Socio-spatial Learning Analytics for Embodied Collaborative Learning

Presenter: Lixiang (Jimmie) Yan
Agenda

1. Backgrounds

2. Conceptual Framework

3. Illustrative Cases

4. Opportunities and Challenges
Backgrounds

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Embodied Collaborative Learning (ECL)

Embodied Collaborative Learning provides unique opportunities for students to practice key procedural and collaboration skills in co-located, physical learning spaces where they need to interact with others (social) and utilise physical and digital resources (spatial) to achieve a shared goal.

Examples of ECL
Traditional Data Collection Approaches
Multimodal Learning Analytics

- Mobile Eye-Tracker
- Hand gestures (leap motion)
- Motion Sensors (Kinect)
- Galvanic Skin Response
- Video and Speech data
- Emotion Detection
- The world’s first $99 eye tracker
Social and Spatial Aspects of ECL


Conceptual Framework

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Social-spatial Learning Analytics: Conceptual Framework
The study of how **physical space** is used during social interactions. (Hall, 1966)

1) educational constructs in interest are strongly associated with students or teachers’ **collaborative behaviours** or **interactions with educational resources**, and

2) these behaviours can be **inferred from their spatial movements** in the learning space.
Foundation Informs Feature Engineering

Learning Analytics Loop
Feature Engineering: Sensor

Wearable tracking systems

Computer vision systems
Feature Engineering: Socio-spatial Traces

Raw data (precise location)

- Timestamp: 22/07/2019 9:38:24.000
- ID: Student0001
- x-y coordinates: 5.3775, 17.645
- yaw, roll, pitch: 2.08, -1.52, -0.32

Raw data (screen distance)

- Timestamp: 00:23:58
- Screen distance: 51 units
- Subject_1: Student0001
- Subject_2: Student0002
Feature Engineering: Proximity

Potential Interaction

Distance threshold: within 1-1.5m.

Time threshold: more than 10s

**Feature Engineering: Orientation**

**F-formation:** when both students are within a certain proximity threshold and are facing toward each others (Zhao et al., 2022).

Feature Engineering: Space of interests

Feature Engineering

- Graduate Nurse
- Ward Nurse
- Vital Signs Monitor
- Oxygen Devices
- Laptop
- IV Fluids
- Resus Trolley
- Family Relative
- Phone

Space of Interest

Examples of Task Space
- Primary Task Space
- Secondary Task Space

Examples of Behaviours
- Task Distribution
- Task Transition

Behavourial Features to Analytics Approaches

Foundations
- Theoretical Foundation
- Learning Design
- Inputs from Stakeholder

Feature Engineering
- Proximity
- Orientation
- Space of Interest

Socio-spatial Traces
- Sensor

Analytic Approaches
- Machine Learning
- Network Analysis
- Sequential Analysis
- Statistical Comparison

Learning Analytics
- Descriptive
- Diagnostic
- Predictive
- Prescriptive
- Evaluation

Educational Insights
- ClassroomOrchestration
- Social/Team Dynamics
- Student Performance

Learning Analytics Loop
Analytic Approaches: Machine Learning

Unsupervised methods (e.g., clustering social participation level)

Consistent

Advance

Improve

Decline

Supervised methods (e.g., predicting students’ maths performance)

<table>
<thead>
<tr>
<th></th>
<th>Accuracy</th>
<th>Precision</th>
<th>Recall</th>
<th>Cohen’s k</th>
<th>AUC</th>
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<td>0.75 (0.06)</td>
<td>0.57 (0.06)</td>
<td>0.79 (0.06)</td>
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<td>0.66 (0.06)</td>
<td>0.73 (0.06)</td>
<td>0.52 (0.06)</td>
<td>0.77 (0.06)</td>
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<td>RF</td>
<td>0.78 (0.06)</td>
<td>0.68 (0.06)</td>
<td>0.67 (0.06)</td>
<td>0.50 (0.06)</td>
<td>0.75 (0.06)</td>
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<tr>
<td>KNN</td>
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<tr>
<td>ANN</td>
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<td>0.61 (0.06)</td>
<td>0.66 (0.06)</td>
<td>0.43 (0.06)</td>
<td>0.72 (0.06)</td>
</tr>
</tbody>
</table>
Analytic Approaches: Network Analysis

Group Cohesion / Density = \( \frac{\text{Actual } \# \text{ of connections}}{\text{All possible connections}} \)

Homophily

Reading lesson on 22/07/2019 from 10:00am to 11:00am
Analytic Approaches: Sequential and Epistemic Analysis

<table>
<thead>
<tr>
<th>student</th>
<th>gender</th>
<th>gender_homogeneous</th>
</tr>
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<tr>
<td>Student_0002</td>
<td>Female</td>
<td>1</td>
</tr>
</tbody>
</table>

Reading (n=80)

- high-performing students
- low-performing students
**Analytic Approaches: Statistical Comparison**

- **Nonparametric Statistics** (e.g., Mann–Whitney U test)
- **Parametric Statistics** (e.g., Student’s t-test)

![Box plot showing comparison of statistical approaches](image-url)
Analytics Approaches to Learning Analytics
Learning Analytics: Descriptive

Making **salient** aspects of complex educational constructs **visible** for both teachers and students.
Learning Analytics: Diagnostic

Identifying meaningful **behavioural indicators** of educational constructs based on theoretical assumptions.
Learning Analytics: Predictive

Powering early detection technologies that teachers can use to identify and support both socially and academically at-risk students.

[Graphs showing clusters with labels: Consistent, Advance, Improve, Decline]
Empirical evidence and **stakeholder endorsements** of the educational values in supporting teachers’ decision-making process are emerging.
Learning Analytics: Evaluation

- Descriptive
- Diagnostic
- Predictive
- Prescriptive
- Evaluation

Learning Analytics to Educational Insights

Foundations
- Theoretical Foundation

Learning Design
- Learning Design

Inputs from Stakeholder
- Socio-spatial Traces
- Sensor

Feature Engineering
- Proximity
- Orientation
- Space of Interest

Analytic Approaches
- Machine Learning
- Network Analysis
- Sequential Analysis
- Statistical Comparison

Learning Analytics
- Descriptive
- Diagnostic
- Predictive
- Prescriptive

Educational Insights
- Classroom Orchestration
- Social/Team Dynamics
- Student Performance

Learning Analytics Loop
Helping teachers to allocate their time better and ensure every student/group are attended.

ID1: Prescribed lab (session 3)
Classroom benches distributed between the teacher assistant and the main teacher

ID2: Project-based lab (session 6)
Both teachers present almost everywhere the classroom

Educational Insights: Social/Team Dynamics

Developing learning analytics dashboards that augment teachers’ awareness of the whole classroom and delivery of evidence-based reflections for potential socially isolated students.
Educational Insights: Student Performance

Supporting researchers and practitioners in understanding social and spatial factors related to students’ performance in collaborative contexts.
Illustrative Cases

Presenter: Lixiang (Jimmie) Yan
Case 1: Open Learning Space
Case 1: In-the-wild Study with Indoor Positioning System

8 Weeks
35 Maths Sessions
23 Reading Sessions
14 Inquiry Sessions
77.15m Data Points
Case 1: Socio-spatial Features

Table 1: Teachers’ Socio-spatial Metrics with the Corresponding Unit and Description.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>stops</td>
<td>instances</td>
<td>The number of stops made by a teacher per session.</td>
</tr>
<tr>
<td>tottime</td>
<td>minutes</td>
<td>The total stopping time of a teacher per session.</td>
</tr>
<tr>
<td>perstop</td>
<td>seconds</td>
<td>The duration of each stop made by a teacher per session.</td>
</tr>
<tr>
<td>entropy</td>
<td>bits</td>
<td>The information density of a teacher’s spatial data per session.</td>
</tr>
<tr>
<td>tPteacher</td>
<td>percent</td>
<td>The percentage of time a teacher spent near other teachers per session.</td>
</tr>
<tr>
<td>tPself</td>
<td>percent</td>
<td>The percentage of time a teacher spent by her/himself per session.</td>
</tr>
<tr>
<td>tPstudent</td>
<td>percent</td>
<td>The percentage of time a teacher spent near students per session.</td>
</tr>
</tbody>
</table>
**Case 1: Teachers’ Spatial Pedagogy**

Teachers’ socio-spatial behaviours based on the four types of pedagogical approaches proposed by Lim et al.’s theory of spatial pedagogy (interactional, supervisory, authoritative, personal).
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Case 1: Context-specific Spatial Pedagogy

Fixed-sitting Classroom
- Interactional
- Supervisory
- Authoritative
- Personal

Open Learning Space
- Interactional
- Supervisory
- Authoritative/Personal
- Collaborative
Case 1: Framework in Action

Foundations
- Theoretical Foundation: Theory of proxemics, Theory of spatial pedagogy
- Learning Design: Learner autonomy across subjects, Pre-designed collaborative task
- Stakeholders’ Inputs: Space functionality

Feature Engineering
- Proximity: One-meter Euclidian distance, Ten consecutive seconds, Proximity among individuals, Proximity to educational resources
- Spaces of Interest: Teachers’ desk, Students’ assigned learning spaces

Analytic Approaches
- Machine Learning: Predictive modeling, Clustering analysis
- Network Analysis: Social networks
- Sequential Analysis: Pattern analysis
- Statistical Comparison: Correlation analysis, Nonparametric test

Analytics & Insights
- Predictive Analytics: At-risk student
- Descriptive Analytics: Spatial Pedagogy, Isolated students
- Diagnostic Analytics: Social participation, Spatial distribution, Homophily, Student performances

LA Loop: novel theories on open learning spaces
Case 2: Team-based Clinical Simulation
Case 2: Floor Plan and Task Spaces

Examples of Task Space
- Primary Task Space
- Secondary Task Space

Examples of Behaviours
- Task Distribution
- Task Transition
**Case 2: Socio-spatial Features**

### Table 2: Spatial-procedural behavioural features (percentage).

<table>
<thead>
<tr>
<th>Features</th>
<th>Spatial-procedural Behaviours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaborate_Primary (CP)</td>
<td>Students working on the primary tasks collaboratively.</td>
</tr>
<tr>
<td>Independent_Primary (IP)</td>
<td>Students working on the primary tasks individually.</td>
</tr>
<tr>
<td>Collaborate_Secondary (CS)</td>
<td>Students working on the secondary task collaboratively.</td>
</tr>
<tr>
<td>Independent_Secondary (IS)</td>
<td>Students working on the secondary task individually.</td>
</tr>
<tr>
<td>Task_Distribution (TD)</td>
<td>Students distributing the responsibility of different tasks.</td>
</tr>
<tr>
<td>Task_Transition (TT)</td>
<td>Students transiting from one task to another task.</td>
</tr>
</tbody>
</table>
Case 2: Epistemic Network Analysis

Task Performance

Collaboration Performance

high-performing teams

low-performing teams
Case 2: Educational Value — Supporting Reflective Practices

“This [epistemic network] would allow us to have a little bit of data to support what happened so that we can have a really good discussion in the debrief”

—— Teacher_02

“I agree completely. Taking the students through something like you just did with us [explaining the epistemic networks] is a really good visual to then open up the discussion about, okay, tell me what was happening”

—— Teacher_01
Case 2: Framework in Action

**Foundations**
- **Theoretical Foundation**
  - Theory of proxemics
  - Formative assessment

- **Learning Design**
  - Priority of different tasks
  - Collaborative teamwork

- **Stakeholders’ Inputs**
  - Spatial meanings

**Feature Engineering**
- **Proximity**
  - Collocation among team members
  - Proximity to medical resources
  - Ten consecutive seconds

- **Spaces of Interest**
  - Primary task spaces
  - Secondary task spaces
  - Outside of either task spaces

**Analytic Approaches**
- **Machine Learning**
  - Predictive modeling

- **Network Analysis**
  - Epistemic networks

- **Statistical Comparison**
  - Correlation analysis
  - Nonparametric test

**Analytics & Insights**
- **Predictive Analytics**
  - Task performances
  - Collaboration performances

- **Descriptive Analytics**
  - Behavioural connections

- **Diagnostic Analytics**
  - Task prioritisation
  - Collaboration
  - Spatial behaviours

**Practical Utilities**
- **Novice Teachers**
  - Confirmatory tools for inexperienced teachers

- **Post-hoc Debriefs**
  - Supportive evidence for student reflections
  - Team-based evidence without individual elements

**LA Loop:** the essential relationships between tasks and spaces
Opportunities and Challenges

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Opportunities for Educational Research

1. A potentially **more reliable and less biased** method to re-investigate previously found relationships between socio-spatial behaviours and educational constructs.

2. Data with greater temporal and spatial precision making advanced data analytic techniques more viable, which could benefit research into contemporary educational theories.

3. New opportunities for assessing the effectiveness of specific learning spaces (e.g., flexible classrooms and open learning spaces) on teaching and learning behaviours.
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Opportunities for Educational Practice

Reflective Practices

Meaningful Insights
Methodological and Practical Challenges

1. **Reliability** of the proximity-based identification approach could potentially decrease in situations where most individuals are strangers.

2. Automation remains an issue as most of the existing innovations still rely on researchers to determine and perform data analysis.

3. Cost of the initial installation and ongoing maintenance of sensor and ubiquitous computing technologies are limiting its practical values.
Methodological and Practical Challenges

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Ethical Challenges

- consent
- privacy
- surveillance
- data
- explainable
- personal
- stability
- misuse
- transparency
- biases
- accuracy
- algorithmic
- trustworthiness
Key Takeaways

Presenter: Lixiang (Jimmie) Yan
Key Takeaways

1. The value of socio-spatial analytics is **context-dependent**

2. Grounding socio-spatial analytics with **foundations**
Key Takeaways

1. The value of socio-spatial analytics is context-dependent

2. Grounding socio-spatial analytics with foundations
References and Reading List


FOR MORE INFORMATION
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