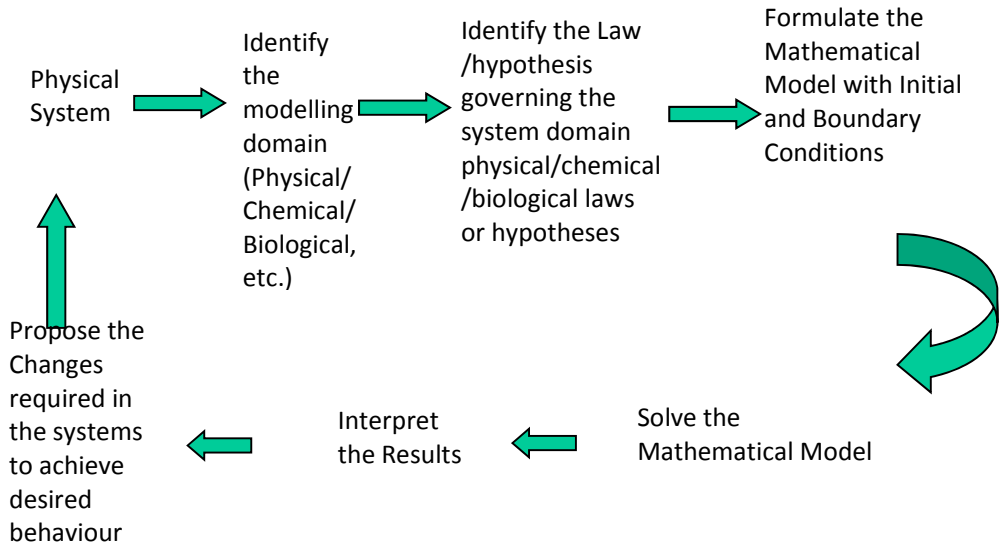
Modelling and Computer Simulation in Engineering, Science & Humanities, Pharmacy and Dentistry

Physical systems are either naturally created or they are engineered. Living physical system like respiratory system of a human being is naturally created and an internal combustion engine is an engineered system. Behaviours and performances of many of the naturally created systems can be studied scientifically and documented. Engineered systems are designed and developed to meet the defined behaviour and performance.

It is well known that many of the times naturally created physical systems may behave differently from what is documented or understood and even the engineered systems may behave differently from what was conceived while engineering. It is possible to predict the behaviour of existing natural or engineered systems or systems that we may plan to engineer for certain applications. Though there are many methods to predict the behaviour, the most intelligent and economic way of predicting and suggesting methods to improve behaviour of systems is to develop mathematical models of systems and solve these models under defined mathematical conditions. Mathematical models are mathematical equations which represent the physical systems to be built or already existing. To solve complex mathematical models, computer algorithms and programmes are developed and solved using computer systems. The solutions of mathematical models are represented numerically and or graphically in an easily understandable way. The system behaviour can predicted by proper interpretation of graphical and or numerical solutions using scientific background of the subject of the system in question. Method of predicting behaviour of systems and finding reasons for deviation in the system behaviour is called Modelling and Computer Simulation. The following figure describes the idea explained above.

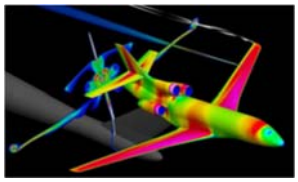
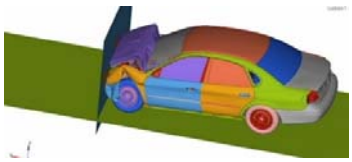
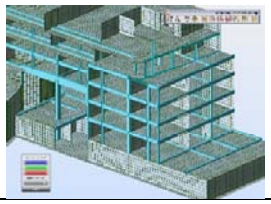
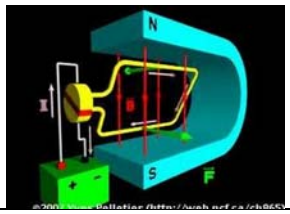
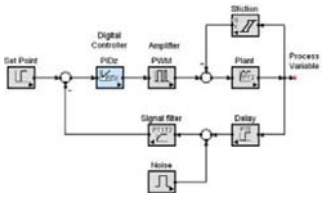


Thus, behaviour of any system and effect of the variables on system behaviour can be predicted by performing simulation and analysing results as long as the mathematical model of the system is available. The accuracy of prediction of the behaviour is very much dependent on the accuracy of the mathematical models. Developing a mathematical model is not easy, needs high level understanding of Physics, Chemistry, Biology and Mathematics depending on the domain of analysis one is interested in and many generic models are available in the form of computation models either commercially or with research groups (simulation tools). Many a times a very specific model may have to be developed by the person involved in simulation studies; knowing boundary and initial conditions, and properties of materials being used in the model are other important aspects in simulation studies.

In other words, modelling and simulation tools are used to model and simulate system behaviour and answer what if questions. Many of the times validation of virtual simulation results are necessary to develop confidence in the accuracy of mathematical models. Thus simulation tool not only act as a design tool also as a research tool.

1. **Modelling and Virtual Simulation in Engineering**

Aeronautical, Mechanical, Automotive, Civil, Electrical, Electronic, Communication, Instrumentation and Control are few important disciplines in engineering and technology. The engineers profusely use modelling and computer simulation tools and technologies for design and development of engineering systems. Today almost all engineering systems are designed using simulation tools. Following are some of the interesting examples

Aerodynamic Simulation 	Mechanism and Dynamic Simulation 
Crash Simulation 	Structural Simulation 
Electric Motor Simulation 	Control System Simulation 

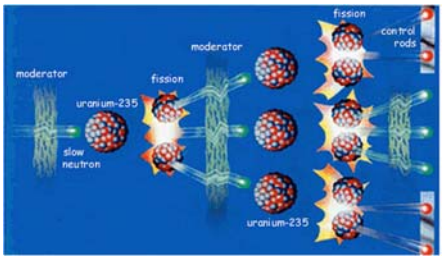
Engineers must be well versed in engineering principles, design methodologies and handling of sophisticated simulation tools.

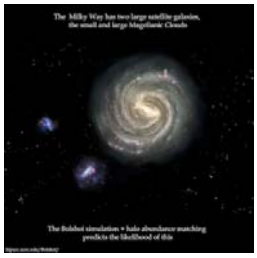
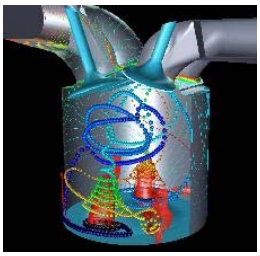
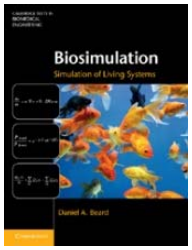
2. **Modelling and Virtual Simulation in Science and Humanities**

Physicists, Chemists, biologists, geologists also profusely use modelling and computer simulation technologies to find answers to what if questions.

Computer simulation was pioneered as a scientific tool in meteorology and nuclear physics in the period directly following World War II, and since then has become indispensable in a growing number of disciplines. The list of sciences that make extensive use of computer simulation has grown to include astrophysics, particle physics, materials science, engineering, fluid mechanics, climate science, evolutionary biology, ecology, economics, decision theory, medicine, sociology, epidemiology, and many others. There are even a few disciplines, such as chaos theory and complexity theory, whose very existence has emerged alongside the development of the computational models they study.

Simulations can be used for heuristic purposes, for the purpose of predicting new data and for generating understanding of data that is available.

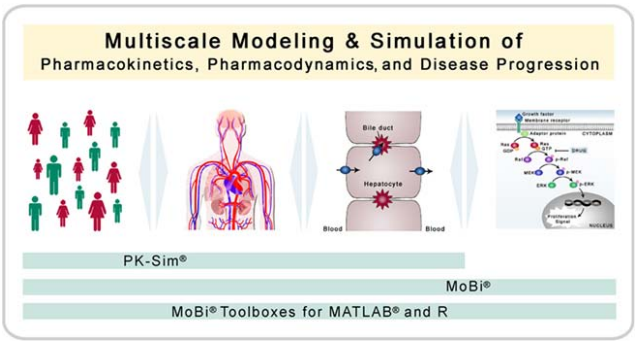


3. **Modelling and Virtual Simulation in Pharmacy**

Modelling and simulation is poised to transform drug development across the entire lifecycle from discovery to commercialization. For the biopharmaceutical industry, this transformation will enable knowledge-based decision making and foster new collaborative ways of working that will translate into more high-value treatments and increased development efficiencies. In the healthcare arena where value for money is paramount, modelling and simulation will inform future healthcare planning and practice.

In model-based development, pharmaco-statistical models of drug efficacy and safety are built from available preclinical and clinical data with expert opinion. The models are used to simulate scenarios of predicted relationships between drug exposure, drug response and patient outcomes (**Lifecycle Modelling and Simulation: Michael O'Kelly, Seth Berry, Davis Walp and Andrew Garrett).**



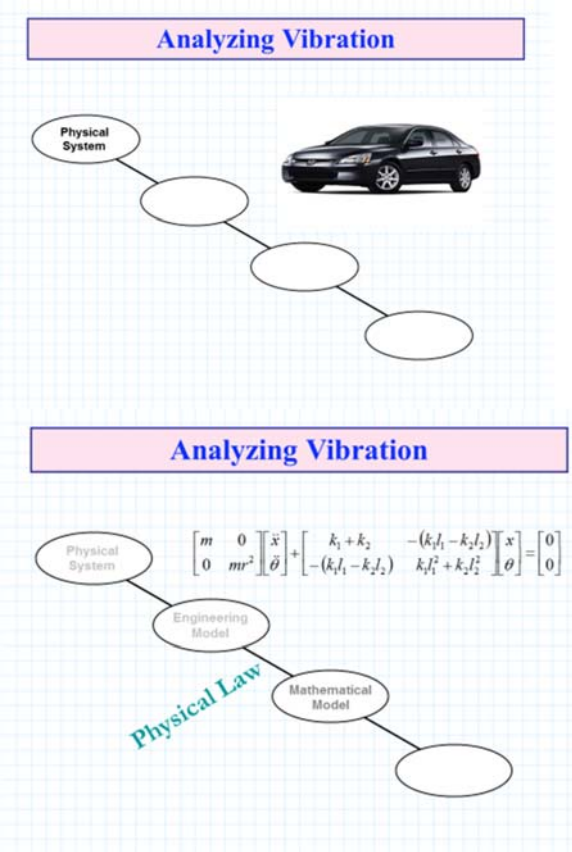
4**. Modelling and Virtual Simulation in Dentistry**

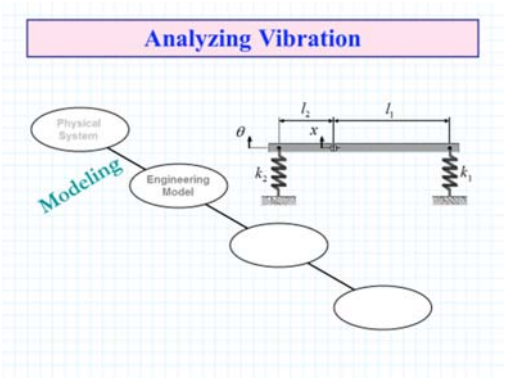
Dental educators must create learning environments that promote critical thinking, decision making and transfer of knowledge from didactic to clinical settings in order to enhance the knowledge, skills and performance of their students. The Simulated Learning Environments in Dentistry and Oral Health Curricula is becoming popular to enhance the competencies in dental graduates. Some of the simulated environmental tools are

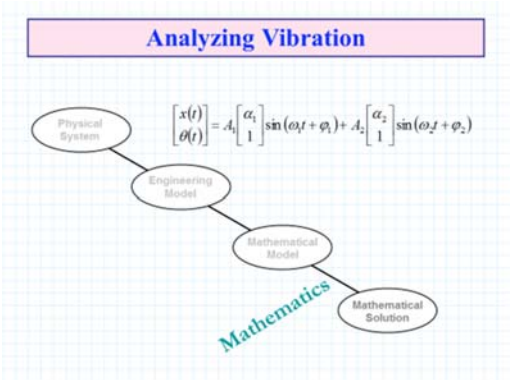
1. Virtual microscopy to augment or replace traditional microscopy with light microscopes for oral biology, oral histology and oral pathology
2. Three dimensional software for appreciating both dental anatomy and dental radiology
3. Haptic simulation units be deployed in dental schools to enrich clinical skills
4. Virtual Reality in Dental Education

Student's view of Moog Simodont Dental Trainer, with haptic handpiece simulator

Modelling and Simulation –An Example







Now solution can be graphically represented and analysed. Here we can use a number of commercial software tools for modelling, simulation and Analysis.

To end let me quote J. Ben Deaton

Simulations are believed by no one except those who conducted them

Experimental results are believed by everyone except those who conducted them

Prof. S.R. Shankapal