Enhancement of Learning via Smart Learning Environment and Learning Analytics

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Being a Head TA in ENGG1203 and CCC courses

❖ “Help students learn”
➢ Tutorials and Labs
➢ Competition
➢ TA management
➢ Teaching study
➢ Student fair
➢ Knowledge blog
➢ IEEE-HK Edu Ch.
What does (engineering) education involve?

“Much more than transferring a body of knowledge from a professor to a student, engineering education involves self-awareness and identity - both of the student and of our collective educational institutions - and how we define (or erase) the boundaries between classrooms and learning.” (via information technologies)

Proceedings of the IEEE, Vol.100, Special Centennial Issue
Understanding of learning is needed

- Understanding of learning should bring about essential implications on human lives
  - Learning lies at the core of all aspects of performance

(Figure: HKU Science of Learning SRT)
Continuous Improvement on Learning

- Improving learning environments
  - Learning design (6C: TALE*, ISCAS etc)
    - Project vehicle; Probing questions; Learning process
  - Learning infrastructure (2J, 5C)
    - Smart Learning Environment; IT in Edu

- Quantitatively studying how people learn
  - Educational Data Mining / Learning Analytics (LA) (1C)

* Lei et al., IEEE International Conference on Teaching, Assessment, and Learning for Engineering, pp. 556-559, Aug 2013. (Best Paper Award)
(Cyber) Learning Infrastructure

Smart Learning Environment
Smart Laboratory

“A scientist in his laboratory is not a mere technician: he is also a child confronting natural phenomena that impress him as though they were fairy tales.” --- Marie Curie
A Smart Learning Environment - Student

- Enrich the end-to-end learning experience
- Provide collaborative student care throughout the entire path of a student learning life-cycle
- e.g. Learning commons in HKU, Smart Class in Tsinghua

Figures: www.hku.hk
A Smart Learning Environment - Facilities

- Self-surveillance
- Proactive self-altering maintenance
- Proactive healthcare or preventive care
- Energy/resource saving
Smart laboratory: What for?

❖ Improve safety and reliability
  ➢ Dangerous conditions may exist
  ➢ Sophisticated experiment
❖ Intelligent advisory
  ➢ Facilitating measurement, conversation and reporting
❖ Align experiments with learning experiences

Figures: Graduate Institute of Cancer Biology of China Medical University
Smart Laboratories: From sensor network to Cyber-physical Systems (CPS)

- Wireless sensor network
  - Sensing, event-handling, data-retrieving
  - Communication

- CPS: WSN + Real-time services
  - Giving cross-domain intelligent advice
  - Acting on relevant information about physical quantities
CPS: Cyber-/Physical-Information

- CPS: Cyber + Physical + Information
- Cyber: Control + Computation + Communication

Figure: Proceedings of the IEEE, Vol.100, Special Centennial Issue
CPS nodes: Installed everywhere

- Linked, distributed and autonomously operated
- Embedded computers and networks monitor:
  - Control the physical processes with feedback loops
- Sensors and actuators:
  - Interact with the physical processes

Figure: http://www.seas.upenn.edu/~pajic/img/pic_evm.jpg
CPS nodes: Measuring everything

- Measuring everything, every minute
  - From burglar alarming to pervasive computing
  - e.g. Temperature, voltage, distance, luminosity
- Powerful processors to process data in real time

Example: Regulating Thermal Comfort in Lab.*

- A poor thermal comfort condition can lead eventually a reduction in work performance and concentration
- Factors determining thermal comfort
  - (Major, Easiest) Humidity; Temperature
  - Air flow
  - (Advanced) Clothing; Actions

Example: Developed Tools for a SL

- **Obj**: Regulate thermal comfort
- **Hardware**: Nodes, robots
- **Algorithms**
  - Habit-based system control
    - Laboratory activities
    - Current environment condition
    - Current node condition
  - Computation for basic statistical analysis
Example: Can make the environment comfortable
LA: Studying how people learn

Learning Analytics (LA)
Educational Data Mining (EDM)

“Not only can you look at unique learning trajectories of individuals, but the sophistication of the models of learning goes up enormously.” --- Arthur Graesser, Editor, Journal of Educational Psychology
LA is for promoting learning

- Assessing learners along multiple dimensions
  - Social, cognitive, emotional, meta-cognitive
  - Individual, group
- Real-time advising for learners
- Advising for courses and institutions

- Advancing learning sciences
- Teach Better and Better! Learn Better and Better!
Why now for the development of LA

❖ e-learning platforms
  ➢ e.g. Moodle, Piazza, FB
  ➢ Recording learning processes and learner behaviors
  ➢ Recording at a fine-grained scale

❖ Massive open online courses
  ➢ A lot of students in a “class”
  ➢ e.g. edX, Coursea, Khan Academy
Big data in education is not “Google Big”; But

- MOOC: Accounting, UPenn Wharton (Sep 13 - Oct 13, six weeks)
  - Students enrolled: 130,290
  - Videos viewed: 1,059,078
  - Forum posts: 8,259
  - Homework submissions: 171,107

- Moodle: CCST9003 FA13
  - 45,972 Moodle pageviews
LA Theme (I): Prediction

❖ “Is the student off-task?”
❖ “Will the student fail the class?”
❖ “Will the student enroll college?”
➢ “Need intermediate interventions?”
LA Theme (II): Knowledge Interference

- Bayesian Knowledge Tracing: Knowing whether the student has a specific latent skill
  - If a student gets 3 problems right in a row for the skill, has the student learned the skill?
    - If \(P(\text{Already known}) = 0.3\),
      \(P(\text{Learned at each trial}) = 0.1\),
      \(P(\text{Guess correctly}) = 0.2\),
      \(P(\text{Make a mistake}) = 0.25\), then
      \[P(\text{Learned}) = 0.955\]
LA Theme (III): Relationship Mining

- Correlations of the question to a range of outcome measures
  - Learning path recommendation
- Collaborations among students
- “What student behaviors cause learning?”
  - e.g. “Is repeatedly retrying quizzes harmful?”
LA Theme (IV): Discovery with models

- A model of a phenomenon is developed ...
  - From prediction, clustering or other models

- ... to study the relationship between a latent construct and a variety of observable constructs
  - e.g. Predicting college attendance via models of Affect and Off-Task Behavior
Example: Text mining in a technological Common Core Curriculum (CCC) course*

❖ “Can students circulate their ideas?”
➢ “Can they write well-organized essays?”
❖ Preliminary study
➢ Analyze linguistic characteristics of student essays
 ■ Relationships between words, sentences, paragraph
➢ 25 essays from three-year curriculum students + 26 essays from four-year curriculum students

* Lei, "Using Coh-Metrix to Analyse Writing Skills of Students: A Case Study in a Technological Common Core Curriculum Course", IMECS 14, 3 pages, accepted
Example: “Well-organized? Easy to read?”

- Rule of Thumb: Flesch Reading Ease Score
  \[ \text{Score} = 206.835 - (1.015 \times \text{ASL}) - (84.6 \times \text{SW}) \]
  - ASL: Average sentence length
  - SW: Average number of syllables per word

- Deterministic: Text mining / Computational Linguistics
Example: Analyzed linguistic characteristics

❖ Narrativity: “Like a conversation?”
❖ Syntactic simplicity: “Simple enough to understand?”
❖ Word concreteness: “Are words too abstract?”
❖ Referential cohesion: “Are words and ideas connected with each other?”
❖ Causal cohesion: “Easy to understand the causality of events, processes, and actions?”
Example: Text mining in a technological CCC course

- 3-Year Curriculum, 4-Year Curriculum
- Benchmark: “Common Core State Standards Initiative”
Not efficient for idea circulation
Future developments of LA research

❖ “Discovery with models become feasible”
❖ “Educational inference and prediction will become more and more effective”
❖ “Validation will become more and more stringent”

➢ Ryan Baker (Founding President of the International Educational Data Mining Society), 2013
Continuous Improvement on Learning

❖ “Help students learn”

❖ Improving learning environments
  ➢ Learning design
  ➢ Learning infrastructure
    ■ Smart Laboratory; IT in Edu

❖ Studying how people learn
  ➢ Educational Data Mining / Learning Analytics (LA)
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Appendix
Examples of CPS Functions in a Smart Lab.

<table>
<thead>
<tr>
<th>Areas of work</th>
<th>Services for staffs</th>
<th>Services for facilities</th>
<th>Relevant physical quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilizing resources</td>
<td>Recommending nearby resources;</td>
<td>Saving and harvesting energy;</td>
<td>Air pressure; Air movement; Power;</td>
</tr>
<tr>
<td></td>
<td>Avoiding interrupts of activities</td>
<td>Managing and tracking available resources;</td>
<td>Temperature; Particulates; Current;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coordinating work space for operations;</td>
<td>Luminosity; (Relative) Humidity;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preventively maintaining of equipment</td>
<td>Liquid flow; Ultrasound; Magnetic field</td>
</tr>
<tr>
<td>Ensuring safety</td>
<td>Sparking alert;</td>
<td>Monitoring infrastructure; Managing inventory;</td>
<td>Rotation; Acceleration; Collusion;</td>
</tr>
<tr>
<td></td>
<td>Recording attendances;</td>
<td>Ensuring the availability of safety equipment;</td>
<td>Vibration; Presence; Orientation;</td>
</tr>
<tr>
<td></td>
<td>Broadcasting events of accidents;</td>
<td>Assessing incidents or abnormalities;</td>
<td>Luminosity; Infra-red; Visual;</td>
</tr>
<tr>
<td></td>
<td>Identifying users</td>
<td>Storing reagents and chemicals properly</td>
<td>Hall effect; Impact; Stretch</td>
</tr>
<tr>
<td>Protecting health</td>
<td>Monitoring health</td>
<td>Tracing and authenticating dangerous materials;</td>
<td>Toxic gas; Particulates; Temperature;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monitoring thermal comfort;</td>
<td>Air movement; Luminosity;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preventive maintaining equipment</td>
<td>Relative humidity</td>
</tr>
</tbody>
</table>
Big LA data from PSLC DataShop

- World’s leading public repository for educational software interaction data
  - >250,000 hours of students using educational software
  - >30 million student actions, responses & annotations
- Actions: entering an equation, manipulating a vector, typing a phrase, requesting help
- Responses: error feedback, strategic hints
- Annotations: correctness, time, skill/concept
LA in HKU

❖ Funding
  ➢ SRT “Science of Learning” .etc

❖ Activities
  ➢ LASI-Hong Kong
  ➢ SRT meetings/activities

❖ Data
  ➢ edX, Moodle
Examples: State Space Diagram

❖ Student learning pathways
❖ “States” that the learning can have during a problem

Fig: Johnson et al., An Algorithm for Reducing the Complexity of Interaction Networks, ICEDM, 2013
Observations from a State Space Diagram

- “Path end up being productive?”
- “Rare paths?”

- Recommendations (hints) that should be made to student’s current state
Examples: Moment-By-Moment Learning Graphs

- Relationships between learning trajectories and learning outcomes
  - Which learning component most promotes learning?
  - “Steady learning”
Examples: Moment-By-Moment Learning

❖ “Eureka”

❖ “Multiple skills treated as a single skill”