Developing Interactive, Computer based Learning Tools for Civil Engineering Students

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Outlines

- Software based Learning Environments
- Knowledge and “Scientific” Knowledge
- The Essence of the Scientific Method
- Data – Information – Knowledge
- Advancements in computing tools
- Emerging technologies, tools and paradigms
- Building and Construction Engineering Computing Standards
- Instructional objectives
- Innovative Tools - Multimedia Learning Process
Fundamentals of Learning Process

a. Knowledge and “Scientific” Knowledge  
b. The Essence of the Scientific Method  
c. Data – Information – Knowledge  
d. Knowledge Cycle  
e. “Computing” and “Learning”  
f. Automated Computing  
g. Software based Learning Environments
Knowledge and "Scientific" Knowledge

intuitive knowledge

knowledge of the concrete

religious knowledge

scientific knowledge

Focuses on
- the abstract
- using logical reasoning
- acquired methodologically
Characteristics of the Scientific Method

- Objectivity
- Systematic Analysis
- Logical Interpretation of Results

Elements of the Scientific Method

- Empirical Approach
- Observations
- Questions
- Hypotheses
- Experiments
- Analysis
- Conclusion
- Replication

Basic Research

Scientific Method

Applied Research

General Laws

Information or Ideas for alternative Courses of action
Measurements of phenomena (e.g. sales statistics of a department store)

Determination of relationship amongst data with a view to facilitating understanding of the phenomena, their relationships and decision-making (e.g. past and predicted future sales trends)

Blend of information, experience and in-sights that provides a framework that can be thoughtfully evaluated when assessing new information or evaluating relevant situations

Measurements of phenomena (e.g. sales statistics of a department store)
Decision-Making is the process of resolving a problem or choosing amongst alternative opportunities.

- What is the problem or opportunity?
- How much information is available?
- What information is needed?
Knowledge Cycle

KT1: Defining research questions and methodologies

KT2: Conducting research (as in the case of participatory research)

KT3: Publishing research findings in plain language and accessible formats

KT4: Placing research findings in the context of other knowledge and sociocultural norms

KT5: Making decisions and taking action informed by research findings

KT6: Influencing subsequent rounds of research based on the impacts of knowledge use
Data > Information

Collective Knowledge Cycle:
- Sharing
- Acquisition
- Action

DATA → INFORMATION
Collect Share

Analysis → MASTERY
Learn
Master Lead

INFORMATION → KNOWLEDGE
Understand
Integrate

INTELLIGENCE → COMPETENCE
Apply
Empirical cycle

- Hypothesis
- Experiment
- Evaluation

“is it true? (and why?)”
Design cycle

- Design
- Simulation/implementation
- Evaluation

“is it possible?” (and how?)
**“Computing” and “Learning”**

- Learning is a social process which proceeds by and through conversations, constructed by the learners themselves.
- In engineering and other technological fields, the old learning paradigm was about what software/tools can do. However the new learning paradigm is all about what learners can do.
- The mentor is second only to the learner in impacting learning effectiveness. The effective mentor helps the student strengthen their values and improves learning efficiency to reduce time required for learning (Kevin 2008).
At present, automated computing is the main means for the application of engineering knowledge.

The growth and development in the application of computing tools and technologies, and the development of new paradigms has been incremental and linear.

Many fields have taken significant advantage of the recent advancements in computing technology, to adapt, apply and enhance the way people learn these fields.

This study reviews some of the recent developments in the computing side, introduces computer based interactive tools and explores how they may be used to improve the way civil engineers use more innovative, effective and efficient techniques to grasp necessary understanding of engineering concepts.
Software-based learning environments provide an opportunity for students to investigate, visualize and discuss their own ideas and explanations of various engineering principles being taught as curriculum.

The development of intelligent tutoring systems provides a new way to harness and exploit the educational potentialities of computers keeping in mind the social dimensions of learning process.

The goal of an intelligent tutoring system can be expressed as its ability to customize or rather individualize the learning process.
An interactive application LEARN CIVIL for computer aided learning of civil engineering curriculum is presented. Designed as a self-tutor program keeping in mind the CE curriculum and hence can run parallel with the theory classes providing an easier and friendly platform to learn and understand the basics of civil engineering.

The interface is developed in a simple and self-interactive manner using tree views for convenient visualization of complete course structure and equipped with self-explanatory interactive graphics, description for each form, theoretical details, worked out examples and “help” will further assist in the learning process.
a. Why Interactive Learning?
b. What is an interactive learning system?
c. Four Types of Emerging Technologies
d. Instructional Objectives
e. KID Concept Model
f. Pyramid Representation of DIKW Hierarchy
Why Interactive Learning?

Learning Pyramid

- 5% Lecture
- 10% Reading
- 20% Audiovisual
- 30% Demonstration
- 50% Discussion
- 75% Practice doing
- 90% Teach others/immediate use

Average student retention rates

Source: National Training Laboratories, Bethel, Maine
At present, automated computing is the main means for the application of engineering knowledge.

Automated computing gives a false sense of accuracy.

Automated computing obscures underlying principles and their significance.

New generation of engineers lack in understanding even if they have computing skills.

To instill understanding, innovative techniques are needed that correspond with applied engineering.

Interest of students in engineering and its applications needs to be emphasized.
What is an interactive learning system?

- Different types of interaction
  - Learner-content
  - Learner-instructor
  - Learner-learner
  - Learner-interface

Ref: Heng Luo, Jing Lei, IDD&E, Syracuse University
## Four Types of Emerging Technologies

<table>
<thead>
<tr>
<th>Type of ICT tools</th>
<th>Definition</th>
<th>Examples</th>
</tr>
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<tbody>
<tr>
<td><strong>Educational Networking</strong></td>
<td>Online learning platforms that connect learners using social networking technologies, exhibiting similar functions to sites like Facebook or MySpace.</td>
<td>Ning, Classroom 2.0, Elgg</td>
</tr>
<tr>
<td><strong>Web-Based Learning</strong></td>
<td>A set of online applications or services that expand learners’ abilities to interact and collaborate with each other in the process of searching, receiving, organizing, and generating educational content.</td>
<td>Wiki, blog, podcasting, social bookmarking, virtual worlds</td>
</tr>
<tr>
<td><strong>Mobile Learning</strong></td>
<td>Mobile devices or technologies used for educational purposes that support different aspects of instruction or make new educational activities available.</td>
<td>Smartphone, PDA, GPS (for augmented reality games), interactive response pads</td>
</tr>
<tr>
<td><strong>Classroom Equipment</strong></td>
<td>Stand-alone devices that are used in traditional classrooms to facilitate the interaction between teachers and students in different class activities.</td>
<td>Interactive whiteboard, touch-screen computer, Kiosk</td>
</tr>
</tbody>
</table>
Instructional objectives may involve skills that cover a broad spectrum of complexity and difficulty. The “Taxonomy of Educational Objectives (Cognitive Domain)” developed by Bloom and colleagues defines a hierarchy of six levels:

- **Knowledge**—repeating memorized information
- **Comprehension**—paraphrasing text, explaining concepts in jargon-free terms
- **Application**—applying course material to solve straightforward problems
- **Analysis**—solving complex problems, developing process models and simulations, troubleshooting equipment and system problems
Instructional objectives

- Synthesis—designing experiments, devices, processes, and products
- Evaluation—choosing from among alternatives and justifying the choice, optimizing processes, making judgments about the environmental impact of engineering decisions, resolving ethical dilemmas
Conceptual structure of data, information and knowledge (denoted as K), with the latter being a special form of information personally held by the individual engineer.

KID concept model showing skill pathways that use data, knowledge and information.
Pyramid Representation of DIKW Hierarchy

- Data
- Information
- Knowledge
- Wisdom
Recent Advancements in Interactive and Innovative Learning Tools

a. Traditional Teaching Methods – An evaluation
b. Paradigm Shifts in Education
c. Innovative Tools - Multimedia Learning Process
d. Advancements in computing tools
e. Computing in Engineering
f. Human-Computer Interface (HCI)
g. Brain Computer Interface (BCI)
h. Information and Data Access
Traditional Teaching Methods – An evaluation

- Teaching process includes two major components
  - Sending and
  - Receiving information.
- Teacher – Sender
- Student – Receiver
- Message – Information
- Teacher controls the instructional process,
- Directed instruction model has its foundations embedded in the behavioral learning perspective (Skinner, 1938).
- The learning mode tends to be passive and the learners play little part in their learning process (Orlich et al., 1998).
Paradigm Shifts in Education

- From linear to hypermedia learning.
- From instruction to construction and discovery.
- From teacher-centered to learner-centered education.
- From absorbing material to learning how to navigate and how to learn.
- From schooling to lifelong learning.
- From learning as torture to learning as fun.
- From the teacher as transmitter to the teacher of facilitator.

I hear and I forget.  
I see and I believe.  
I do and I understand.  
- Confucius

Damodharan V. S. et al.

Traditional method – A one way flow

Multimedia learning – An interactive learning process
The instructional approaches based entirely on self-paced computer-assistance are extremely effective.

The widespread use of internet, intranet and more recently cloud computing is changing the way computers are being used, and information is being shared and stored.

The practicing civil engineers are involved in a broad spectrum of activities and tasks, such as, conception, selection, and development of structural systems, suitable for a particular application, preliminary sizing and design of structural components, coordination and collaboration with several other disciplines etc.

All these skills require an extensive, rigorous and efficient instructional system in universities.
Emerging technologies, tools and paradigms

- The World Wide Web offers educators a new medium to deliver teaching and learning material – one which bring new and exciting ways of learning, and an alternative to traditional teaching techniques” (Allen 1998).
- The old computing is about what computers can do; the new computing is about what people can do (Ben 2002).
- Not only transmitting information, but engaging the students in authentic tasks will also be the key for a successful learning approach. Thus, the fundamental idea of interactive learning is to help learners become actively engaged in collaborative work via various computer-supported processes.
Advancements in computing tools

- Tremendous development is going on in various fields related to computing software and hardware and its applications for last several decades.
- Often these developments are done independently with a particular focus, including the development of new Human Computer Interfaces (HCI), the new display technologies and devices, the Brain Computer Interface (BCI), and in Robotics etc.
- Several new integrated devices such as the smart phones, the tablet and slate computers have become more popular.
- A similar development is happening in computing paradigm and software with the special focus on visualization.
- The wide spread use of internet, intranet and more recently cloud computing is changing the way computers are being used, and information is being shared and stored.
Technology, Tools and Paradigms

- **Methods**
  - Basic way of solving a Problem

- **Techniques**
  - Effective way of using Methods

- **Tools**
  - Collection of “Techniques” in an applied way

- **Paradigms**
  - Way of thinking, style of approaching a problem

- **Technology**
  - An applied collection of Methods, Techniques, Tools and Paradigms
- New tools give rise to new applications
- New applications demand new tools
- Research in tools and in applications feed each other
Human–computer interaction (HCI) is the study, planning and design of the interaction between people (users) and computers.

Interaction between users and computers occurs at the user interface (or simply interface), which includes both software and hardware.

For example, characters or objects displayed by software on a personal computer's monitor, input received from users via hardware peripherals such as keyboards and mice, and other user interactions with large-scale computerized systems such as aircraft and power plants.
A brain–computer interface (BCI), sometimes called a direct neural interface or a brain–machine interface (BMI), is a direct communication pathway between the brain and an external device.

The field of BCI research and development is focused primarily on neuroprosthetics applications that aim at restoring damaged hearing, sight and movement.

Because of cortical plasticity of the brain, signals from implanted prostheses can, after adaptation, be handled by the brain like natural sensor or effector channels.

Following years of animal experimentation, the first neuroprosthetic devices implanted in humans appeared in the mid-nineties.
Human-Computer Interface (HCI)  
Brain Computer Interface (BCI)
Information and Data Access

• Mobility, Connectivity and Access Technologies
  – Internet, intranet, remote desktop, VPN, WLAN, wireless technology, 3G, 4G, GPS, GPRS, Cable TV, WiMax, Mobile Broadband and many other innovative techniques has made it possible to access any sort of knowledge within such a limited time which was not even imaginable in the past
Cloud Computing

– Cloud computing differs from the classic client-server model by providing applications from a server that are executed and managed by a client's web browser, with no installed client version of an application required.

– Users may remotely store and access personal files such as music, pictures, videos, and bookmarks; play games; or do word processing on a remote server.
Cloud Computing

Cloud computing logical diagram
Information and Data Access

• Social and Professional Networks
  – Networks like Twitter, Facebook, LinkedIn etc. have made it possible to get in touch with family, friends and work groups around the clock, no matter where you are.
  – Online journals, blogs, newsgroups, Wikipedia and several search engines are available to find the relevant information in abundance.
  – Google maps and Google earth can guide us to any part of the world and even it is possible to upload structures related information in Google Earth
Information and Data Access

Operating Systems and Platforms

- An operating system (OS) is software, consisting of programs and data that runs on computers, manages computer hardware resources, and provides common services for execution of various application software.

- Operating systems are found on almost any device that contains a computer, from cellular phones and video game consoles to supercomputers and web servers.

- Examples of popular modern operating systems are: Android, BSD, Linux, Mac OS X, Microsoft Windows, and Unix, each offering its own specific advantages and domains of applications.
Integration of Information and Communications Technology in Teaching and Learning

a. Reasons to Integrate
b. Barriers to Integration
c. Suppressing the barriers
d. Tools for Integration
Reasons to Integrate

• ICT provides opportunities for effective communication between teachers and students in ways that have not been possible before
• Learners have changed
Barriers to Integration

- **Teacher-level barriers**
  - Lack of teacher confidence and competence
  - Resistance to change & negative attitudes

- **School-level barriers**
  - Lack of time
  - Lack of effective training
  - Lack of accessibility
  - Lack of technical support
Suppressing the barriers

- Teacher-level
  - Lack of access
    - Taking advantage of resources offered at schools
    - Access to ICT resources at home
  - Resistance to change
    - Being open minded towards new ways of teaching
  - Lack of time
    - Acquiring skills of self-organization and time management
  - Lack of training
    - Preparing themselves by self-training
    - Knowing how to access resources
    - Taking up opportunities offered at schools
  - Lack of technical support
    - Relying on themselves to be able to solve problems in their use of ICT
    - Accessing available support
Suppressing the barriers

• School-level
  – Lack of access
    • Providing ICT resources including hardware and software
  – Resistance to change
    • Training in new pedagogical approaches
  – Lack of time
    • Providing sufficient time: reducing number of teacher lessons or increasing the daily lesson time
  – Lack of training
    • Providing training courses in dealing with new devices, modern technologies, and new pedagogical approaches
  – Lack of technical support
    • Providing continued technical support
Tools for Integration

• **Hardware Tools**
  – PCs, handheld devices

• **Software Tools**
  – Courseware (e-Learning, LMS, etc)
  – Web-based resources
  – Communication (voice chat, forums, video conference)
  – Mind tools (concept mapping, multimedia authoring)
Civil Engineering Computing – Interactive Learning Tools
Paradigms in Structural Engineering

- Structural System Development and Preliminary Design
- Structural Modeling, Analysis and Design
- Detailing, Drafting, Construction
- Collaborative Research, Design and Communication
- Development and Use of Software
- Teaching and Professional Development
- Performance Based Design
- Modeling Techniques (Mesh Less Methods for Structural Analysis)
- Structural Instrumentation and Monitoring
- Smart Materials
The practicing structural engineers are involved in a broad spectrum of activities and tasks, such as:

- Conception, selection, and development of structural systems, suitable for a particular application
- Preliminary sizing and design of structural components
- Coordination and collaboration with several other disciplines to consider their requirements, such as with architects, mechanical and services engineers, electrical engineers, geotechnical engineers, etc.
- Structural modeling and analysis
- Detailed design of structural components
Performance based evaluations, design of strengthening and retrofitting systems

Detailing and drafting to produce construction drawings and documents

Support during construction to tackle changes and issues arising after design
With the increasing interest in building information modeling in the industry, various model-based applications have been introduced to facilitate the professionals.

Building Information Modeling (BIM) is the process of generating and managing building data during its life cycle. BIM design tools allow for extracting different views from a building model for drawing production and other uses.
IFC (Industry Foundation Classes) are a vendor-neutral data repository for building information models (BIM) including both geometry and properties of 'intelligent' building objects and their relationships, thus facilitating the sharing of data across otherwise incompatible applications.

Another tool used in the computing field is OpenSees. OpenSees, (the Open System for Earthquake Engineering Simulation), is an object-oriented, open source software framework. It allows users to create finite element applications for simulating the response of structural and geotechnical systems subjected to earthquakes.
“A picture is worth a thousand words”

A graphic representation is worth a thousand data points

Same Data or Information can be represented in a number different ways

The faculty should use visualization to aid in teaching and to increase student interest

Students should be encouraged to graphically represent data and infer information and knowledge from it
Levels of Visualizing

• Hand Sketches
  – Raw but serve as a starting point and increase understanding

• Physical models
  – May be expensive and may be unrealistic at times
  – Time consuming and require special skills

• Virtual Models
  – Allow versatility, visualization, better understanding of theory and what-if types of studies
• 1V Visualization
  – Value Bar Charts
• 2V Visualization
  – X-Y Plots
• 3V Visualization
  – X,Y, Value Flat Contours
  – X,Y, Z Plots
• 4V Visualization
  – X, Y, Z, Value Contours
• 5V Visualization
  – X, Y, Z, t, Value Contours
Example 1: Cross-Section Response

- The Section Geometry
- Elastic Stresses
- Load Point
- Neutral Axis
- Ultimate Stresses
- Cracked Section Stresses
- Section Capacity
- Moment Curvature Curve
Load Point and Eccentricity

Biaxial Elastic Stress Distribution

Neutral Axis and Strain Plane

Ultimate Stress – Rectangular Block
Stresses in Rebars

Cracked Section Stresses

Axial-Flexural Capacity
Example 2: Visualization of Framing Conditions

XZ-Plane

YZ-Plane
If a picture is worth a thousand words, an animation is worth a million.

Animation can show sequence of graphic representations with changing parameters or effect of parameters.

Animation can be used to show:
- Change of values with time
- Change of values between a range

Almost any graphic visualization can be animated.
• **Structural Engineering**
  – Animation of static analysis results for emphasis
  – Mode Shapes to provide insight into intrinsic response
  – Results of Time History Analysis at Time Step
  – Results of Nonlinear Analysis and Load Step

• **Other Fields**
  – Traffic Simulation
  – Hydraulic Modeling
  – Seepage Flow
Virtual Reality

- Virtual Reality uses interactive, real-time manipulation of parameters and showing their effect
- Special hardware may be needed to fully exploit the Virtual Reality advantages
- Simplified PC based implementation may be sufficient for most classroom teaching problems
- The use of Virtual Reality Modeling Language (VRML) is commonplace in many universities as a teaching tool
• An extension of Virtual Reality using special hardware extending to complete enclosures or rooms where a large interactive and responsive environment is created
• The “users” of this environment are actually part of the environment itself and feel themselves completely immersed in it
• Large Immersive environments extending to several actors or avatars sometimes connected through internet at various locations can interact and learn from each other and from environment
Visualization of Structural Response

- Deformations
- Mode Shapes
- Action Diagrams (M, P, V ...)
- Action Contours (M11, M22, M12, Min, Max, Vector ...)
- Stress Contours (S11, S22, S12, Min, Max, Vector ...)
- Virtual Work Diagrams
- Action-Deformation Plots
- Combined Deformed and Action Plots
- ...

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Effect of Beam Size on Moment Distribution

a) Beam Depth = 300 mm

b) Beam Depth = 500 mm

c) Beam Depth = 1000 mm
Eccentric and Concentric Response

Unsymmetrical Mass and Stiffness

Symmetrical Mass and Stiffness

Mode-1  Mode-2  Mode-3
Introduction to LEARN CIVIL – An interactive self-tutor program for CE Curriculum
An Interactive computer program developed to facilitate interactive way of learning civil engineering subjects, is introduced.

- Designed keeping in mind the curriculum and hence can run parallel with the theory classes.
- The basic idea behind the project is to make the engineering concepts familiar and clear with the students.
- Easier, friendly and self tutor platform to make the students learn and understand the basics of engineering in an easier, simpler and fun way.
Key objectives of LEARN CIVIL include

- To generate a learning attitude among the students,
- To make them friendly with their subjects and not just memorize for exams and to lay a reinforced foundation stone for the four years degree program.

It covers a wide spectrum of CE areas (courses modules) including engineering mechanics, strength of materials, theory of structures, surveying, fluid mechanics, structural analysis, design of concrete structures, design of steel structures, foundation engineering, hydraulics, environmental engineering, soil mechanics and water resource engineering.

Proposed to be an integral part of curriculum
The interface is very simple and self interactive.
The left side tree view of the complete course structure makes it easy to select any topic from any of the subjects.
Interface is also equipped with all the necessary tools on the top toolbar to open, new, save, print any file or data.
The help provided in the software makes it easy to adopt for the students.
The graphics included in the project are very attractive and self explanatory.
The theory button in each of the form provides the necessary theoretical help on the related topic.
The examples are mostly taken from the course modules/text books which will help the students in their understandings.
Introduction to LEARN CIVIL

Stress on Inclined Plane for Simple Tension & Compression

Torque Applied on this Shaft
Torque Shifted to this Shaft

Both Shafts Joined

Torque Shifted from one Shaft to other Shaft

Properties
- Speed in RPM: 1200
- Torque (applied): 250

Calculations
- Angle turned per min: 0
- Power Transmitted: 0

Status

Units + Theory
Courses covered in 1st Phase

Engineering Mechanics:
• Simply supported beams carrying different load conditions.
• Sectional properties of different shapes and common beam sections.
• Friction on plane and inclined surfaces.
• Newton's law of motion.
• Rotational motion.
• Centrifugal force.
• Angular motion and acceleration.
• Angular momentum.
• Virtual work.
Courses covered in 1st Phase

Strength of Materials.

• Hooke’s Law.
• Stress – Strain study on inclined planes for tension and compression.
• Thin cylinder subjected to internal pressure.
• Poisson’s Law.
• Mohr’s stress strain circle.
• Stresses generated due to torsion in a circular shaft.
• Power transmitted due to torsion.
• Torsion of hollow shafts.
• Composite shafts.
• Close coiled springs.
• Elastic Stability of Struts (Euler’s Theory).
Courses covered in 1st Phase

Theory of Structures.
- Statically determinate structures.
- Simply supported beams.
- 3 hinged arches carrying different load conditions.
- Cables carrying different load conditions.
- Practical cases for cables used as bridges.
- Analysis of Trusses.
Simply supported beam carrying point load

Poisson’s law
Stress strain study

Hooke’s law
Stresses on inclined planes

Hoop stress

Stresses on inclined planes
Mohr’s stress circle

Power transmitted by a circular shaft
Stresses generated in a hollow shaft

3 hinged arch carrying uniformly distributed load
Cable carrying point load

Cable carrying uniformly distributed load
Theory is provided in all the topics just need to click a button.
Conclusions
Discussion and Conclusions

- The impact of knowledge explosion in almost all areas of engineering demands a rationalization of curriculum which requires a fundamental change in current teaching and learning methods.
- In this paper, an efficient engagement of latest computing technologies in interactive learning process is discussed with special emphasis on curriculum of civil engineering.
- A newly developed computer tool focusing on above mentioned facts is introduced.
- Conventional instructional simplicity in conjunction with collaborative interactive software-based learning can successfully facilitate the knowledge transfer as well as understanding of engineering concepts.
Thank You