \frac{E_pE_q}{2} - \left(BE_p + \frac{E_pE_q}{2}\right)
\end{aligned}
$$

$$
f(X', X'') = \frac{\Gamma}{2} \sum \frac{\frac{X'^{\delta\alpha \max(\phi^2)}}{X''_{\Gamma^{3/2}}} \sum \epsilon \sqrt{AB + AE_q - \frac{E_pE_q}{2} - \left(BE_p + \frac{E_pE_q}{2}\right)}}{\int_R \phi\rho f(\overrightarrow{X}|S_k) \frac{1}{(2\pi)^{d/2}\sigma^d} * \frac{1}{P_k} \sum_{i=1}^{P_k} \exp\left[-\frac{(\overrightarrow{X}-\overrightarrow{W_{ki}})^T(\overrightarrow{X}-\overrightarrow{W_{ki}})}{2\sigma^2}\right]}
$$

- OBVIOUS SYNTHESIS OF POSSIBLE SOLUTIONS



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Results

SIMULATION DATA

TO PROVE BRILLIANCE of THEOREM

A	B	C	D	E
0.78799174	0.87677244	0.99348605	0.23781547	0.24437526
0.24910355	0.79708654	0.39825661	0.4894876	0.22079456
0.65729261	0.46901063	0.36471191	0.04697233	0.63468059
0.48205396	0.52657506	0.70503426	0.35280176	0.40935313
0.46328137	0.0774365	0.71517444	0.9394662	0.46843638
0.09762717	0.70884867	0.81407539	0.24571711	0.72497819
0.00773315	0.39906447	0.42344939	0.90776976	0.22209006
0.15857663	0.4181197	0.56488165	0.91405841	0.3578349
0.59242455	0.17894389	0.61926672	0.02978346	0.50789172
0.41285757	0.71470398	0.31906988	0.79658426	0.21587647
0.8855586	0.46534556	0.3701164	0.12452538	0.33415497
0.28231467	0.17509894	0.85801024	0.72984635	0.94731238
0.82370951	0.03235362	0.95622299	0.27726297	0.76619879
0.86245578	0.21094811	0.93272287	0.48265505	0.04960646
0.38953201	0.3665743	0.33754918	0.28178635	0.39637009
0.80522838	0.63509032	0.43333321	0.97677807	0.96198172
0.35928212	0.14878634	0.44201417	0.23251612	0.83375154
0.72099806	0.75212293	0.81061259	0.23756284	0.48518996
0.13329065	0.31602317	0.87489249	0.5304632	0.26191565
0.2588109	0.89039838	0.81380512	0.59139955	0.48488759
0.99314419	0.34635186	0.73292414	0.25933239	0.29230491
0.88041055	0.11473455	0.01934078	0.15717245	0.93780676
0.72332226	0.80195173	0.1792961	0.07832254	0.41154579
0.95925002	0.41696749	0.24905812	0.2111233	0.00256536
0.00580885	0.65322119	0.49666074	0.91641276	0.40573275
0.26004883	0.3010126	0.45604195	0.99935168	0.91271048
0.1508427	0.84418604	0.96241158	0.05548096	0.94093154
0.63750743	0.08979734	0.11100042	0.34646613	0.09994533
0.17176871	0.85518113	0.94522781	0.29368901	0.77444161
0.15186964	0.53105474	0.69991523	0.07876247	0.0023978
0.72306385	0.73755246	0.71402806	0.68090612	0.76015636
0.42140074	0.39036871	0.02247591	0.94725973	0.70692042

PERFORMANCE of MODEL vs MEASURED for 4 TEST cASES

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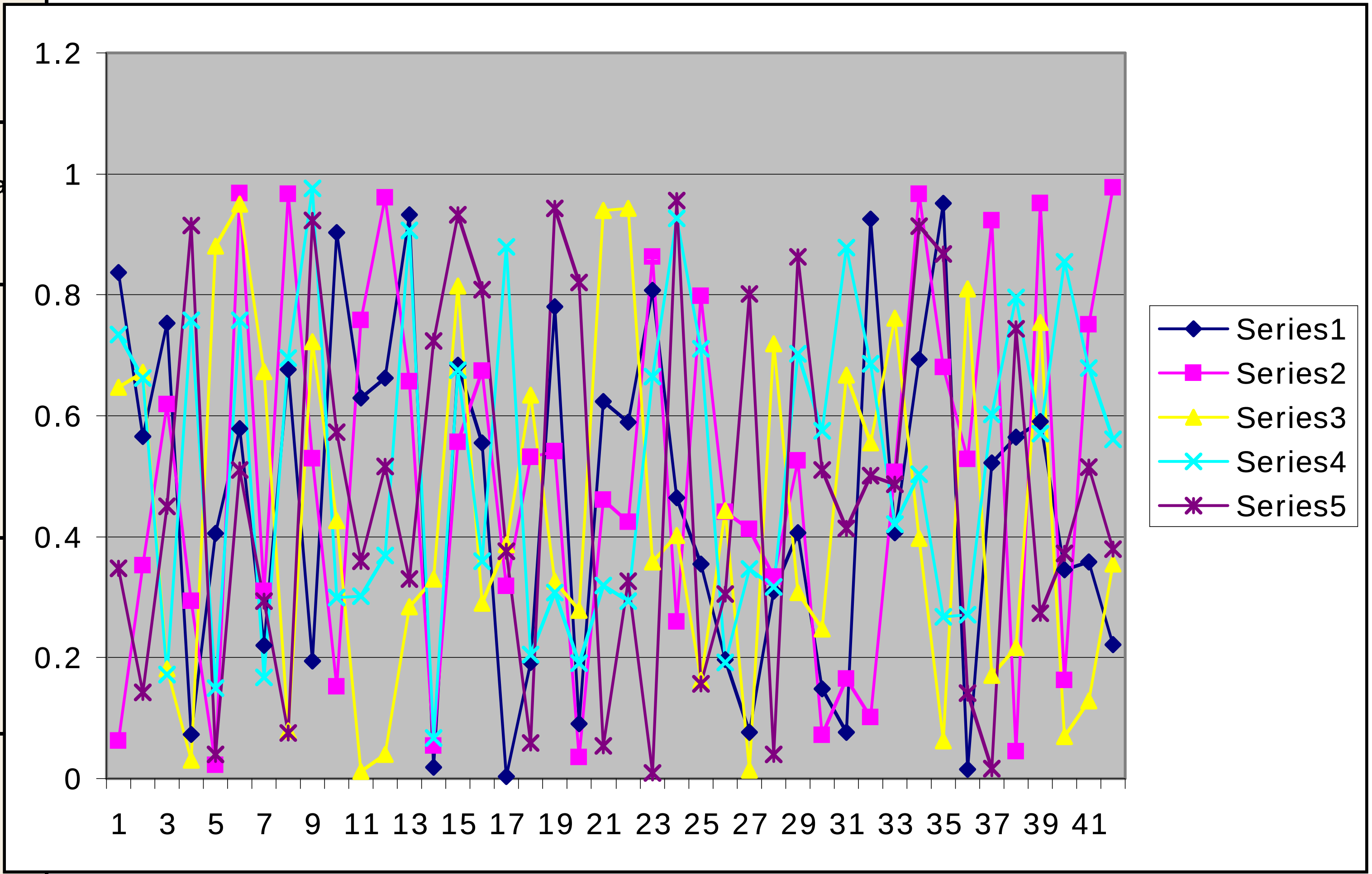

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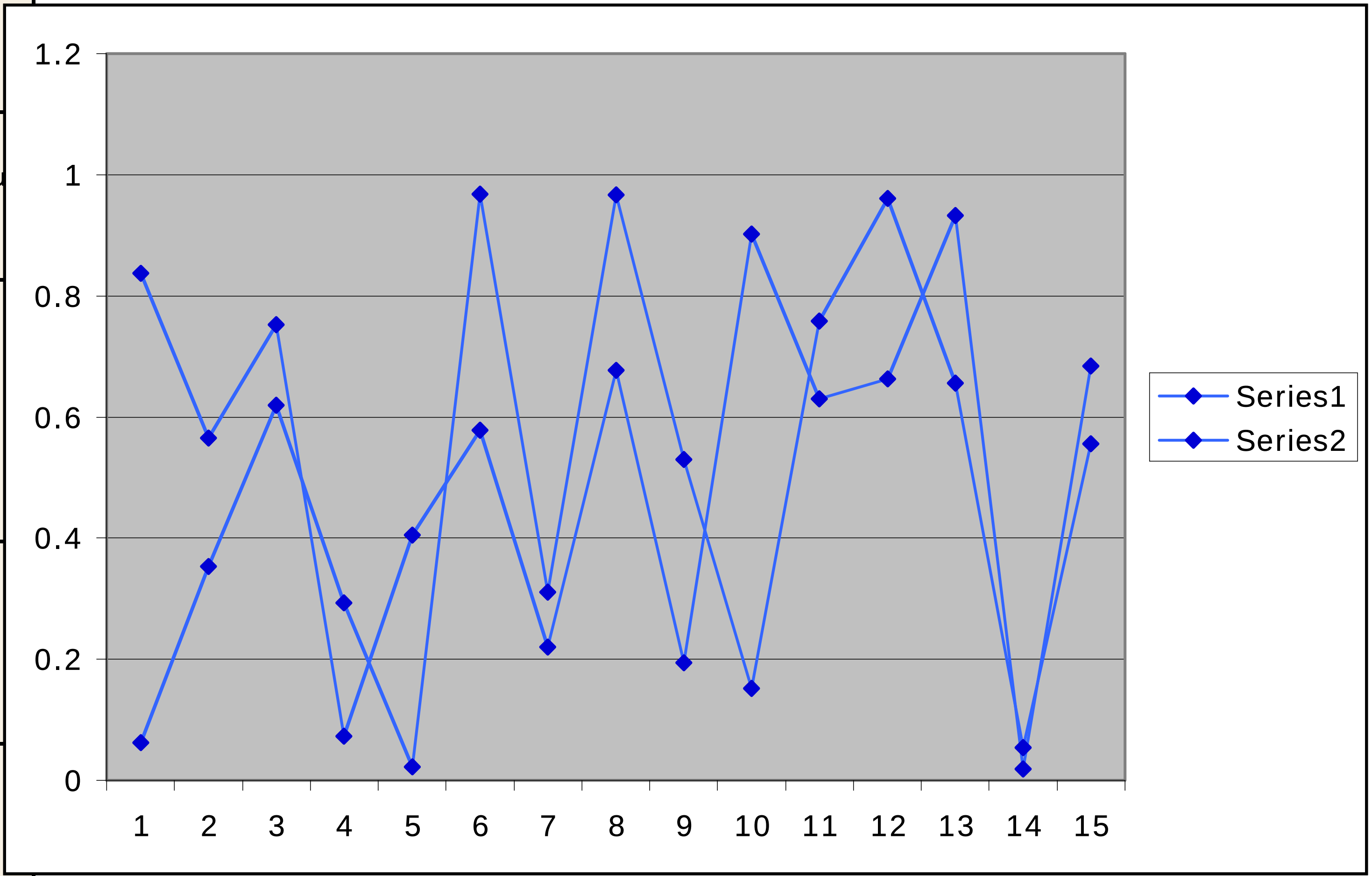
CONCLUSION



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TWO MAIN TYPES OF DESIGN PROCESSES - ON THE EXAM

Two main types of Design processes:

1 - Evolutionary Design

Means solutions are based on improvements to existing solutions

Competitive analysis is the process of comparing a design to a similar design or product

Benchmarking is the determination of how well a finction is performed

Reverse engineering is the process of decomposing an existing solution to understand how it has been constructed and where its design limitations lay.

2 - Innovative design

An innovation is a new or original idea and implies a novel way of solving a problem.

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Complex design relies on a combination of evolutionary and innovative design. Henry Petroski presents entertaining case studies of the common zipper, paper clips and pop cans to illustrate evolutionary and innovative design approaches. His book is entitled "Invention by Design".

Multiple Choice:

The term Qwerty is used to describe:

1. A relic bathymetric feature left from de-glaciation
2. The mechanical design of an 1870's typewriter
3. The marking scheme on a MENSA IQ exam
4. Term for one's age between 25 and 30
5. All of the above
6. Absolutely nothing

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Nth-Generation Design: Refining the Typewriter (1867–Present)

Early eighteenth- and nineteenth-century typing machines were designed to print raised characters that could be read by the blind.[27] The British engineer Henry Mill (although a prototype of his 1714 design was apparently never constructed), William A. Burt (whose 1829 machine featured a manually rotated circular carriage), Xavier Progin (who in 1833 marketed a circular device for the blind), Charles Thurber (who developed an automatic means for rotating the circular carriage on his typewriter in 1845), and others developed clever devices as the years went by, but the invention of the modern typewriter did not occur until 1867.[28]

Christopher Latham Sholes, together with Carlos Gidden and Samuel W. Soule, developed a carriage that would shift automatically to the left as each character was typed. In addition, the keys of their typewriter all struck the same point on the platen as they were typed, i.e., pianoforte movement (Progin's 1833 machine featured a similar movement). In fact, Sholes referred to the device as the "literary piano"—a very descriptive name. They were issued a patent for this work in 1868.

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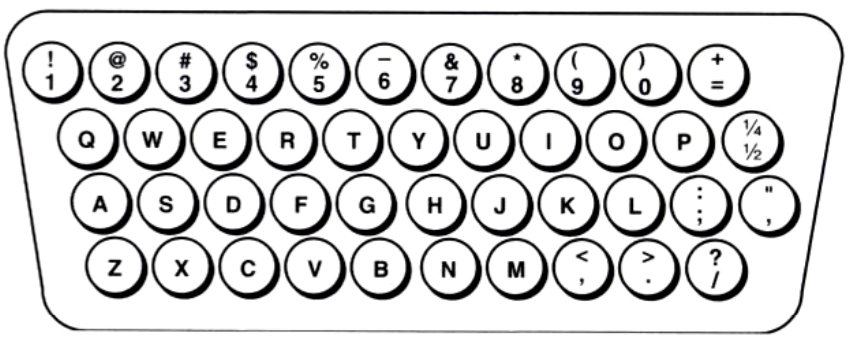

Pearson/Prentice H

FIGURE 1.10 The QWERTY keyboard.

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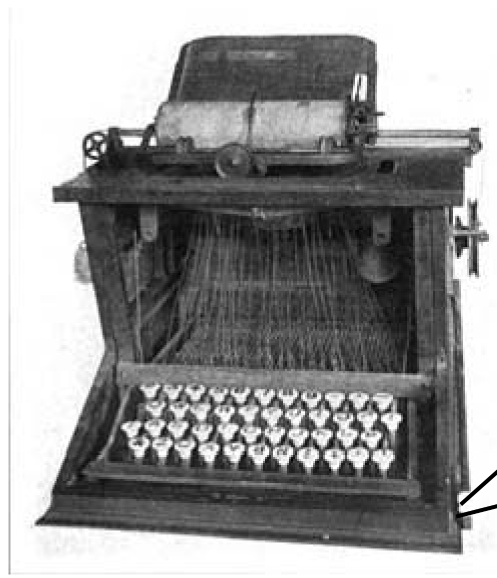
ERGONOMIC AND MECHANICAL GOALS

Sholes recognized that their machine, although satisfactory, was imperfect. One of its principal flaws was that quickly typed keys tended to collide or jam. He decided to separate the most frequently used keys on the keyboard (corresponding to the most frequently used letters of the English alphabet). Of course, a simply random placement of these keys about the keyboard was unacceptable since the user might then be required to strike the keys with awkward and difficult motions. Sholes needed to satisfy two goals: a mechanical one (separation of the keys from one another) and an ergonomic one (placement of these keys in a configuration that would aid rather than hinder the typist). His solution was the QWERTY layout, so named because of the first six letters along the top left of the keyboard. Developed over a five-year period involving more than 30 different models, the QWERTY layout became the standard typewriter keyboard configuration (Figure 1.10).

Christopher Latham Sholes



Ref: Engineering By Design 2nd edition – Gerard Voland Pearson/Prentice Hall

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Other, more efficient keyboard layouts have been developed in recent years (e.g., the Dvorak simplified keyboard shown in Figure 1.11). One might then ask why the QWERTY configuration remains the standard for today's computer keyboards. The answer: *entrenchment!* Sometimes it is very difficult to change people's habits even when such change offers substantial benefits. The QWERTY layout is most familiar to typists, programmers, and other users of keyboards. After all, typing classes usually focus on the QWERTY system; as a result, most professional typists expect to use this layout. Industry has been somewhat reluctant to adopt new, efficient keyboard layouts because of the retraining that would be necessary for their typists to become adept with these layouts. Such retraining would necessitate a temporary loss in productivity and efficiency (although long-term benefits of the new keyboard layouts could be substantial). Because of these factors, most keyboard manufacturers are very cautious about introducing any changes in their products that might alienate their customers and harm their sales. Although other keyboard layouts may indeed be more efficient than the QWERTY system, these new layouts have been introduced to the market in very small doses, thereby allowing people to become familiar with them while limiting risks to the manufacturers. (Of course, many computer software systems now allow the user to alter the keyboard layout electronically, replacing the QWERTY system with one more suited to the needs of the user. However, keyboards themselves continue to be manufactured with the original QWERTY layout.)

In 1873, the Remington Arms Company bought the patent rights to the improved design from Sholes and his business partner, James Densmore, for $12,000. The Remington Model I was released to the public and soon thereafter Mark Twain submitted to a publisher the first manuscript typed on this machine.

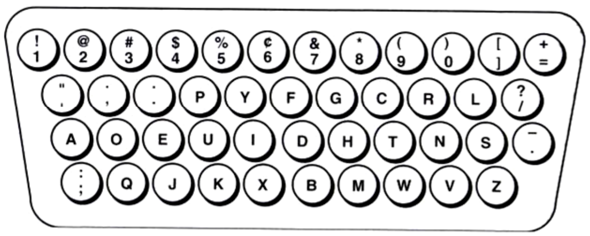

FIGURE 1.11 The Dvorak simplified keyboard.

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FURTHER IMPROVEMENTS IN NTH-GENERATION DESIGNS

Each later generation of the basic typewriter design continued to include improvements developed by others. These improvements included:

- the shift-key mechanism (1878)
- the first portable machine (the "Blick"), developed by George C. Blickensderfer (1889)
- the front-stroke design (1890)
- electrically powered systems, first developed and manufactured by Thaddeus Cahill in a 1901 form that was a commercial failure because of its exorbitant cost: $3,925 per machine; the much more successful IBM Electromatic, developed by R. G. Thomson over an 11-year period, was released in 1933
- the portable electric typewriter (1956)
- a stationary carriage with IBM spherical ball elements for changing font styles (1961)
- the IBM 72BM, an electronic typewriter with a magnetic tape that provided it with a memory (1965)
- rotating print wheels (1978)
- a portable electronic typewriter (Olivetti's Praxis in 1980)

A successful engineering solution is only satisfactory; improvements can—and should—always be made through *N*th-generation design efforts.

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Good engineering design practices enable difficult problems to be solved.

Seven (7) Characteristics of good practices are:

1 - List criteria, requirements and constraints

Criteria are general factors that can be listed, that directly affect the solution or the process of obtaining a solution, and that may aid in the choosing of a best solution

Requirements and constraints are criteria with more specific meanings either properties that a solution must possess, or limitations on the solution or the process. They must be objective and quantitative whenever possible so that the performance or characteristics of a solution can be measured and defended.

3 - Identify Users and their Tasks

The discipline of human factors engineering and ergonomics is devoted to the study of the capabilities and limitations of the human users so that designers can meet requirements while preserving safety and public welfare.

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Continued characteristics of good practices:

4 - Identify effects on all environments

All engineering works consume resources and affect their environment, natural and/or organizational/corporate environments. Continued scientific research is vital to predicting effects and mitigating problems.

2 – Generate Multiple Solutions

Engineering design often allows for many possible solutions. Only after thorough analyses and decision making techniques are applied should the most appro

Selection criteria are used for guiding the process for identifying the optimal solution.

"Gentlemen, I've decided to retire. The new chairman will be the first one to throw a six."

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Continued characteristics of good practices:

6 - Select Optimal Solution

The solution that best satisfies the selection criteria (maximizes benefits, minimizes costs) while including consideration of one's responsibility toward one's client, employer, colleagues and society – is referred to as the optimal solution.

5 - Make defensible decisions

It is the engineer's responsibility to understand the applied science involved in the solution – opinion is not enough. To ensure public safety designs must be tested and validated before products or constructed facilities are released for public use.

7 – Use Best Practice

Best that solutions are based on recognized methods, procedures, codes and standards. These evolve with advances in applied science and technologies but must do so in a methodical fashion to guarantee safety. For instance; originality is not a highly prized aspect of seatbelt design.

"Heuristic" means a "rule of thumb" T or F?

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Increasingly defined detail

TERMS used to define design requirements:

Heuristics

A very general rule of thumb like, "make it easy to use"

Guidelines

Provides more information like approximate ranges for various aspects of design, but, is still general in nature.

Standards

Provide more direction than a guideline by stating technical requirements that normally must be met for a particular industry.

Specifications

A description of the technical requirements for a specific project in sufficient detail that someone else can build or implement what was envisioned by the designer.

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Just a reminder because you've all seen this before but its on your exam – BIGTIME!!!!!

The Design Process:

Needs Assessment

What is the problem? What are the existing solutions? Whome does it affect? What does the solution need to do? What is desirable? What are the constraints?

Synthesis

What ideas are there for solving the problem.

Design Analysis

Is the design idea feasible? Best practices used? Priorities given?

Implementation

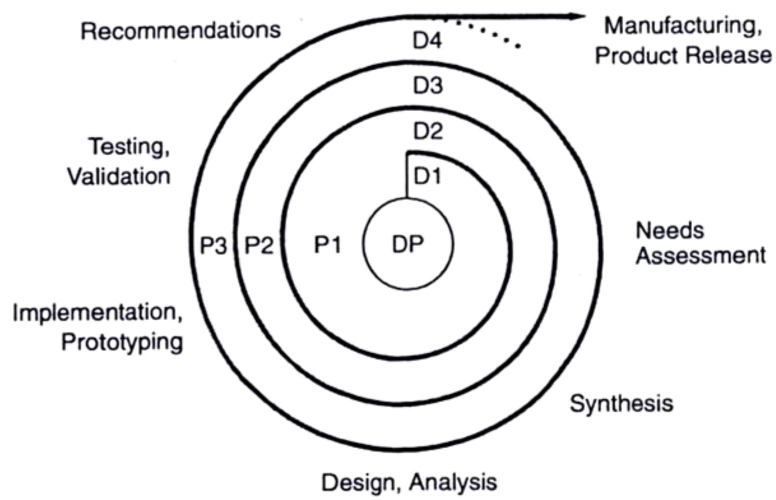
How will the solution be built? Model or simulation required? Prototype required for testing?

Testing and validation

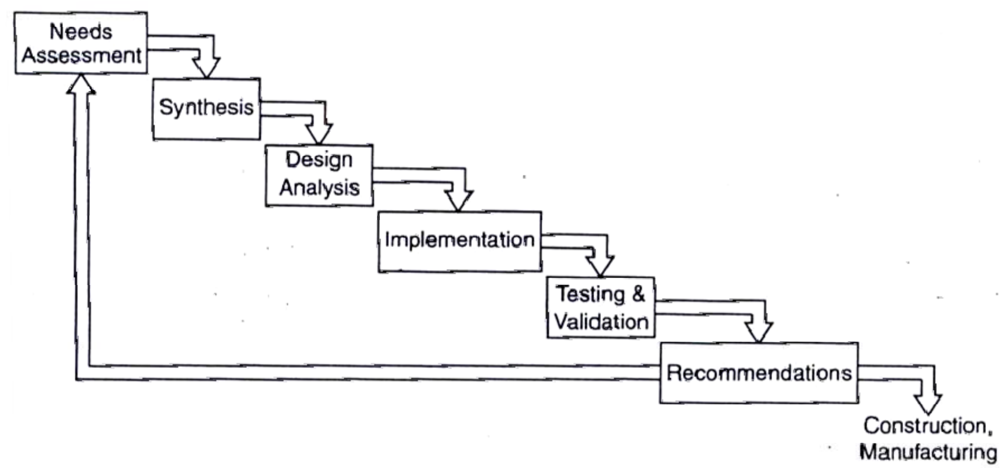
How will we evaluate solution and measure results or outcomes?

Recommendations

Are we ready to clearly state the design specifications for construction



The use-centred spiral approach ensures that testing is an integral part of design development. DP represents the design problem and includes the users, the task, and associated environments that must be considered. P1, P2, and P3 represent a progression of prototypes or models used for testing. D1 starts the feasibility cycle; D2 starts the preliminary design cycle; D3 begins the detailed design cycle; and D4 represents the final design.



Design activities are carried out in discrete stages in a typical waterfall approach, also known as the “drawing board” approach, because designers must go “back to the drawing board” (start over) when design solutions do not work out as anticipated.

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Design Skill ... est challenges are:

Cle ... problem, requirements and constraints

s of existing solutions.

s and contributing factors to problems.

tence format

ires you to restate it clearly

valuating them for feasibility or practicality -

ing ideas, (not to be confused with

er something fails.

ve challenging of established assumptions that a solution

cs thus boxing in, when out of the box may be better.

HINTS

B ... ate models to test the design solution

Concrete models are physical objects, abstract models are not touchable

... s, simulations, CAD...), Symbolic models are higher abstractions of reality, Analog models are functionally equivalent to the real object but may contain different physical qualities, deterministic models have cause-effect outcomes that are predictabl and of a measured quantity, whereas probabilistic models have contain inherent uncertainty and yield statistics.

A **Prototype** is a physical mock-up of the intended solution with sufficient functionality allow for testing. It may have high or low fidelity (accuracy of physical representation) and/or high or low functionality (extent to which it performs the intended function of t proposed solution)

NEXT TIME WE'LL COVER THIS BUT I'LL MAKE SURE YOU KNOW THE PREVIOUS THINGS

No exceptions, excuses or whining whatsoever!!!!!!

HINTS