Socio-spatial Learning Analytics for Embodied Collaborative Learning

Presenter: Lixiang (Jimmie) Yan

MONASH University

COLAM
Centre for Learning Analytics Monash

Agenda

1. Backgrounds

2. Conceptual Framework

3. Illustrative Cases

4. Opportunities and Challenges

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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.

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Ioannou, M., Georgiou, Y., Ioannou, A., Johnson, M.: On the understanding of students' learning and perceptions of technology integration in low-and high-embodied group learning. In: CSCL, vol. 1, pp. 304–311. ISLS (2019)

Examples of ECL

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Traditional Data Collection Approaches

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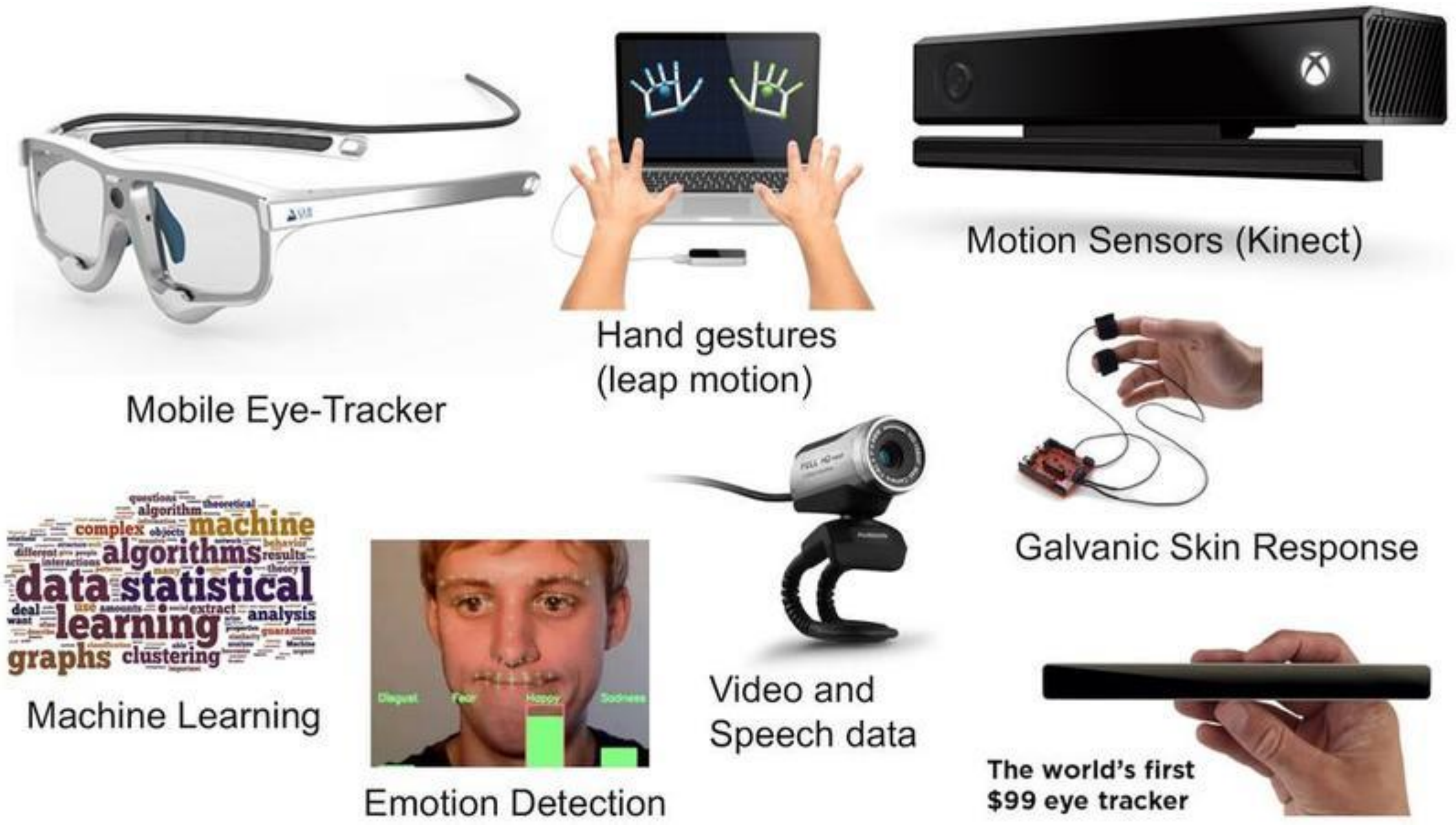
Multimodal Learning Analytics



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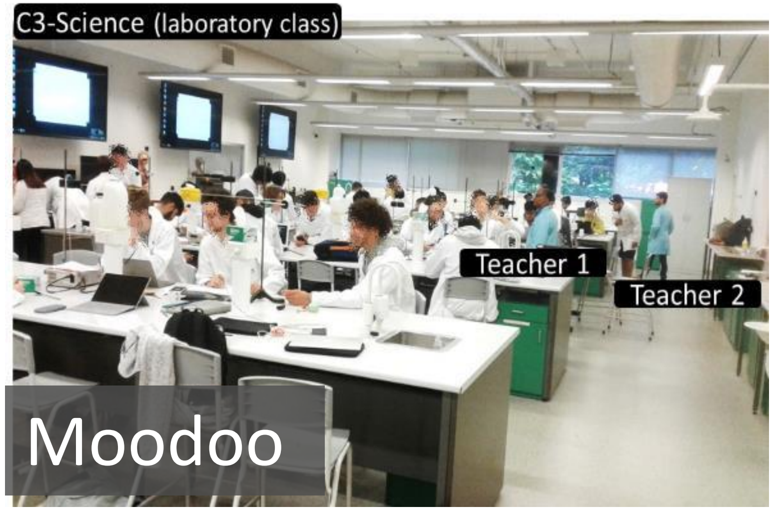
Social and Spatial Aspects of ECL



Martinez-Maldonado, R., Echeverria, V., Schulte, J., Shibani, A., Mangaroska, K., & Shum, S. B. (2020, July). Moodoo: indoor positioning analytics for characterising classroom teaching. In *International Conference on Artificial Intelligence in Education* (pp. 360-373). Springer, Cham.

Saquib, N., Bose, A., George, D., & Kamvar, S. (2018). Sensei: sensing educational interaction. Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 1(4), 1-27.

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Conceptual Framework

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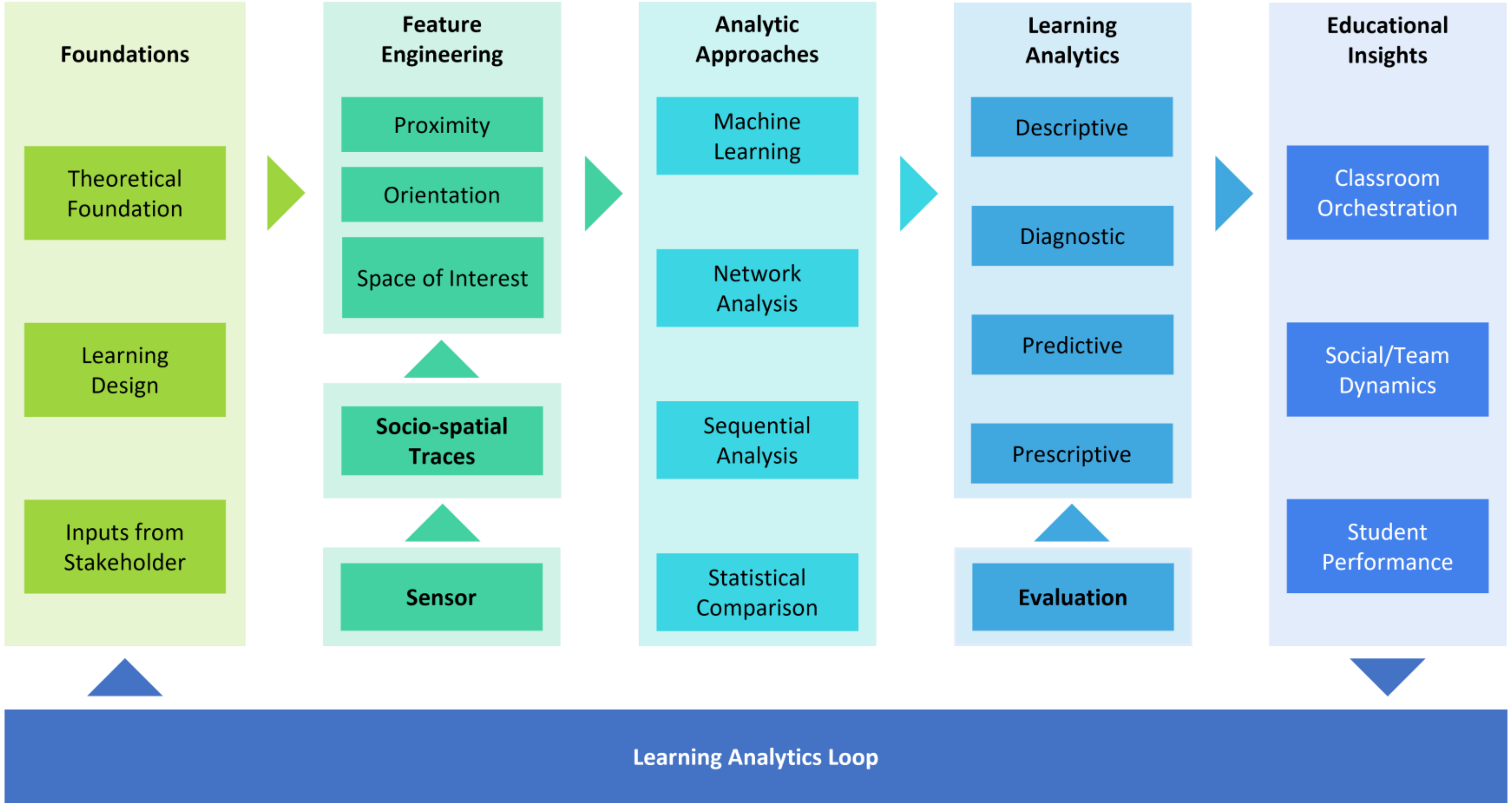
Social-spatial Learning Analytics: Conceptual Framework



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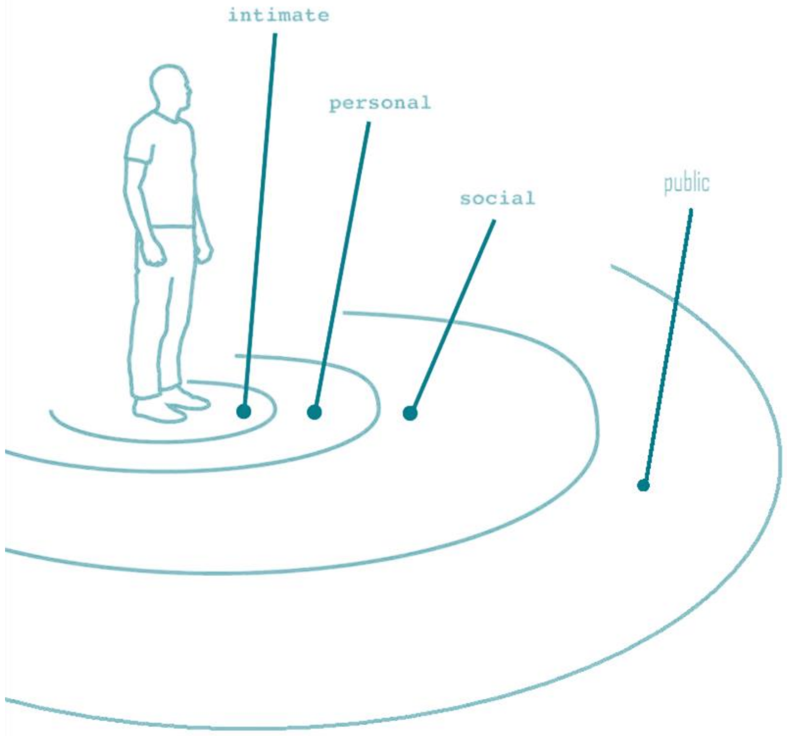
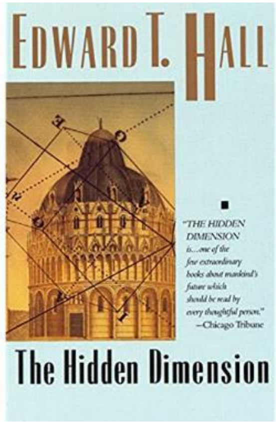
Foundation: Theoretical Foundations

Foundations

Theoretical Foundation





Theory of Proxemic

The study of how physical space is used during social interactions. (Hall, 1966)

Hall, E. T. (1966). *The hidden dimension* (Vol. 609). Garden City, NY: Doubleday.

Foundation: Learning Design

Foundations

Learning Design

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.

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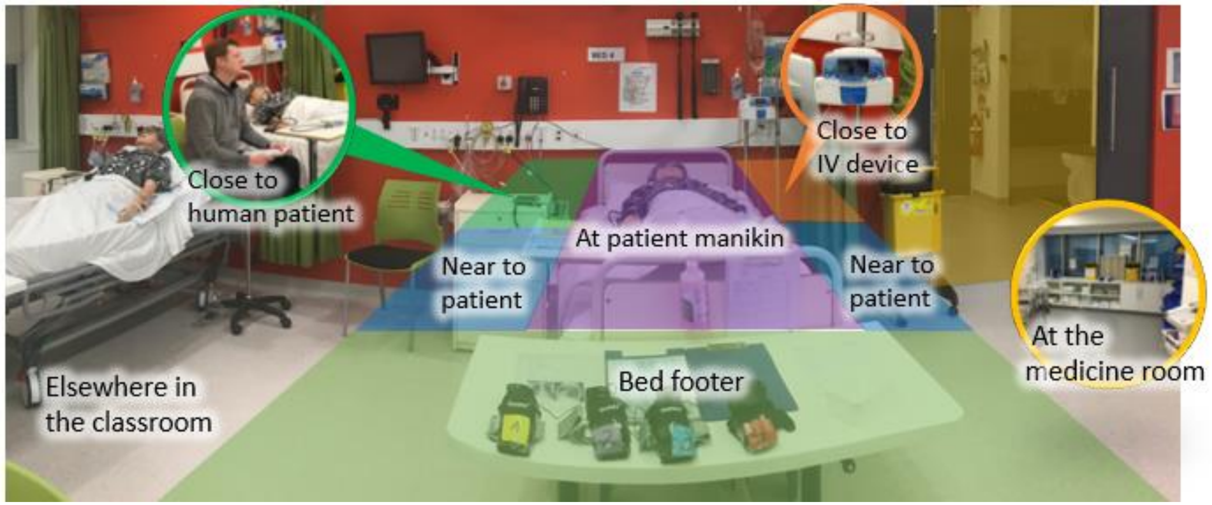
Foundation: Stakeholders' Inputs

Foundations

Inputs from Stakeholder

Infuse **Space** with **Meaning**



Fernandez-Nieto, G. M., Martinez-Maldonado, R., Kitto, K., & Buckingham Shum, S. (2021, April). Modelling spatial behaviours in clinical team simulations using epistemic network analysis: methodology and teacher evaluation. In *LAK21: 11th International Learning Analytics and Knowledge Conference* (pp. 386-396).

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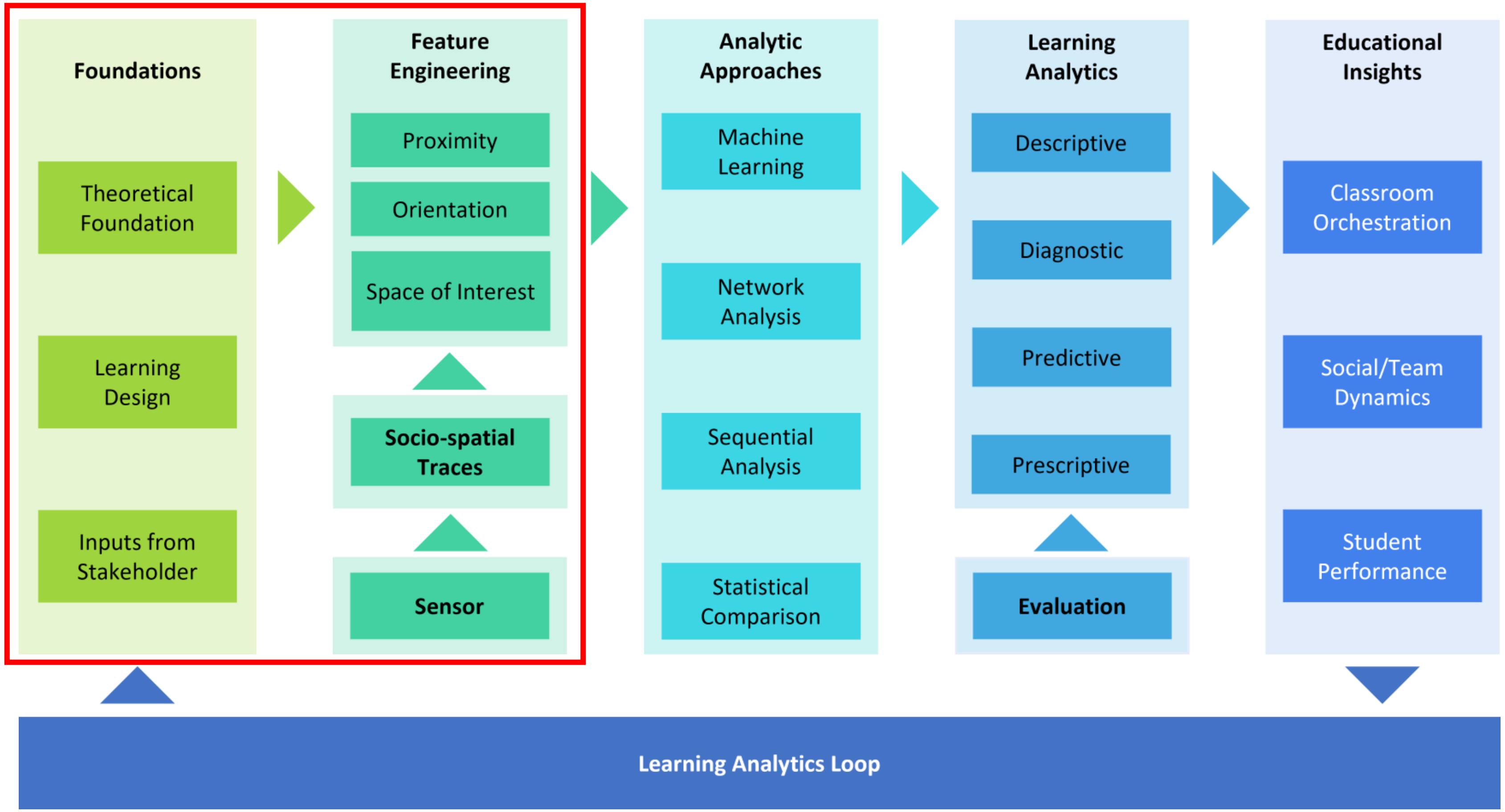
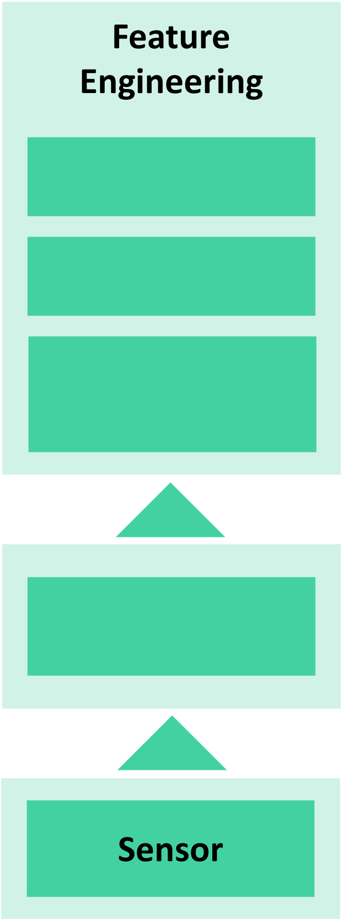
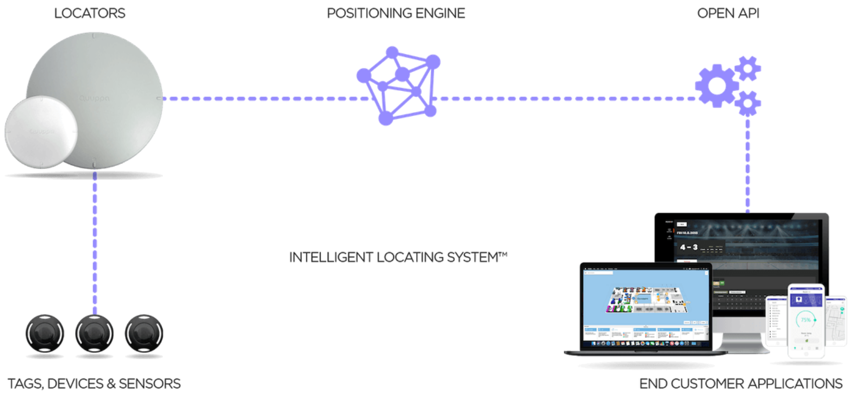
Foundation Informs Feature Engineering



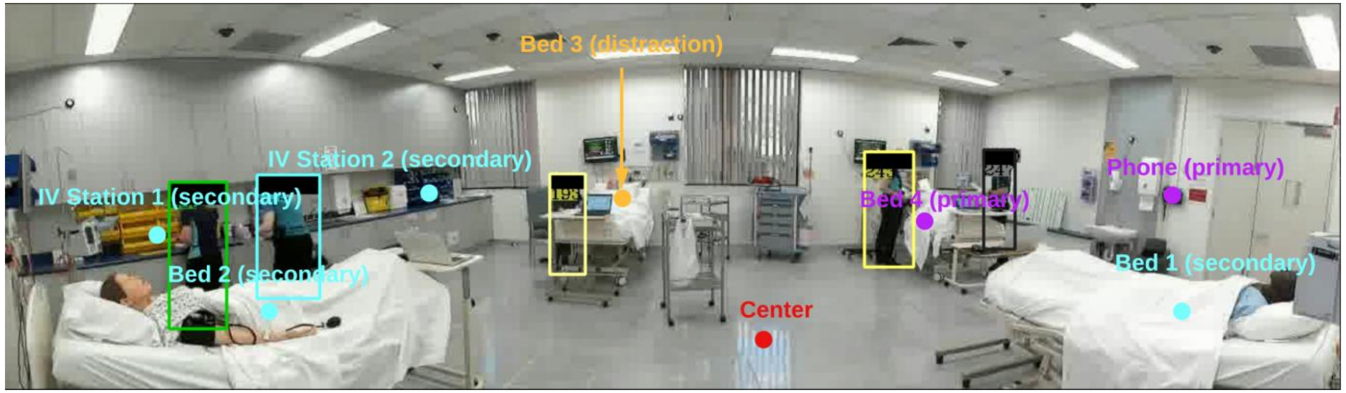
Feature Engineering: Sensor



Wearable tracking systems



Computer vision systems



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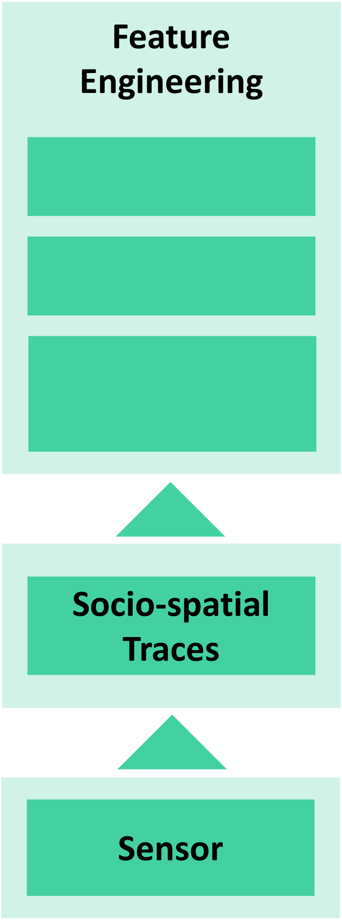
Feature Engineering: Socio-spatial Traces



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

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Feature Engineering: Proximity

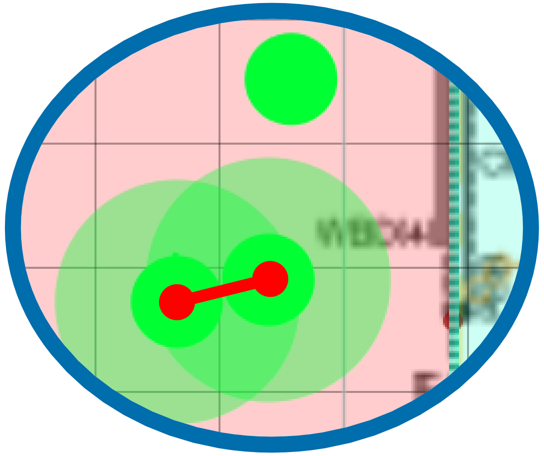
Feature Engineering

Proximity

Socio-spatial Traces

Sensor

Potential Interaction

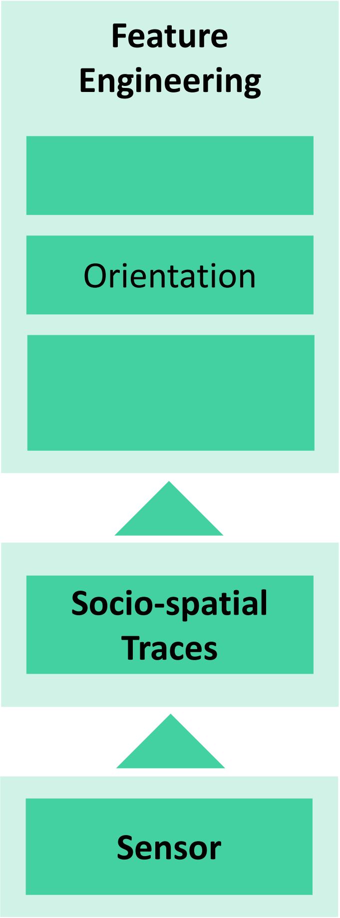


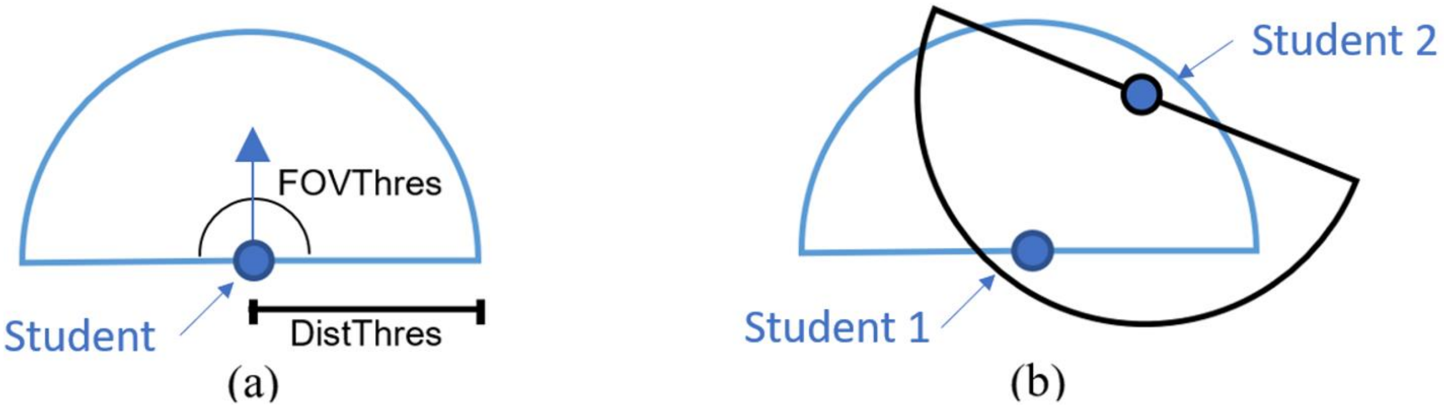
Distance threshold: within 1-1.5m.

Time threshold: more than 10s

Martinez-Maldonado, R., Schulte, J., Echeverria, V., Gopalan, Y., & Shum, S. B. (2020). Where is the teacher? Digital analytics for classroom proxemics. *Journal of Computer Assisted Learning*, *36*(5), 741-762.

Feature Engineering: Orientation





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

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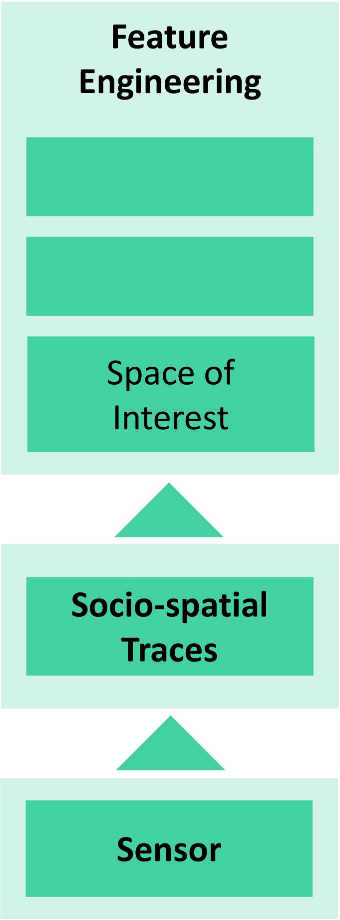
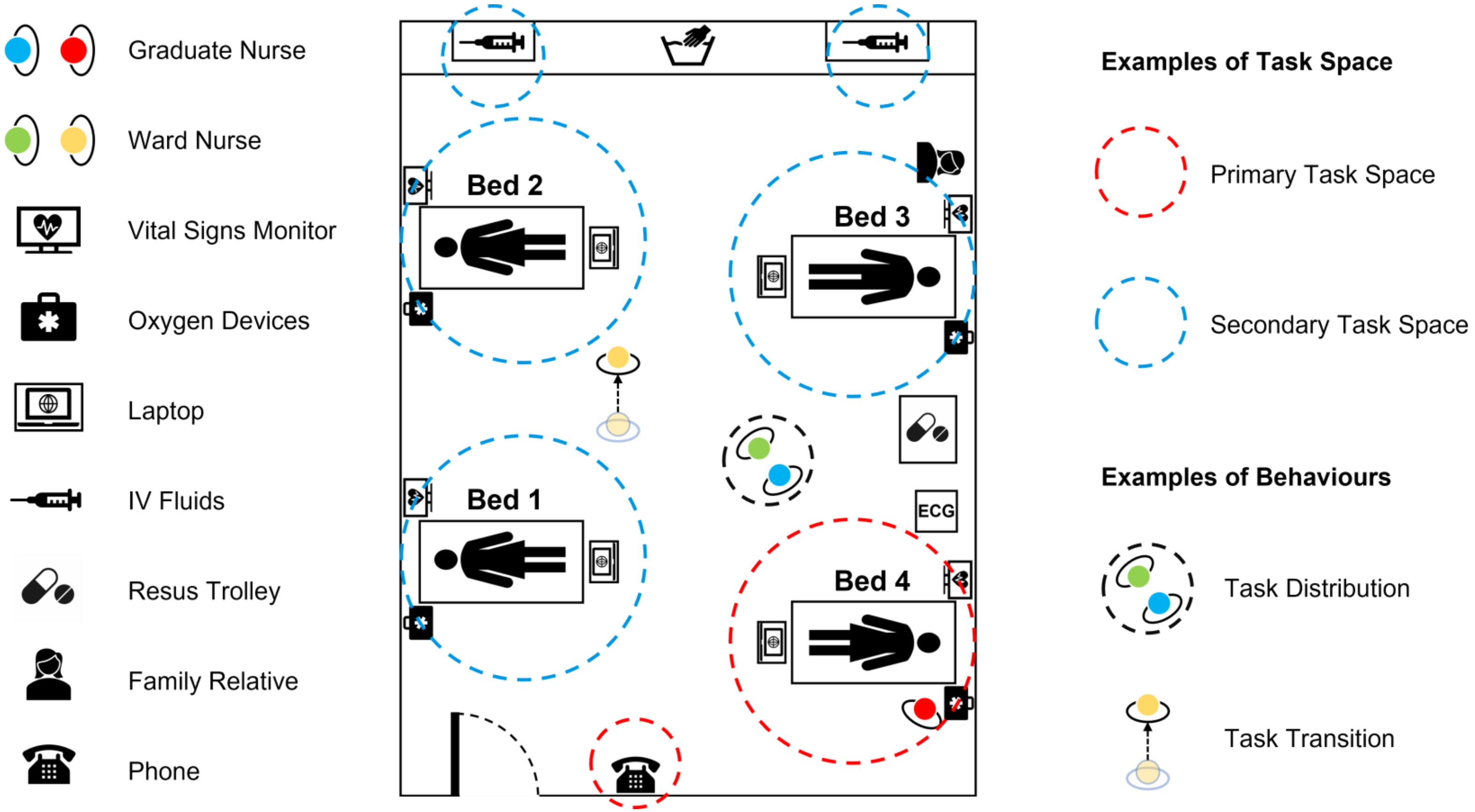
Zhao, L., Yan, L., Gasevic, D., Dix, S., Jaggard, H., Wotherspoon, R., ... & Martinez-Maldonado, R. (2022, March). Modelling co-located team communication from voice detection and positioning data in healthcare simulation. In *LAK22: 12th International Learning Analytics and Knowledge Conference* (pp. 370-380).

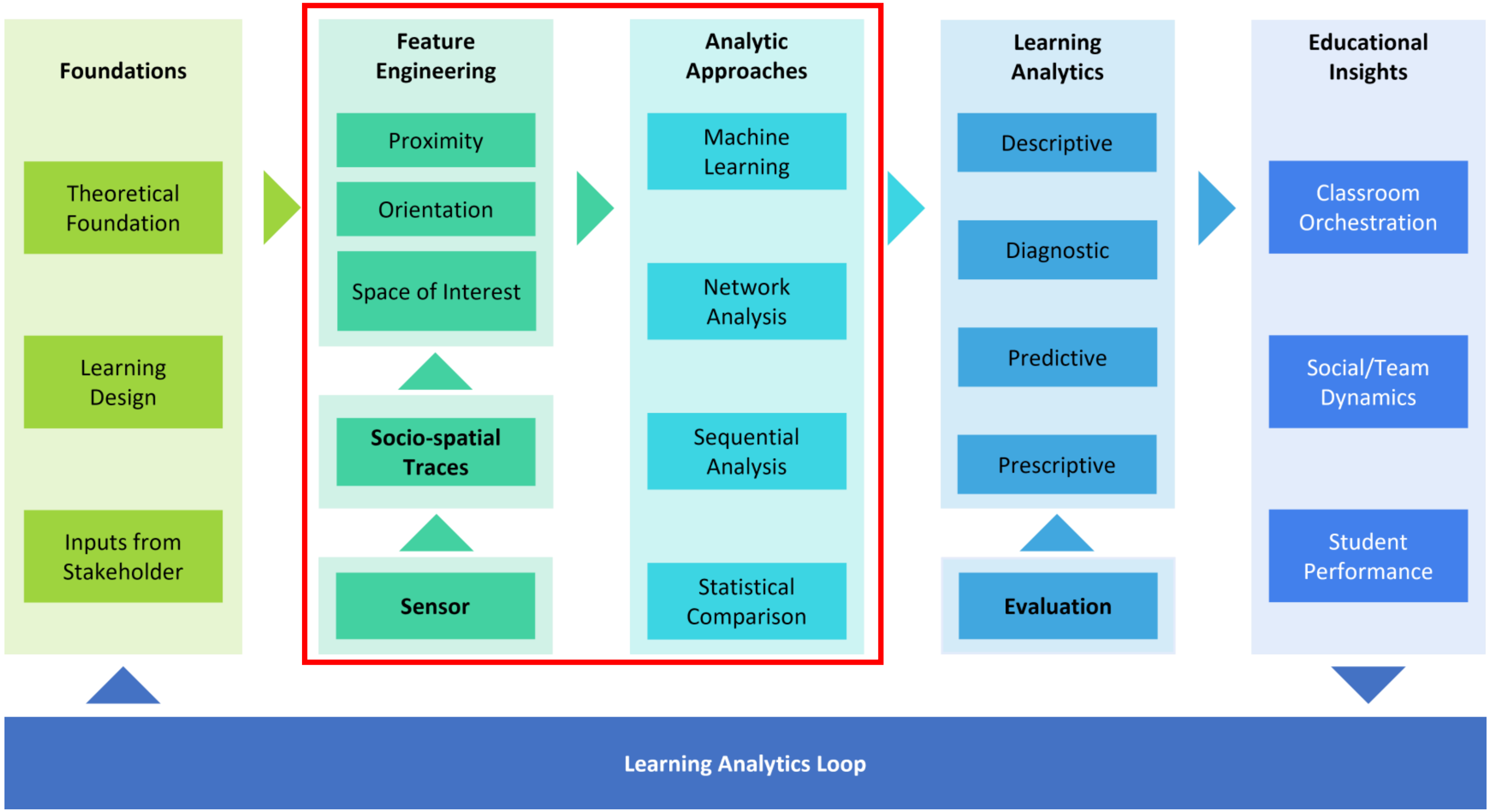
Feature Engineering: Space of interests





Yan, L., Martinez-Maldonado, R., Zhao, L., Dix, S., Jaggard, H., Wotherspoon, R., ... & Gašević, D. (2022). The role of indoor positioning analytics in assessment of simulation-based learning. *British Journal of Educational Technology*.

Behavioural Features to Analytics Approaches



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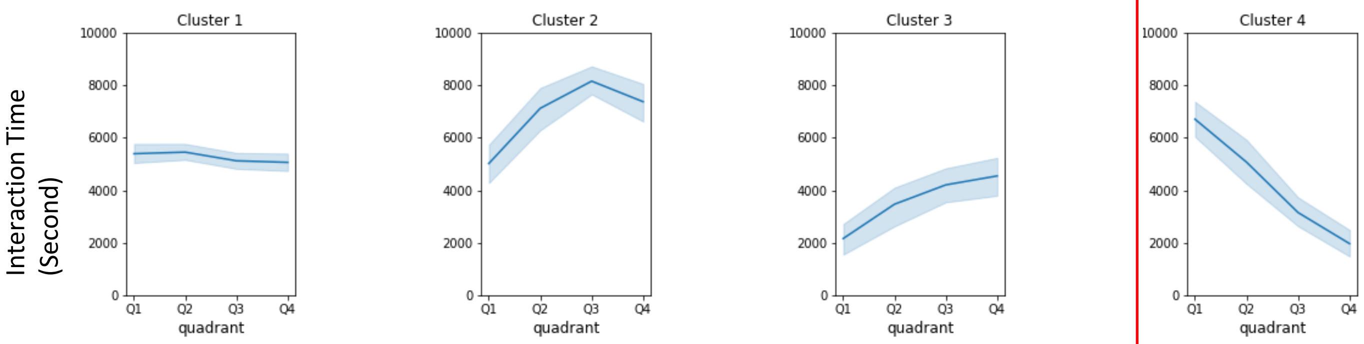
Analytic Approaches: Machine Learning

Analytic Approaches

Machine Learning

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



Consistent Advance Improve Decline

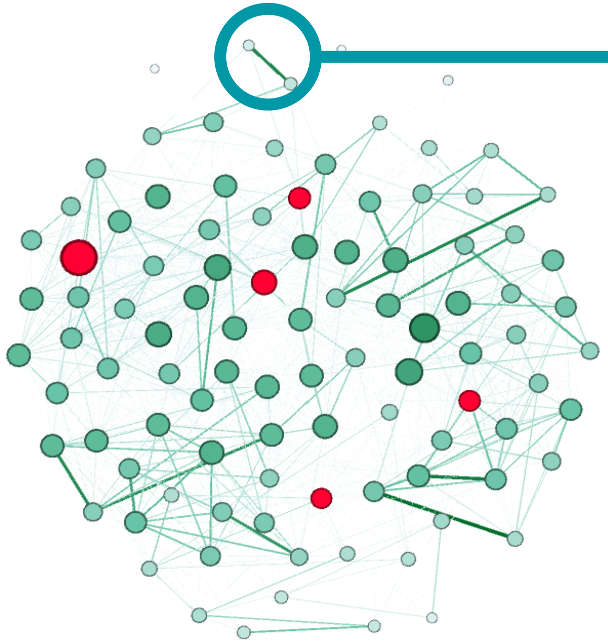
Supervised methods (e.g., predicting students' maths performance)

	Accuracy	Precision	Recall	Cohen's *k*	AUC
LR	0.81 (0.06)	0.71 (0.06)	0.75 (0.06)	0.57 (0.06)	0.79 (0.06)
SVM	0.78 (0.06)	0.66 (0.06)	0.73 (0.06)	0.52 (0.06)	0.77 (0.06)
RF	0.78 (0.06)	0.68 (0.06)	0.67 (0.06)	0.50 (0.06)	0.75 (0.06)
KNN	0.76 (0.06)	0.64 (0.06)	0.68 (0.06)	0.47 (0.06)	0.74 (0.06)
ANN	0.74 (0.06)	0.61 (0.06)	0.66 (0.06)	0.43 (0.06)	0.72 (0.06)

Analytic Approaches: Network Analysis

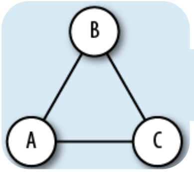
Analytic Approaches

Network Analysis



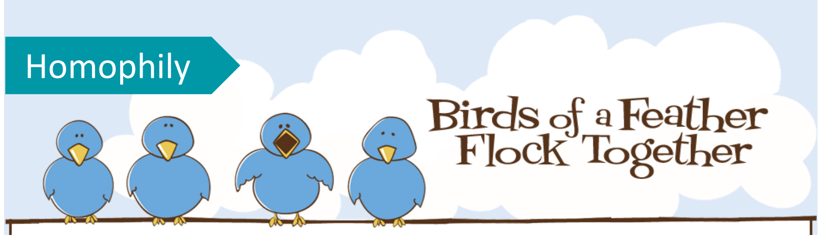
Reading lesson on 22/07/2019 from 10:00am to 11:00am

Pair interactions



Small groups

Group Cohesion / Density = $\frac{Actual\ \#\ of\ connections}{All\ possible\ connections}$



Analytic Approaches: Sequential and Epistemic Analysis

Analytic Approaches

Sequential Analysis

student	gender	gender_homogeneous
Student_0002	Female	1
Student_0002	Female	1
Student_0002	Female	1
Student_0002	Female	1
Student_0002	Female	1
Student_0002	Female	0
Student_0002	Female	1
Student_0002	Female	1
Student_0002	Female	1
Student_0002	Female	0
Student_0002	Female	1
Student_0002	Female	1
Student_0002	Female	1
Student_0002	Female	1
Student_0002	Female	1
Student_0002	Female	1
Student_0002	Female	1
Student_0002	Female	1
Student_0002	Female	1
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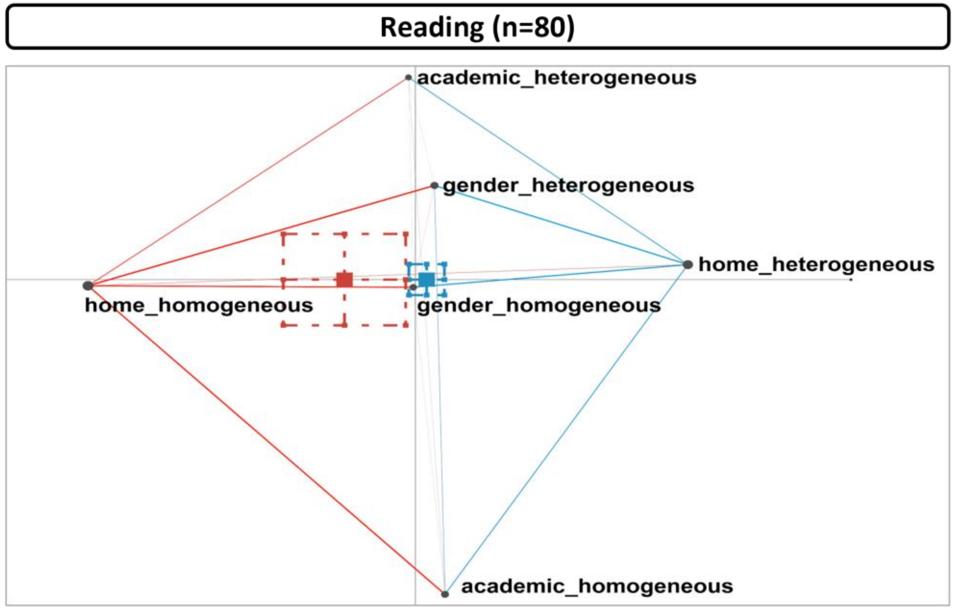
Student_0002	Female	1
Student_0002	Female	1



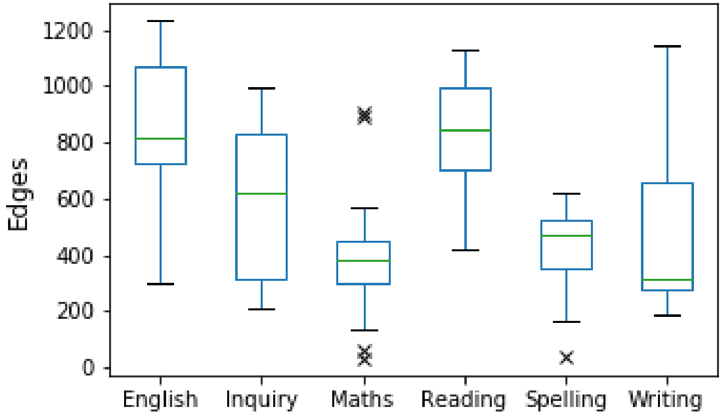
high-performing students

low-performing students

Analytic Approaches: Statistical Comparison

Analytic Approaches

Statistical Comparison



Nonparametric Statistics

(e.g., Mann–Whitney U test)

Over

Parametric Statistics

(e.g., Student's t-test)

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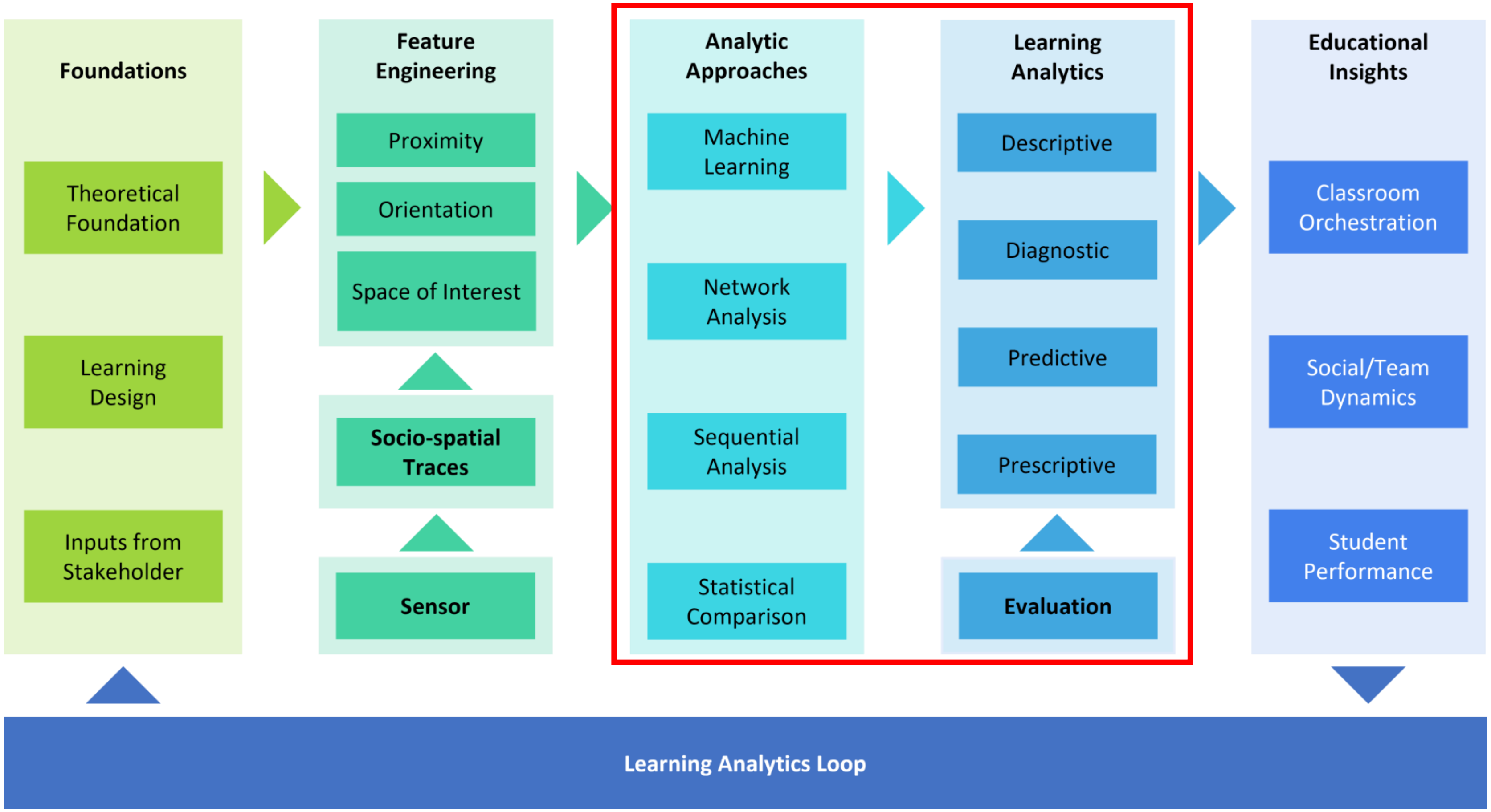
Analytics Approaches to Learning Analytics



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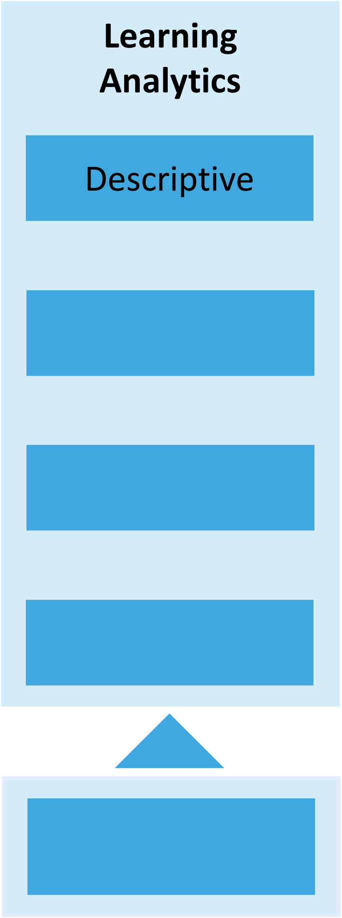
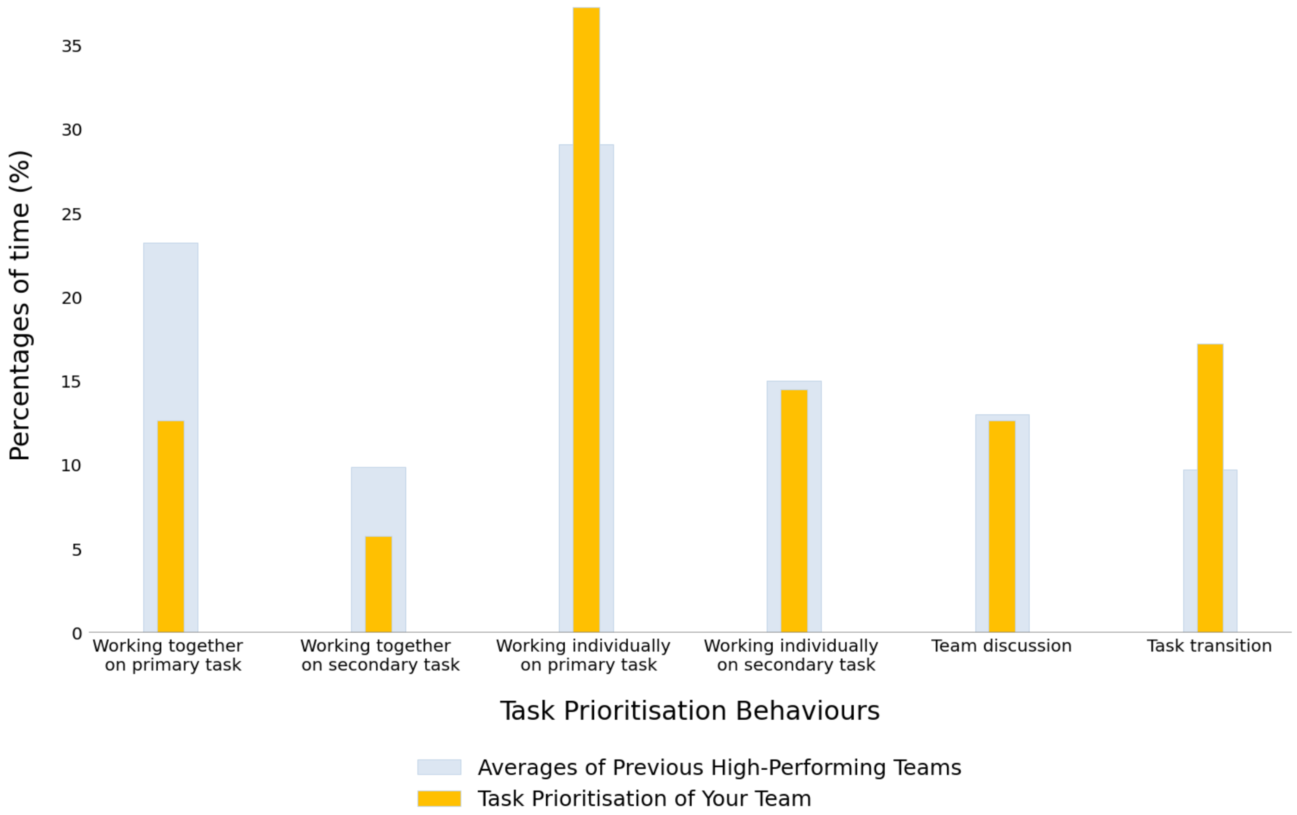
Learning Analytics: Descriptive



Making **salient** aspects of complex educational constructs **visible** for both teachers and students.



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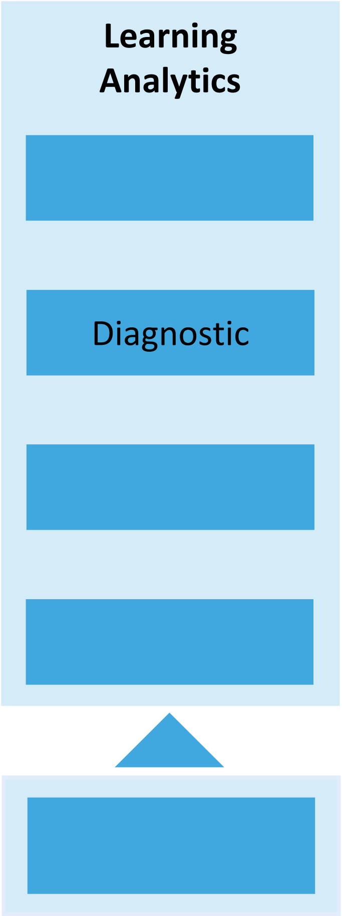
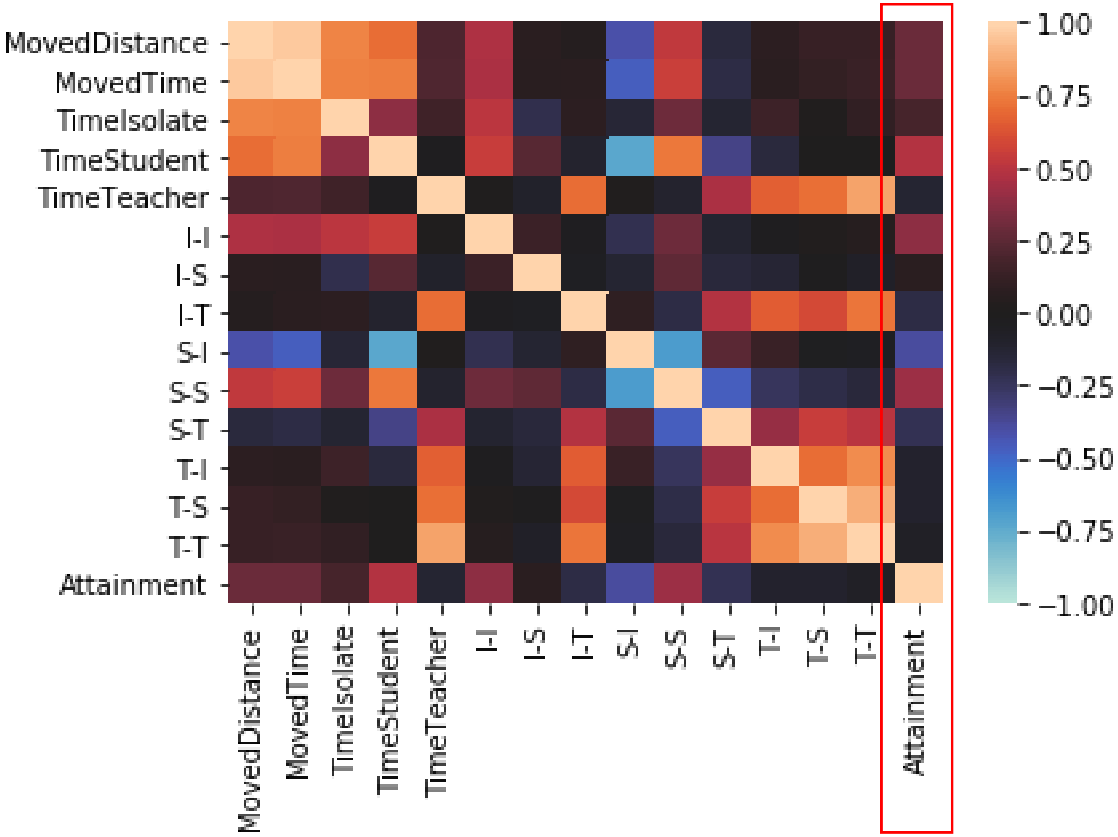
Learning Analytics: Diagnostic



Identifying meaningful **behavioural indicators** of educational constructs based on theoretical assumptions.

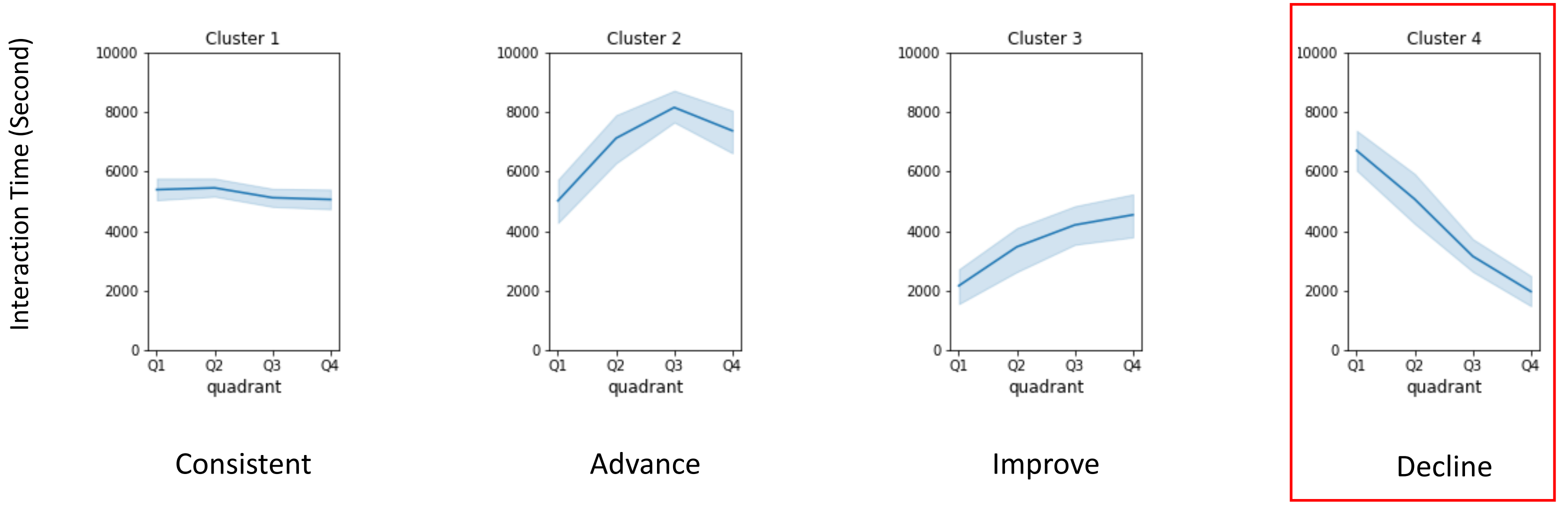


Learning Analytics: Predictive

Learning Analytics

Predictive

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

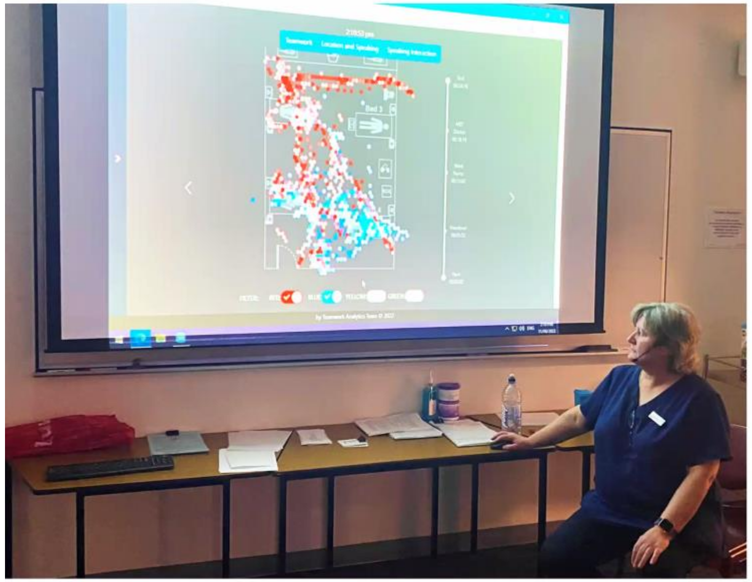


Learning Analytics: Prescriptive

Learning Analytics

Prescriptive

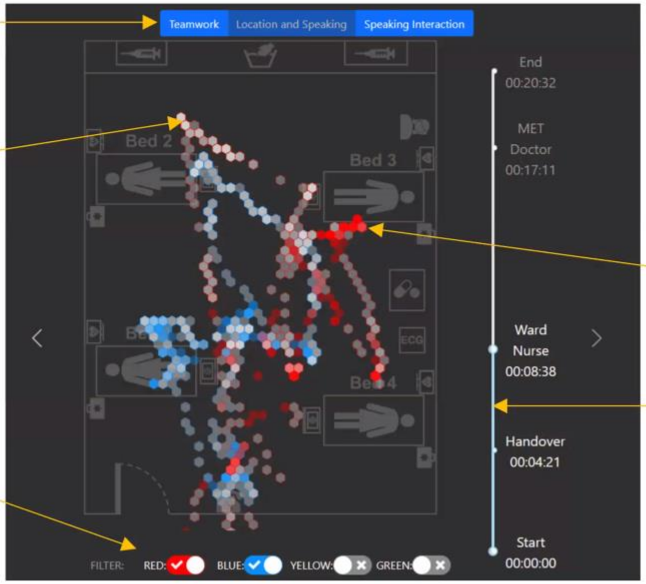
Empirical evidence and **stakeholder endorsements** of the educational values in supporting teachers' decision-making process are emerging.



Visualisations' menu

Student location **without** speaking

Filter by student role



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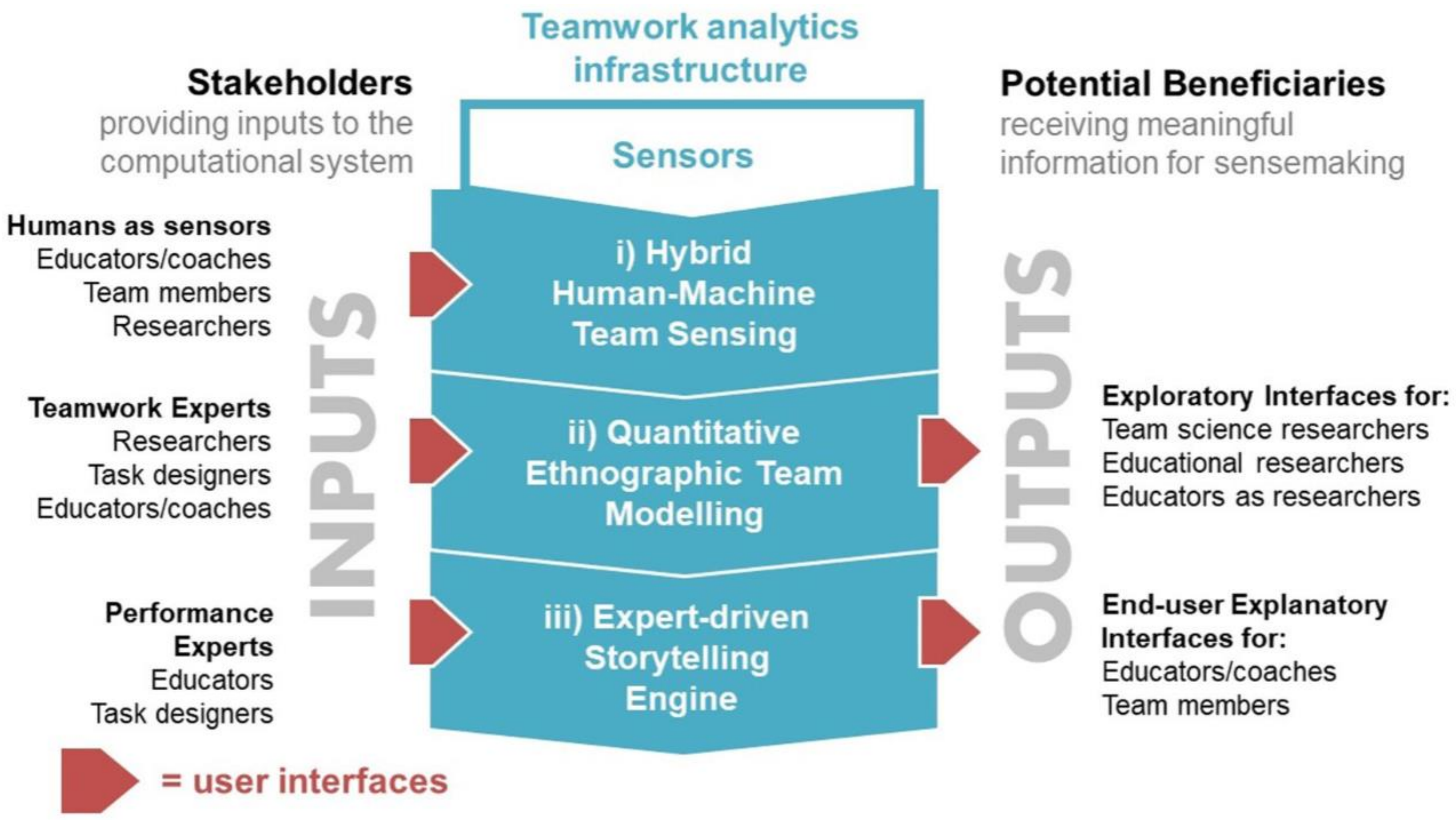
Learning Analytics: Evaluation

Learning Analytics

- Descriptive
- Diagnostic
- Predictive
- Prescriptive

Evaluation



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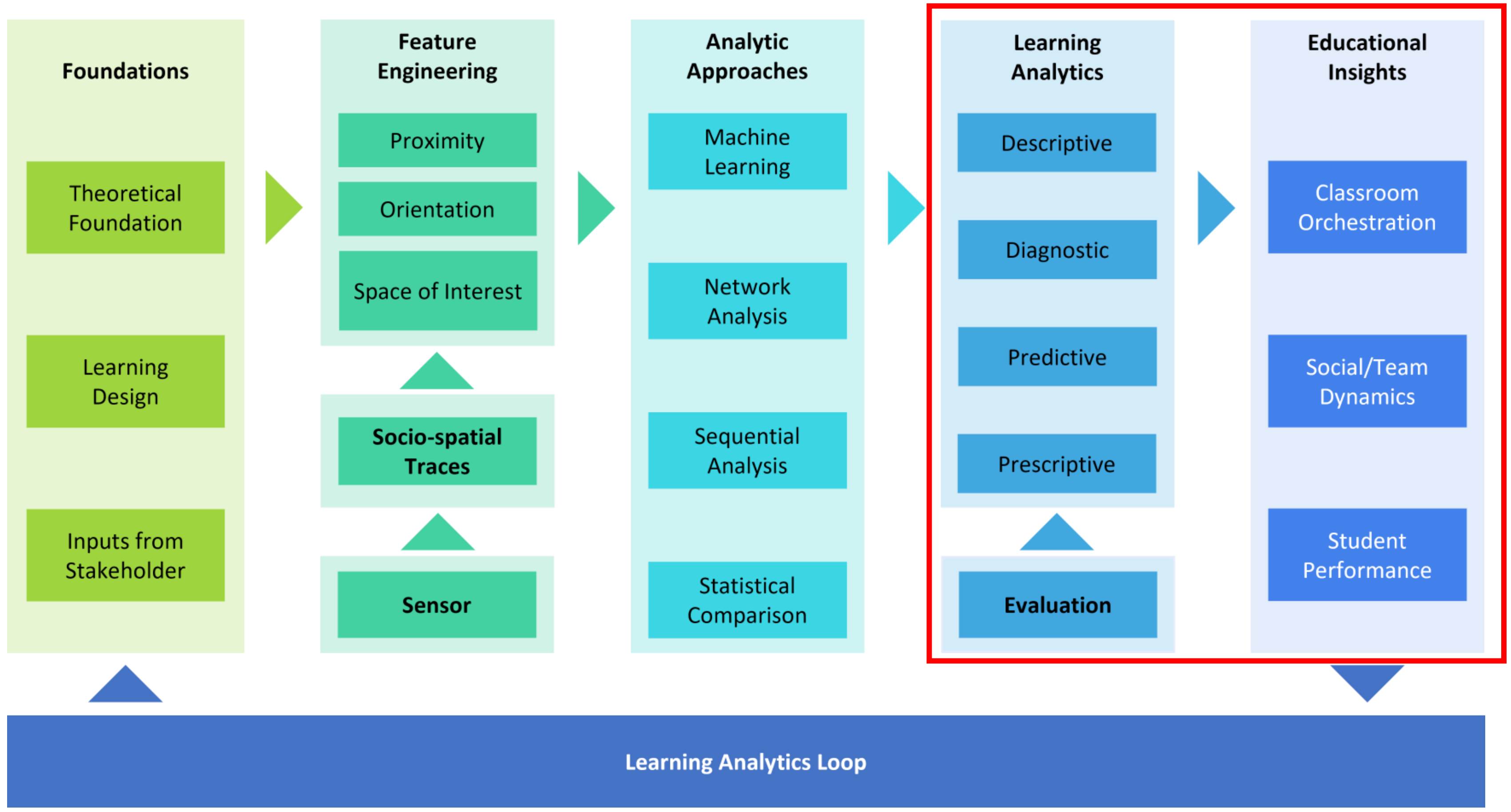
Echeverria, V., Martinez-Maldonado, R., Yan, L., Zhao, L., Fernandez-Nieto, G., Gašević, D., & Shum, S. B. (2022). HuCETA: A Framework for Human-Centered Embodied Teamwork Analytics. *IEEE Pervasive Computing*.

Learning Analytics to Educational Insights



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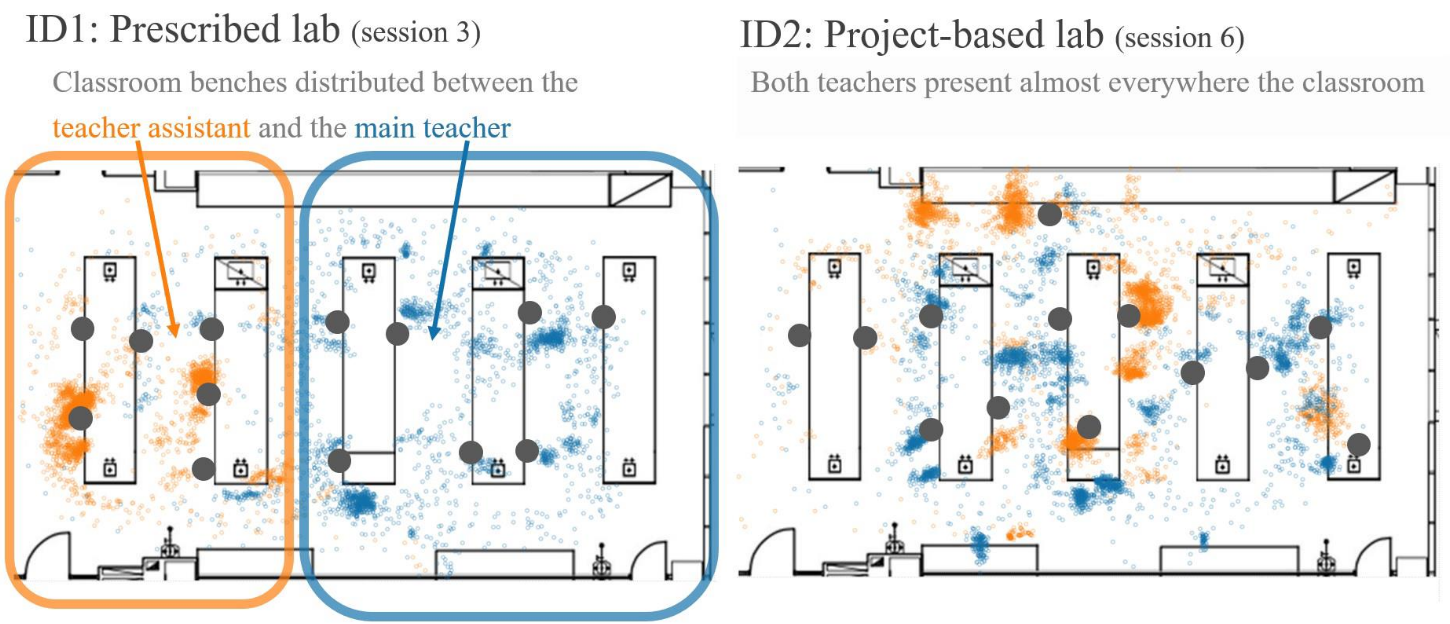
Educational Insights: Classroom Orchestration

Educational Insights

Classroom Orchestration

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



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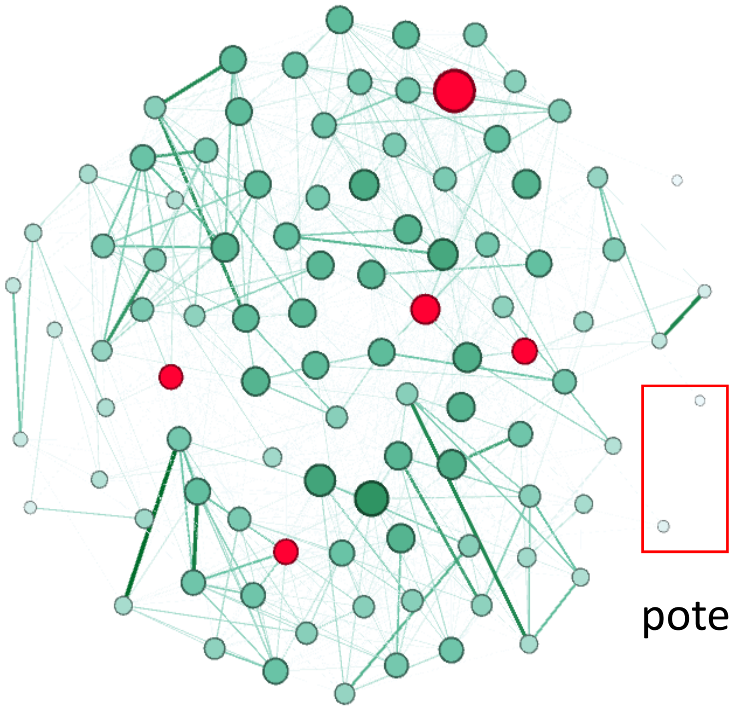
Martinez-Maldonado, R., Mangaroska, K., Schulte, J., Elliott, D., Axisa, C., & Shum, S. B. (2020). Teacher tracking with integrity: What indoor positioning can reveal about instructional proxemics. Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 4(1), 1-27.

Educational Insights: Social/Team Dynamics

Educational Insights

Social/Team Dynamics

Developing learning analytics dashboards that augment teachers' **awareness** of the whole classroom and delivery of evidence-based reflections



potential socially isolated students

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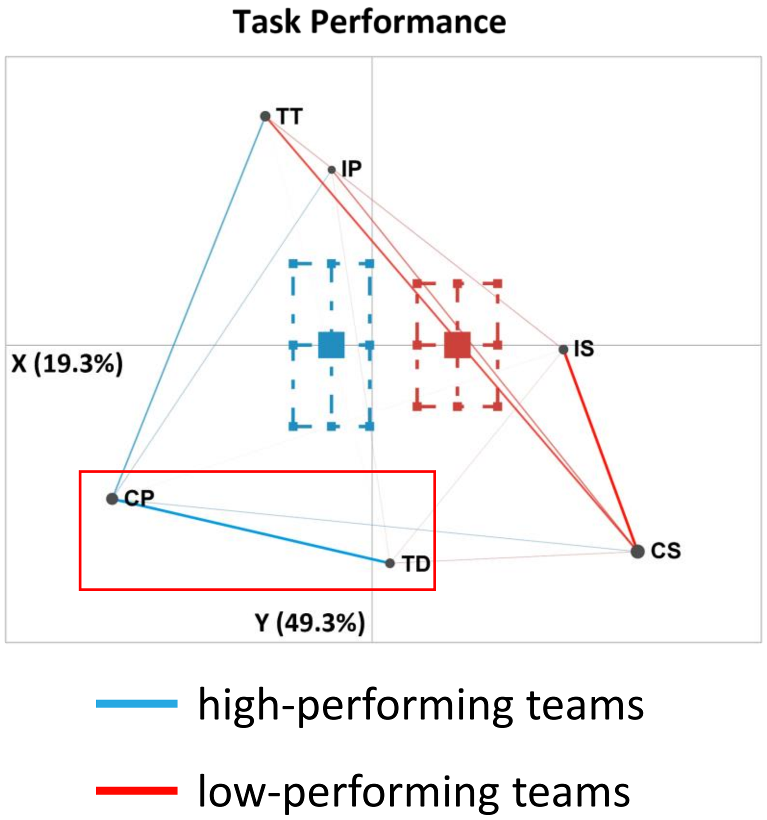
Educational Insights: Student Performance

Educational Insights

Student Performance

Supporting researchers and practitioners in **understanding** social and spatial factors related to students' performance in collaborative contexts



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Illustrative Cases

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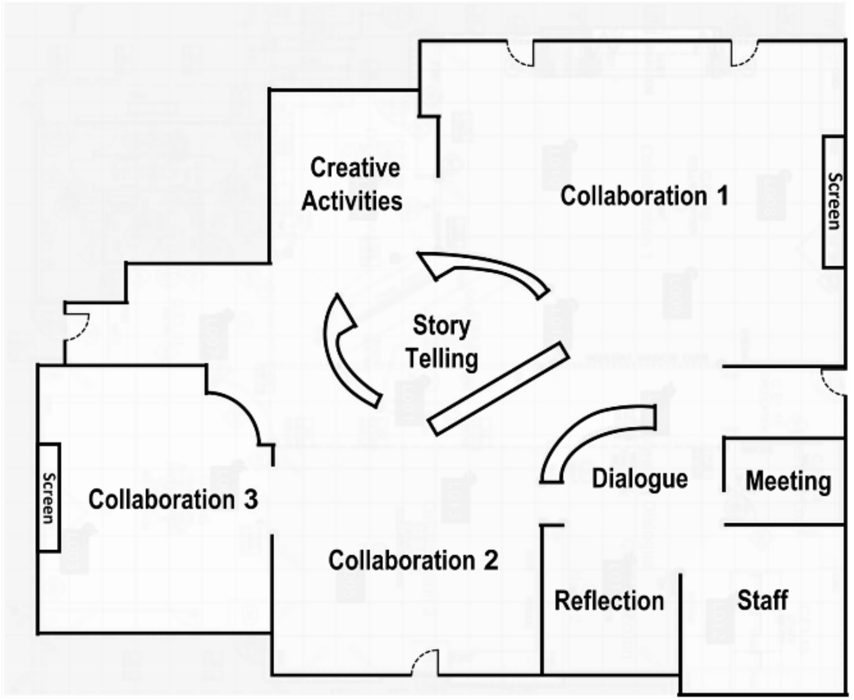
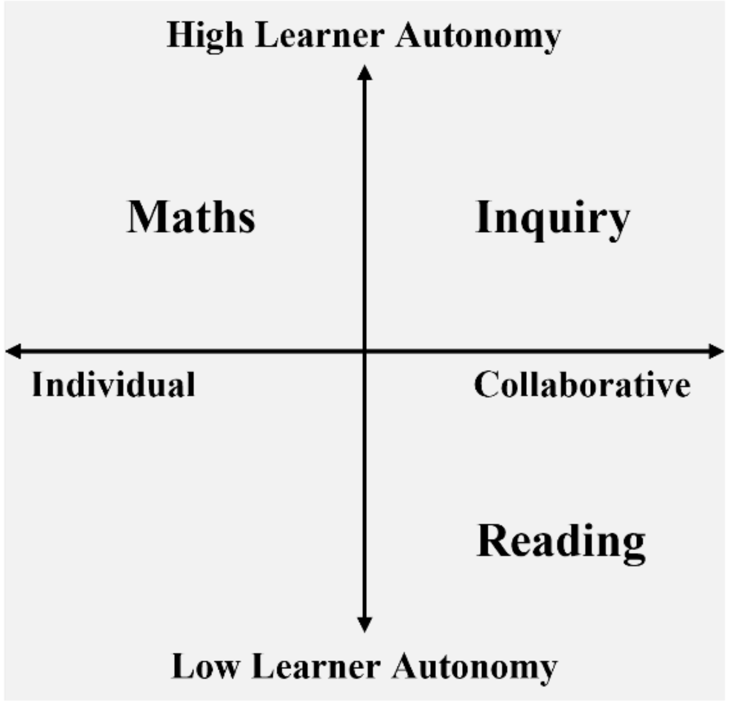
Case 1: Open Learning Space





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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

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Case 1: Socio-spatial Features

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

Metric	Unit	Description
stops	instances	The number of stops made by a teacher per session.
totaltime	minutes	The total stopping time of a teacher per session.
perstop	seconds	The duration of each stop made by a teacher per session.
entropy	bits	The information density of a teacher's spatial data per session.
tPteacher	percent	The percentage of time a teacher spent near other teachers per session.
tPself	percent	The percentage of time a teacher spent by her/himself per session.
tPstudent	percent	The percentage of time a teacher spent near students per session.

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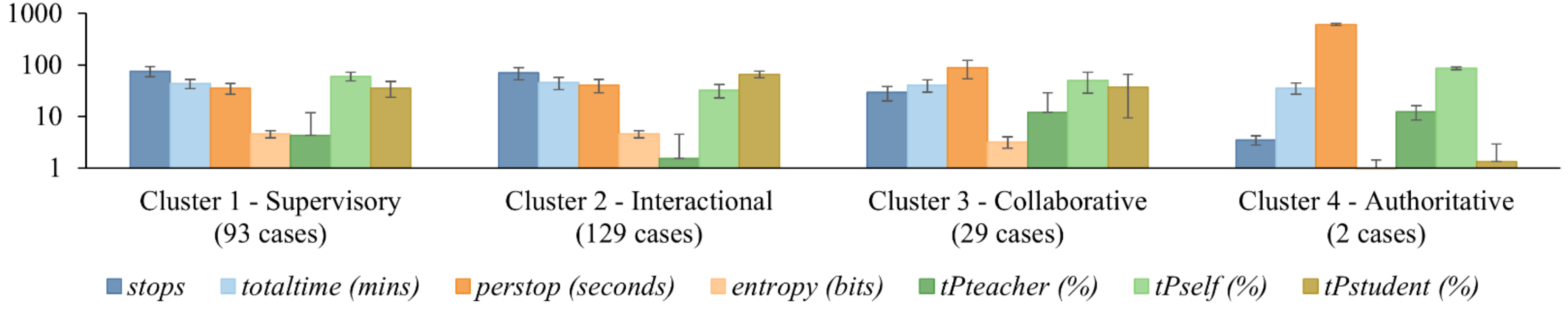
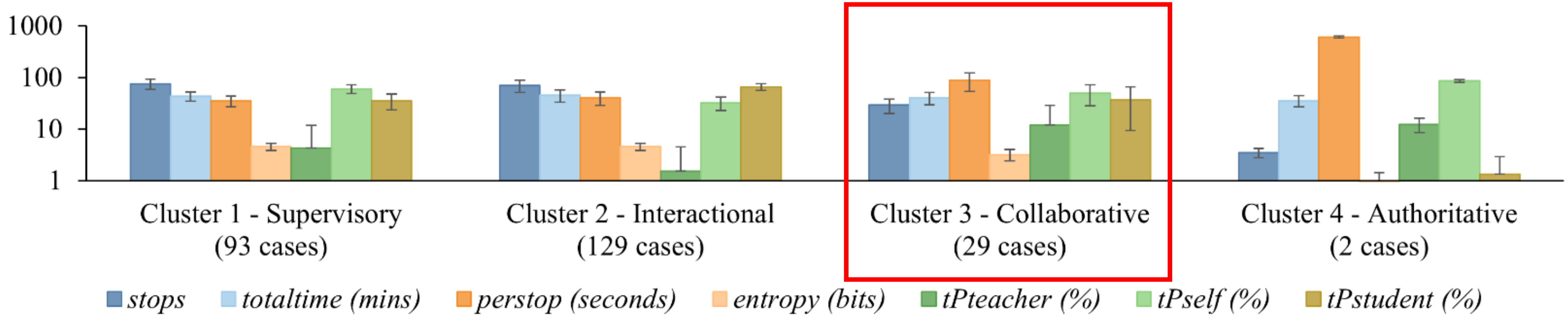
Case 1: Teachers’ Spatial Pedagogy



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).

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		Open Learning Space
• Interactional		• Interactional
• Supervisory		• Supervisory
• Authoritative	→	• Authoritative/Personal
• Personal		• Collaborative

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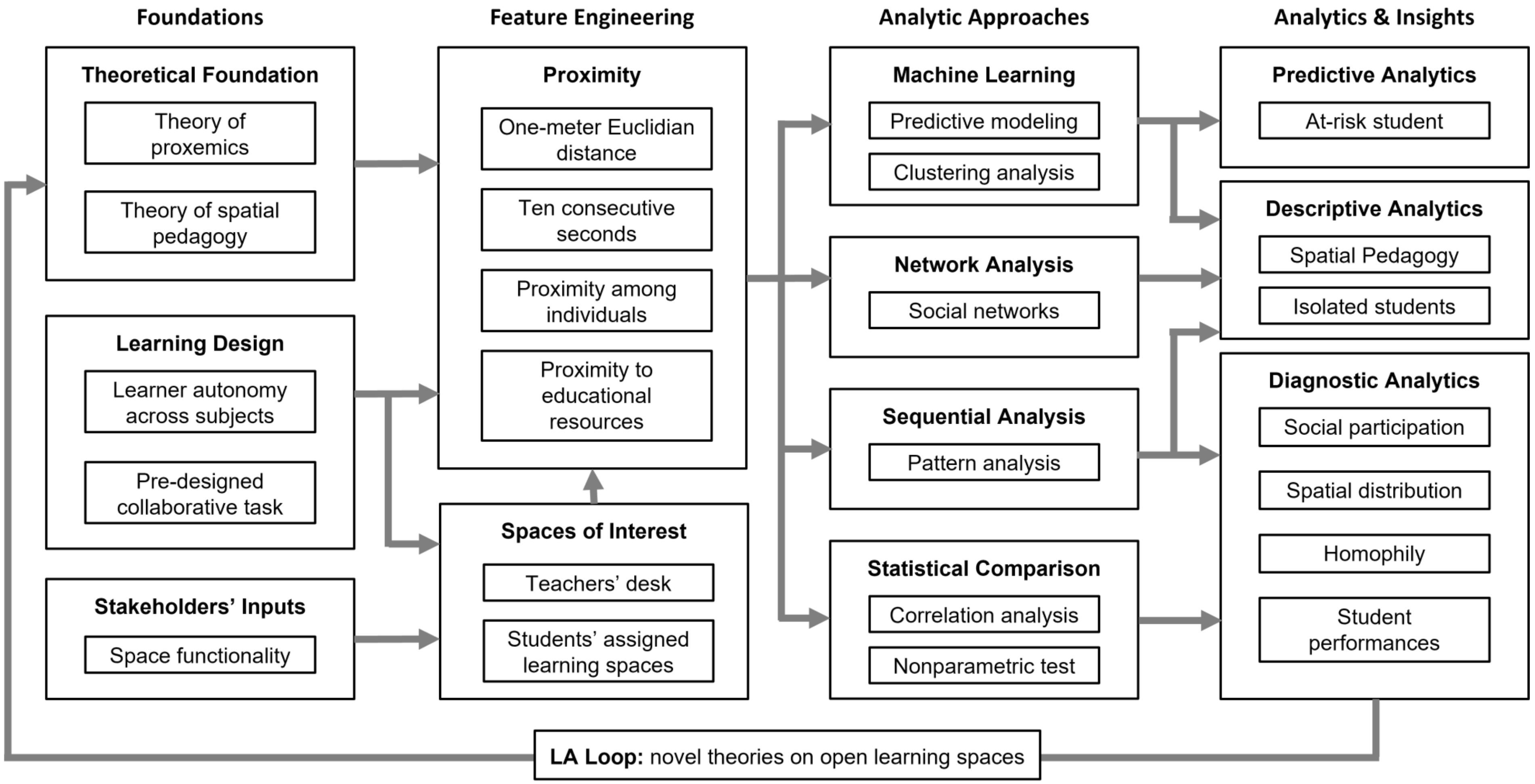
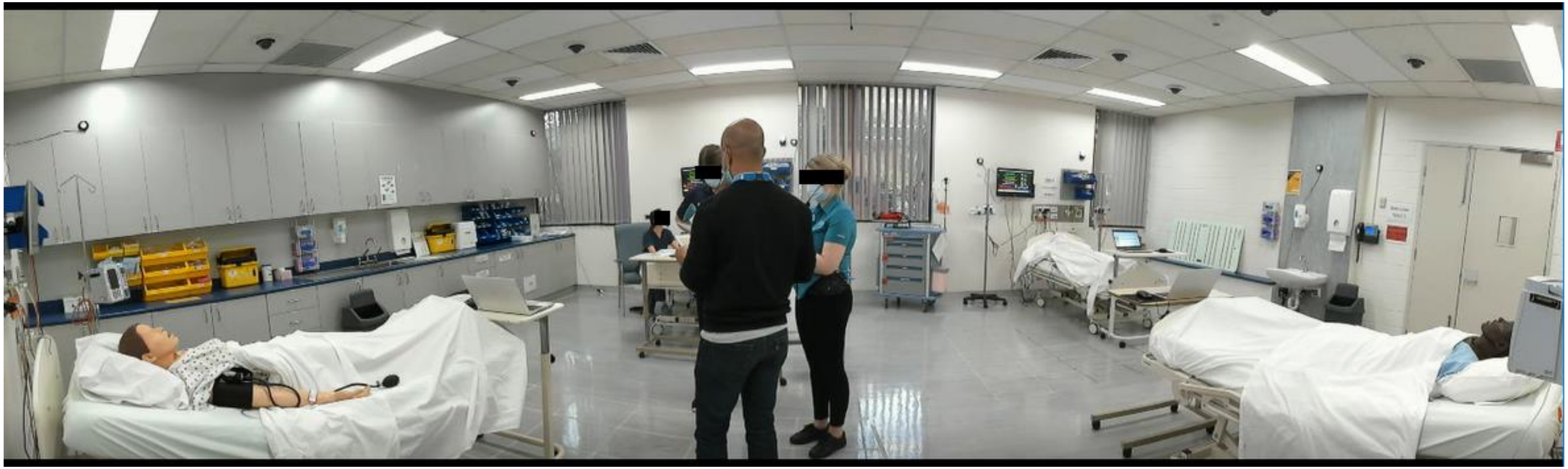
Case 1: Framework in Action



Case 2: Team-based Clinical Simulation



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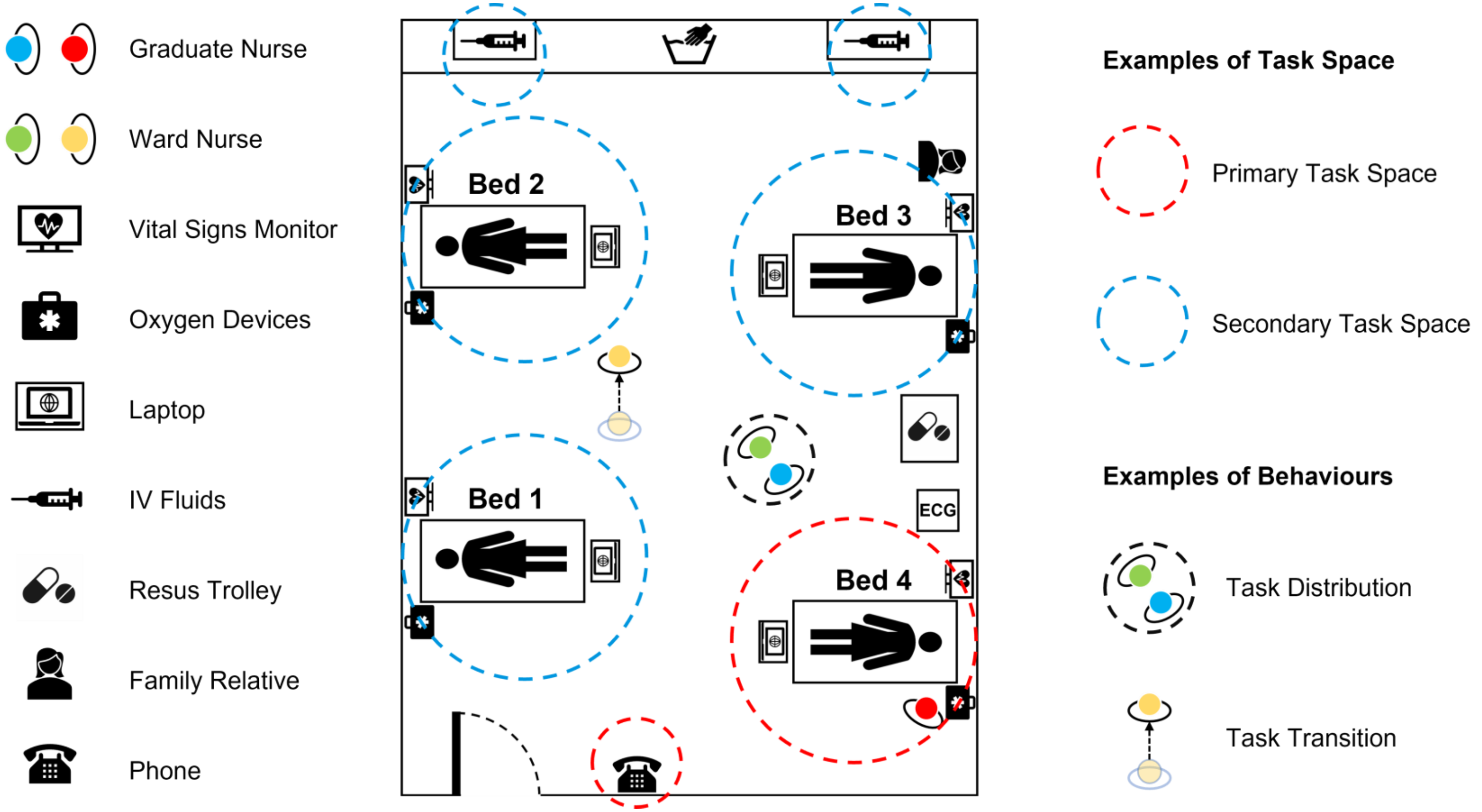
Case 2: Floor Plan and Task Spaces

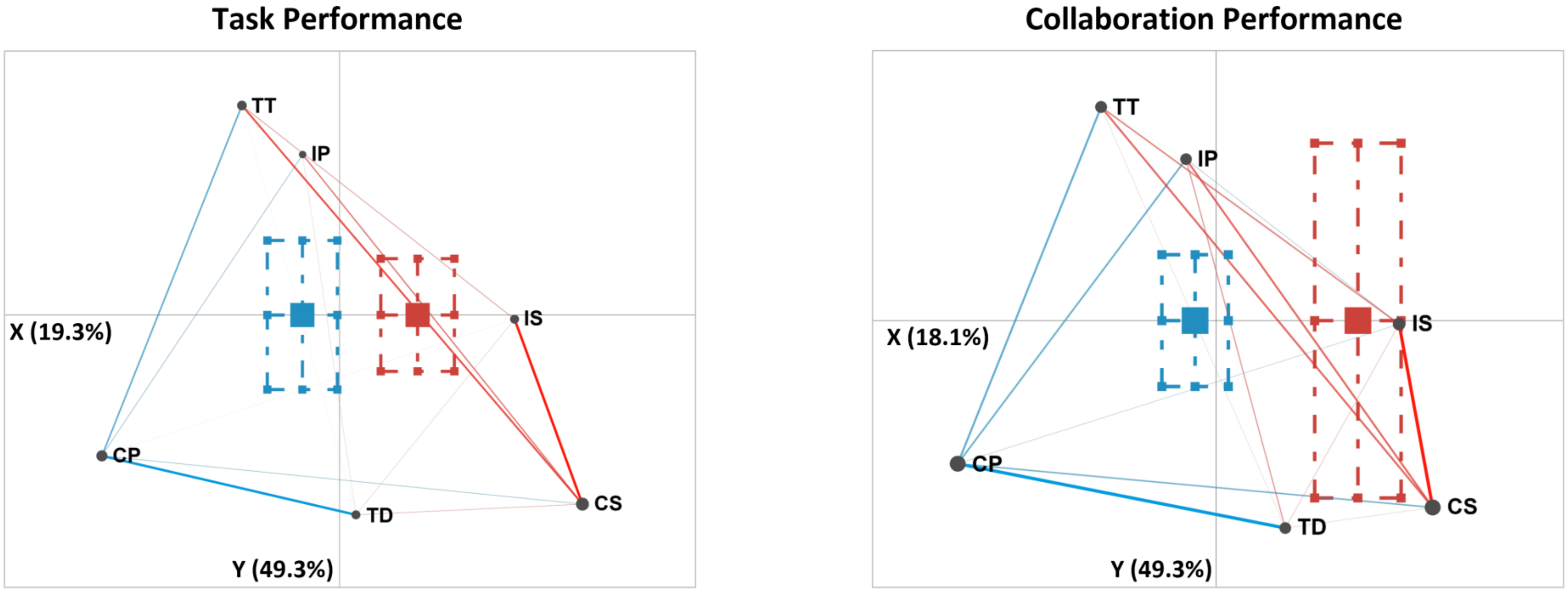


Case 2: Socio-spatial Features

TABLE 2 Spatial-procedural behavioural features (percentage).

Features	Spatial-procedural Behaviours
Collaborate_Primary (CP)	Students working on the primary tasks collaboratively.
Independent_Primary (IP)	Students working on the primary tasks individually.
Collaborate_Secondary (CS)	Students working on the secondary task collaboratively.
Independent_Secondary (IS)	Students working on the secondary task individually.
Task_Distribution (TD)	Students distributing the responsibility of different tasks.
Task_Transition (TT)	Students transiting from one task to another task.

Case 2: Epistemic Network Analysis



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

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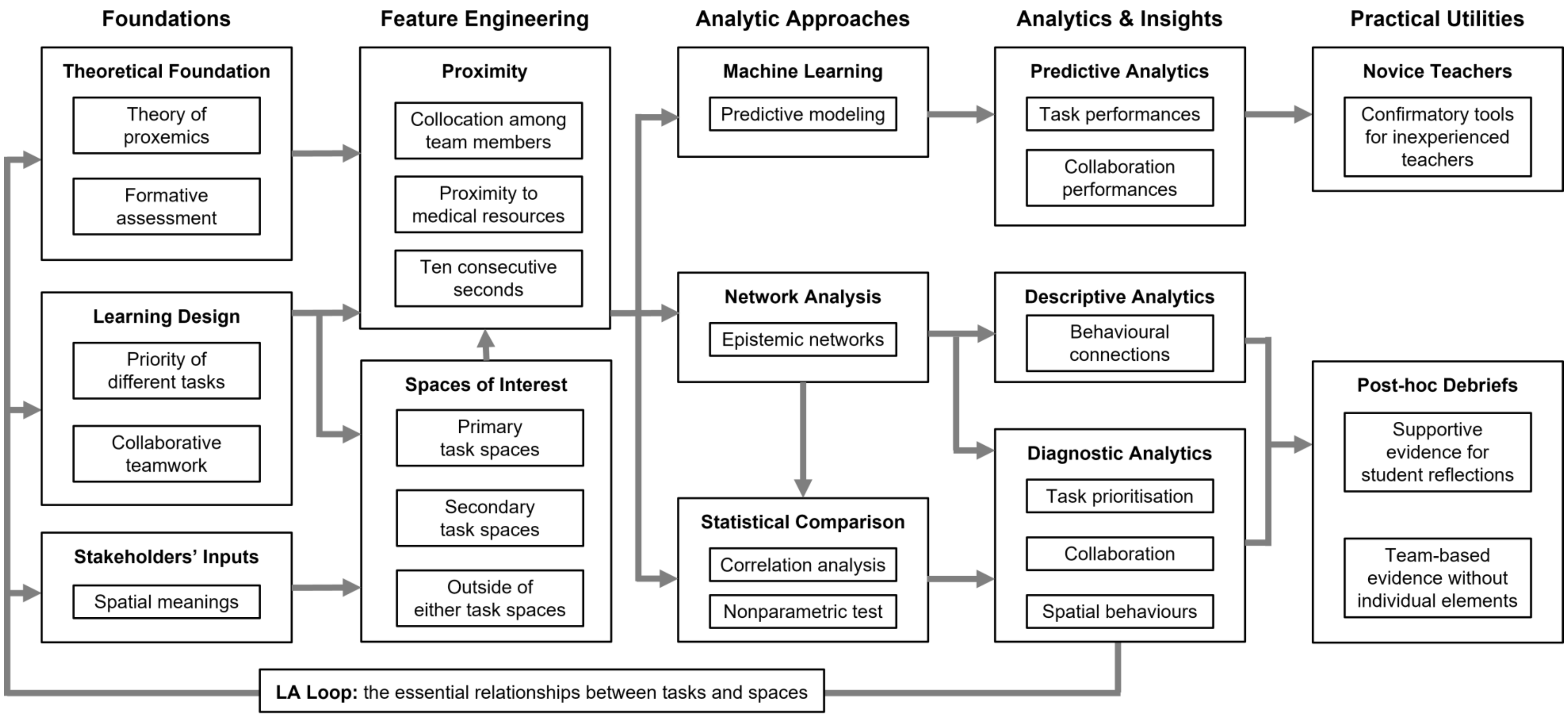
Case 2: Framework in Action



Opportunities and Challenges

Presenter: Lixiang (Jimmie) Yan

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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 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

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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.

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Ethical Challenges

privacy
consent
data
labelling
surveillance
explainable
stability
personal
misuse
transparency
biases
accuracy
algorithmic
trustworthiness

Key Takeaways

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Key Takeaways

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

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

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