Integration of Emerging CE Technologies into Undergraduate Curricula:

ISIS Canada’s Educational Modules

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To advance civil engineering to a world leadership position, through development and application of:

- Fibre reinforced polymers (FRPs)
- Structural health monitoring (SHM)

for the benefit of Canadians (and others) through innovative and intelligent infrastructure

The objective is to revolutionize the design of civil engineering structures…

- while recognizing the resulting educational need

A RESEARCH organization which has EDUCATION as a PRIMARY FOCUS
There is an urgent need to introduce **emerging technologies and research** in undergraduate civil engineering curricula.

The question is: how can we **enable and encourage** student exposure to the **principles and philosophies** of their use?
To maintain what we have as we plan and build for the future, civil engineers will have to apply **creative and innovative technologies** and solutions.

Use of SHM systems and FRP materials in structural applications is increasing steadily:
- **Effective and efficient** solutions
- Numerous field applications
- Implementation guidelines are now globally available

SHM and FRPs are still not considered mainstream technologies:
- Lack of **awareness and basic understanding** by most members of engineering community
Growing need for **interdisciplinary** and **system-based** approaches to UG education

Increasing need to understand **advanced, smart materials and structures**:

- Photonics-based technologies such as **fibre optic sensors** (FOSs) will become more significant in engineered products and systems
- Optical **sensing and monitoring** will continue to advance
- Everything will, in some sense, be **“smart”**; infrastructure will be attuned to our needs and will adapt its behavior accordingly
- Advances in computing and simulation may radically redefine common practices in engineering
- There will be growth in areas of simulation and modeling around the creation of new engineering “structures”
Background: Motivation

- Technology transfer
  - A critical component of ISIS Canada’s mandate

- Training of “HQP”
  - A central theme of the ISIS Research Network

- ISIS Canada education committee
  - Develop and implement strategies to attain educational, training & technology transfer objectives
  - Project 4.1.5: Educational modules
  - Focus on undergraduate and college students
Increased use of innovative technologies in the engineering profession requires a **basic understanding and awareness** by all members of the profession.

Combined with a **recognition of competence** (or lack thereof) and the **need for lifelong learning**

**Objectives:**
- Infiltrate existing curricula (university & college)
- **Make it easy** to teach about FRPs and SHM
- **Teach the teachers**…
- New technologies are **NOT exotic**

Development of **“educational modules”**
Ten targeted educational modules:

1. Mechanics examples Incorporating FRPs
2. Intro to FRP composites for construction
3. Intro to FRP-reinforced concrete
4. Intro to FRP-strengthened concrete
5. Intro to structural health monitoring
6. Handling & Application of FRPs for Construction
7. Intro to life cycle costing for innovative infrastructure
8. Durability of FRP composites for construction
9. Intro to prestressing with FRPs
10. Compendium of FRP and SHM case studies
Components

a) Notes
   – In MS Word and PDF
   – 20 to 30 page booklet

b) Slides (and handouts)
   – In MS PowerPoint and PDF
   – Over 500 slides to accompany notes

c) Worked examples

d) Suggested assignments (solution sets) and laboratories (materials and support)
Benefits

1. Students become **active participants** in the broader engineering (research) community
   - Excitement, motivation, and inspiration = student success

2. Increased depth of **student understanding**
   - Opportunity for instructors and students to consider important issues in the in-service behaviour of structures

3. Supports rather than displaces **fundamentals**

4. An awareness of the full suite of potential infrastructure solutions **makes graduates more attractive** to employers and more successful in industry
5. Increased **sustainability** of infrastructure solutions

6. True **integration** of engineering disciplines

7. Exposure to **real-world** engineering problems

8. Builds “**competency awareness**”

9. Encourages a **culture of innovation** in civil engineering (new technologies are NOT exotic)
Example: Module 5 on SHM

1. What is structural health monitoring?
2. Methodology
3. Sensor technology
4. Testing categories
5. SHM system design
6. Case studies of SHM applications in Canada
7. Civionics specifications
8. Detailed example: SHM of the Golden Boy
9. The future of SHM
10. References and additional guidance

Give the big picture. Not only research.
Sample Lecture Notes

Section 2
What is Structural Health Monitoring?

Structural health monitoring is essential in the field of engineering, particularly in the construction and maintenance of bridges and other large structures. It involves the continuous monitoring of a structure to ensure its safety and efficiency. The goal is to detect and predict the onset of potential failures before they become catastrophic. This section will discuss the importance of structural health monitoring and its applications.

Definition of SHM
Structural health monitoring (SHM) is a process that involves the continuous monitoring of a structure to detect and predict potential failures. This is achieved through the use of advanced sensors and data analysis techniques. The primary goal of SHM is to ensure the safety and efficiency of structures by identifying and addressing potential problems before they become catastrophic.

Methodology

System Components

A typical SHM system consists of several components, including sensors, data acquisition software, and data analysis tools. These components work together to monitor the structural health of a building or a bridge. The sensors collect data, which is then processed and analyzed to identify any issues that may arise.

Figure 2.1: Schematic diagram of a typical SHM system

Acquisition and Collection of Data

The data collected by the sensors is then processed and analyzed. This is typically done using data acquisition software, which can be integrated with the sensors. The software is responsible for collecting, storing, and analyzing the data. This information can then be used to make decisions about the maintenance and repair of the structure.

Figure 3.1: Data processing (automatically by computer)

Conclusion

Structural health monitoring is a critical aspect of modern engineering. It is essential for ensuring the safety and efficiency of structures. By continuously monitoring a structure, engineers can detect potential failures before they become catastrophic. This allows for timely and effective interventions, which can save lives and prevent costly disasters.

Figure 4.1: Showing the magnitude of vibrations in the Golden Gate Bridge support shaft at different locations

Decision to Replace Support Shaft

The decision to replace the Golden Gate Bridge support shaft was based on data collected from the structural health monitoring system. This data indicated that the shaft was approaching its design limit and could no longer support the bridge. This decision was made to ensure the safety of the bridge and its users.

Figure 5.1: Inspection of the Golden Gate Bridge support shaft at different locations

Table 1: Data collected from different sensors in the support shaft

<table>
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<tr>
<th>Sensor Type</th>
<th>Measured Value</th>
<th>Factor</th>
<th>Location</th>
<th>Calculation Method</th>
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<td>Dead Load</td>
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Sample Presentation Slides

Detailed Example: Golden Boy

Screen capture from ISIS Canada website (www.isiscanada.com)
## Module Integration Matrix

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<th>2</th>
<th>3</th>
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Outreach Activities

- Modules are **free and available online:**
  - [www.isiscanada.com](http://www.isiscanada.com) “Educational Modules”
  - Modules “advertised” internationally at conferences and in print

- Professors’ workshops
  - Annual meeting of undergrad and college CE instructors
  - **Costs covered** by ISIS
  - **Train the trainer** sessions

- Technical and **physical** support for education

- Modules have been used in **undergraduate, college, and professional education** in North America
Professors’ Workshops

- **1\textsuperscript{st} ISIS professors’ workshop:**
  - For university professors
  - May 2004
  - Presentation of modules

- **2\textsuperscript{nd} ISIS professors’ workshop:**
  - For technical college instructors
  - May 2005
  - Two full days of lectures & laboratories

- **3\textsuperscript{rd} ISIS professors’ workshop:**
  - For both university and college profs
  - Focus on SHM
  - *Building connections between colleges and universities*
Global Impact

- **Web downloads (as of 05/06):**
  - >150 downloads to date
    - 102 academic
    - 27 industry
    - 26 students
    - 8 government
  - At least 33 countries

- **Module use in the “Classroom”:**
  - Numerous Canadian and US universities
  - Professional education (Canada & USA)
  - Currently being modified for use by others (e.g. ACI)
Summary & Conclusions

- ISIS Canada has developed targeted Educational Modules covering various important aspects of emerging FRP & SHM technologies.

- When integrated into existing undergraduate civil engineering curricula, the modules provide engineering graduates with the tools to make educated decisions regarding the potential use of these technologies in civil infrastructure applications.

- This approach has been highly successful in Canada.
A sea change in university priorities is required to promote educational development within civil engineering.

To encourage instructors to teach about emerging technologies we need to:

1. Educate ➔ bring them up to speed
2. Enable ➔ make it easy
3. Empower ➔ support & encouragement
4. Reward ➔ cultural shift within universities
Thank you

http://www.isiscanada.com/education/education.html