Aligning learning design and learning analytics: Towards a human-centered design of actionable learning analytics

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What is this talk about

- A set of connections on Learning Analytics (LA)
  - Learning Analytics for Learning Design (LD)
  - Learning Design for Learning Analytics
  - Human-Centered Design (HCD) of Learning Analytics
  - Learning Theory for Learning Analytics
- An overview of proposals and associated evidence
- An illustrating longitudinal study
- Some take-home messages
The complexity of TEL ecosystems

- Mor, Dimitriadis & Köppe (2019)
- Luckin (2010)
Design and orchestration

Activities
What processes does it entail?

Actors
Who performs those processes?

Background
Why is orchestration done this way?

Prieto, Dimitriadis, Asensio-Pérez & Looi (2015)
Design for Learning

- **What can be designed** for learning?
  - The learning (performed by students) and support (made by teachers) **tasks**
  - The “physical” environment
    - Spaces, tools, infrastructures, artifacts-resources (to be consumed and/or produced)
  - The **social** architecture
    - Groupings, interactions with external agents
- **Design is indirect** (tasks vs. activities)
  - Learners may change-interpret tasks in **learntime**

- Goodyear & Dimitriadis, 2013
- Dimitriadis & Dimitriadis, 2013
Balancing computer-human agents

- Sharples (2013) - Figure
- Soller, Martínez-Monés, Jermann & Muehlenbrock (2005)
LD and orchestration tools

- Villasclaras-Fernández, Hernández-Leo, Asensio-Pérez & Dimitriadis (2013)
- Håklev, Faucon, Hadzilacos & Dillenbourg (2017) - Figure
- Laurillard, Kennedy, Charlton, Wild & Dimakopoulos (2018) - Figure
Teachers as designers

- **Pedagogical knowledge**
  - Eventually embedded in tools
  - Complements / cooperates with the tacit and explicit knowledge of the teachers

- **Teachers**
  - Are and can serve as designers
  - Should participate in the design and orchestration of the teaching and learning processes

Kali, McKenney & Sagy (2015)
Learning analytics is defined as

“measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs”

But most research was devoted

– Mining patterns
– Deriving predictive models
– Providing dashboards

What about “Teacher Inquiry into Student Learning”? 

• Mor, Ferguson & Wasson (2015)
• Dawson (2020)
Wrap up of some questions

■ Who and how designs LA solutions?
■ What are the trade-offs in using a Human-Centered Approach for LA?
■ How can we enhance teachers’ agency and design knowledge?

- Buckingham Shum, Ferguson, & Martinez-Maldonado (2019).
- Holstein, McLaren & Aleven (2019)
LA and LD

- LA as a “contextual overlay” for understanding and optimizing LD
- LD as framework for analyzing student behavior and driving meaningful pedagogical action
- Increasing awareness since 2014 but still a long way to go

- Mangaroska & Giannakos (2019)
- McFayden, Lockyer, Rienties, (2020)
- Pishtari, Rodríguez-Triana et al. (2020)
Learning Analytics Implementation Design (LAID) principles

■ Coordination
  - Which analytics, what productive patterns and what “logistics”, i.e. when and how, whether free or guided

■ Comparison
  - With respect to absolute or relative reference

■ Customization
  - Multiple needs and paths to use LA, implemented as adaptive (by system/agent) or adaptable (by users)

■ Extracted vs. embedded analytics

Wise & Vytasek (2017)
A process model of LA use

Wise & Jung (2019) - figure
• Lockyer, Heathcote & Dawson (2014)
• Corrin, L., et al. (2016) - Figures
• Bakharia, et al. (2016)
Bringing the teacher in the loop

- Customization of LD and orchestration increases efficacy and teacher agency and trust

- LA solutions based on concrete LD information provided by the teacher: course checkpoints, script and activity constraints, orchestration problems

- Rodríguez-Triana, et al. (2015, 2018, 2018)
Consolidated model for LA

- Gasevic, Dawson & Siemens (2015)
- Saint, Gasevic, Matcha, Ahmad & Pardo (2020)
- Gasevic, Kovanovic & Joksimovic (2017) - figure
- Reimann (2016)
Orchestrating LA (OrLA)

Teacher starts here...

| Name your educational context |  |
|--------------------------------|  |
| Brief description of your context (educational level, subject, student characteristics, ...): |  |
| What is peculiar or special about this context? |  |
| What is your favorite classroom technology and why? |  |
| How comfortable are you using technology in the classroom? (score 1-5; add comments if necessary) |  |
| How comfortable are you learning new technologies? (how do you need in order to accept a new one?) |  |
| What do you expect from a LA tool? |  |

**Teaching activities / Practices:**

<table>
<thead>
<tr>
<th>In your context, who does this kind of activity? (e.g., teachers, students, ...)</th>
<th>How is this activity normally done in your context?</th>
<th>What technologies do you normally use to support this activity?</th>
<th>What time constraints do you have for this activity?</th>
<th>System developer comments</th>
<th>Miscellaneous comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design/Planning/Preparation of the learning activities</td>
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<td>Classroom management and adaptation to the face of unexpected events</td>
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<tr>
<td>Awareness of the learning environment and tracking Evaluation and reflection about the success of the learning activities (for future designs)</td>
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</tbody>
</table>

Prieto, Rodríguez-Triana, Martínez-Maldonado, Dimitriadis & Gašević (2019) - figures
Research and design methodologies

- Researcher Practice Partnerships (RPP)
- Design Based Research (DBR)
- Human Centered Design (HCD)

- Buckingham Shum, Ferguson & Martinez-Maldonado (2019)
- Holstein, McLaren & Aleven (2019)
LATUX workflow for LA solutions

- Martinez-Maldonado, Pardo, Mirriahi, Yacef, Kay & Clayphan (2016) - figure
- Holstein, McLaren & Aleven (2019)
Data Storytelling and Explanatory LA

Echeverria, Martinez-Maldonado, Buckingham Shum, Chiluiza, Granda & Conati (2018) - figures
Human-Centered Design of LA

- Design of LA solutions involve a socio-technical system
- LA solutions should be embedded in a human ecology of formal and informal activities
- Students and teachers have partial understanding i.e. they are not “authoritative sources”
- Academic rigor and practitioner knowledge may be combined
- Eventually the benefits of enhanced agency, adoption and impact of the LA solutions overcome the costs of difficult, time and resource consuming participatory processes
- All the important aspects of learning (cognitive, metacognitive, affective and social) are highly sensible and dependent on the context.

Buckingham Shum, Ferguson & Martinez-Maldonado (2019)
An illustrative study

From Theory to Action:

Developing and Evaluating Learning Analytics for Learning Design

- Wiley, Y. Dimitriadis, A. Bradford, M. Linn (2020a)
- Wiley, Y. Dimitriadis, A. M. Linn (2020b)
An overview of the study

Design and development of Teacher Action Planner, a LA tool that supports teachers’ orchestration actions:

- Grounded on learning theory (Knowledge Integration) and using the Inquiry Based Learning approach.
- Aligned with the Learning Design (Global Climate Change and Photosynthesis Units) and platform (WISE)
- Aligned with stakeholders’ needs (OrLA)
- Functional within the constraints of the technical and learning environments
DBR research approach

- KI
- LAID

OrLA

Requirements

Analysis

Implementation

Design

Re-Design

Implications for Theory

LA Solution v.1

LA Solution v.2

Sandoval & Bell (2004) – figure adapted from
The role of Theory: KI framework

Knowledge Integration (KI) Framework (Linn & Eylon, 2011)

- Eliciting Ideas
- Adding Ideas
- Connect Ideas
- Distinguishing Ideas
LD informed by Learning Theory

Global Climate Change Unit

Learning Design Aligned with Learning Theory

Elicit Ideas

Add Ideas

Distinguish Ideas

Connect Ideas

2: Energy from the Sun

2.1: How does the Sun warm Earth?
2.2: What do you think?
2.3: Energy Transfer
2.4: How Does Energy from the Sun Reach Earth?
2.5: Prediction: Solar Radiation to Heat
2.6: What Happens to Energy from the Sun?
2.7: What Happens to Solar Radiation on Earth?
2.8: MySystem of Earth, Space, and Sun
2.9: CQ: When does energy from the Sun warm Earth?
2.10: What do you think now?
2.11: Staying Cool
Teachers identified “Multiple Number of Attempts” (MNA) feature as a potential analytic for student engagement and performance.
Are the data used to generate the learning analytics useful for understanding student learning?

- **Participants**: 479 students across 5 teachers in 1 school
- **Data**: Log data and student work
- **Analysis**: Logistic regression modeling

S=students
Validating the usefulness of LA (II)

Unit Assessment Items

- **Multiple-choice**
  - Max 3 attempts

- **Multiple-choice**
  - Max 4 attempts

- **Open-response**

High Number of Attempts Predicts Performance on Subsequent Explanation Item
Optimizing the LD based on LA

Place Add Ideas & Distinguishing Ideas Items on Same Page

Optimization: Fuse two steps of the unit
Creating a useful LA solution towards pedagogical action

RQ2: Is the resulting learning analytics solution useful for informing pedagogical action?

System developers suggest emailing LA report while preparations made for system integration (6 months)
Hello Ms. Kerrington,

I noticed that most of your students completed Step 1.4 which has the maximum number of attempts feature, so I've analyzed the log data from that step.

Learning goal: Step 1.4 targets MS-ESS3-5 and the stability and change CCC. Students need to be able to recognize the scale of the timeline and interpret the graphical data.

Answered correctly on the first attempt
- Period 1 - 46% (6/13)
- Period 2 - 79% (11/14)
- Period 3 - 75% (9/12)

How many multiple attempts were needed (by workgroup)?
- 2 attempts were needed by those who didn't answer correctly on the first attempt.

What was the most common incorrect answer on the first attempt?
- Most students chose "It was ALWAYS MUCH COLDER than today"
- Students who followed a different pattern, by period:
  - Period 1
    - 397583, 397597 - It was ALWAYS MUCH WARMER than today, then answered correctly.
  - Period 2
    - 397640 - It was ALWAYS THE SAME temperature as today, then chose the correct answer
  - Period 3 (all followed primary pattern)

Researcher Insight: This suggests that students' prior knowledge that current global temperatures are the highest they have been in recent history is overriding their analysis of the actual data presented in the timeline of Earth’s history.

Here is my analysis (by class period) of the log data of your students' responses. Note: You can find the students associated with the workgroup ID by clicking on the "Manage Students" link in the Teacher Tools.
Evaluating the LA solution

Same analytics different pedagogical actions

“I created a page with the question on it and a prompt for the students to discuss in groups why they or others chose the main incorrect answer.”

Theory-grounded LA can also improve teacher practice

“...this data makes me want to implement more pre-activities that help students understand their background knowledge before beginning the next unit.”
**Global Climate Change**

**LAID Principle** - Conceptual Coordination

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**Class Report**

**Item Prompt:** Has global temperature in the past always been the same as it is today? In the past: A) It was ALWAYS THE SAME temperature as today. B) It was ALWAYS MUCH COLDER than today. C) It was ALWAYS WARMER than today. D) It was BOTH COLDER AND WARMER than today.

Students should be able to interpret the patterns in graphical data that show how global temperatures have changed over time.

**Step 1.4 - Attempts Till Correct**

Target = 100% →

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**Key Insights**

1.) No period achieved your targeted goal of 100% of students correctly answering on the 1st attempt.

2.) The most common incorrect response was: “It was ALWAYS MUCH COLDER than today.”

3.) The data suggests that students’ prior knowledge that current global temperatures are the highest they have been in recent history is overriding there analysis of the actual data presented in the timeline of Earth’s history.
Global Climate Change

**Key Insights**

1. No period achieved your targeted goal of 100% of students correctly answering on the 1st attempt.

2. The most common incorrect response was: “It was ALWAYS MUCH COLDER than today.”

3. The data suggests that students’ prior knowledge that current global temperatures are the highest they have been in recent history is overriding their analysis of the actual data presented in the timeline of Earth’s history.

**Description:** The item for this milestone is located in Step 1.4 and aligns with the NGSS MS-ESS3-5 performance expectation.

**Item Prompt:** Has global temperature in the past always been the same as it is today? In the past: A) It was ALWAYS THE SAME temperature as today. B) It was ALWAYS MUCH COLDER than today. C) It was ALWAYS WARMER than today. D) It was BOTH COLDER AND WARMER than today.

Students should be able to interpret the patterns in graphical data that show how global temperatures have changed over time.

**Step 1.4 - Average Response Sequence**

- **Target = 100%**
- **Step 1.4 - Attempts Till Correct**
- **Period 1**
- **Period 2**
- **Period 3**

<table>
<thead>
<tr>
<th>Attempt Type</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Attempt</td>
<td>50%</td>
<td>50%</td>
<td>25%</td>
</tr>
<tr>
<td>2 Attempts</td>
<td>25%</td>
<td>25%</td>
<td>0%</td>
</tr>
<tr>
<td>3 Attempts</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Never Correct</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Never Answered</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

- **Step 1.4 - Average Response Sequence**

- **It was ALWAYS the same temperature as today**
- **It was ALWAYS MUCH COLDER than today**
- **It was ALWAYS MUCH WARMER than today**
- **It was BOTH COLDER AND WARMER than today (CORRECT)**

**LAID Principle**
- Comparison
- Absolute + Relative
**Global Climate Change**

**LAID Principle**

**Customization**

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**Description:** The item for this milestone is located in **Step 1.4** and aligns with the **NGSS MS-ESS3-5** performance expectation.

**Class Report**

**Item Prompt:** Has global temperature in the past always been the same as it is today? In the past: A) It was ALWAYS THE SAME temperature as today. B) It was ALWAYS MUCH COLDER than today. C) It was ALWAYS WARMER than today. D) It was BOTH COLDER AND WARMER than today.

Students should be able to interpret the patterns in graphical data that show how global temperatures have changed over time.

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**Key Insights**

1. No period achieved your targeted goal of 100% of students correctly answering on the 1st attempt.

2. The most common incorrect response was: “It was ALWAYS MUCH COLDEDE than today.”

3. The data suggests that students’ prior knowledge that current global temperatures are the highest they have been in recent history is overriding their analysis of the actual data presented in the timeline of Earth’s history.
The Teacher Action Planner (TAP)

Milestone: Photosynthesis Reaction

Period: 4

Description: The item for this milestone is located in Step 2.10 and aligns with the NGSS MS-LS1-6 performance expectation.

Class Report

Item Prompt: “Write an energy story below to explain your ideas about how animals get and use energy to survive. Be sure to explain how energy and matter move AND how energy and matter change.”

Students should be able to: 1) Coherently describe the photosynthesis reaction, 2) Explain how it cycles energy and matter within and across organisms.

Key Insights
The majority of your students are coherently linking ideas related to this topic but most students need to improve their understanding of the details of the photosynthesis reaction.

Sample response: “The energy goes into plants, the animals eat the plants, then animals eat those animals. Basically what I’m saying, the sun drives the food chain. The animals use their mitochondria to release energy by sending it into their muscles and also by defecating.”

Knowledge Integration (KI) score measures how well students are identifying and linking topic-related ideas (1-5 scale).

Sub-scores measure student understanding of the key ideas related to this topic (1-3 scale).

Recommended Action

Pair-share + Class-share
Students need support in developing an understanding of the photosynthesis reaction. Encourage students to consider their classmates’ ideas by facilitating a pair-share exchange, followed by a class-share using this guiding prompt:

“The photosynthesis reaction is \( \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{glucose} + \text{oxygen} \). Use the model (Step 1.11) to write a step by step guide for how the plant completes this reaction.”

Targeted idea: Plants use energy from sun/light to do photosynthesis reaction, \( \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{glucose} + \text{oxygen} \).

Rationale: Pair-share supports all students to develop an understanding of the photosynthesis reaction; Class-share provides opportunities for them to learn from each other how to link ideas.

Student Completion

Team

Student 231225

Completed

Not Completed
### Recommended orch. actions

**Recommended Action**

**Pair-share + Class-share**

Students need support in understanding and linking the details of the photosynthesis reaction. **Encourage students to consider their classmates' ideas by facilitating a pair-share exchange, followed by a class-share** using this guiding prompt:

*"Use evidence from the model (Step 1.11) to describe exactly how energy from the sun ends up in the glucose that plants make during photosynthesis."

**Targeted idea:** Plants use energy from sun/light to do photosynthesis reaction, \( \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{glucose} + \text{oxygen} \) (via arrangement or chemical reaction).

**Rationale:** Pair-share supports all students to use their understanding of how photosynthesis cycles energy and matter to develop an understanding of the details of the photosynthesis reaction; Class-share provides opportunities for them to learn from each other how to link ideas.

<table>
<thead>
<tr>
<th>Knowledge Integration Process</th>
<th>Recommended Action #1 (above)</th>
<th>Recommended Action #2 (below)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elicit Ideas</td>
<td>Sharing with partner</td>
<td>Looking for evidence in the model</td>
</tr>
<tr>
<td>Add Ideas</td>
<td>Exploring model</td>
<td>Reading peers responses</td>
</tr>
<tr>
<td>Distinguish Ideas</td>
<td>Using evidence to describe how glucose gets energy from the sun</td>
<td>Determining whether to support, refute, or clarify their peers ideas</td>
</tr>
<tr>
<td>Connect Ideas</td>
<td>Class discussion facilitates synthesis of ideas</td>
<td>Using evidence to support, refute, or clarify their peers ideas</td>
</tr>
</tbody>
</table>

**Jigsaw based on KI score**

Students need support in both developing and linking their ideas about this topic. **Have students engage in a jigsaw discussion activity, pairing up teams that have different KI scores.** Use this guiding prompt:

*"Find evidence in the model (Step 1.11) to either support, refute, or clarify the claims made in this response (use responses from each KI level."

**Targeted ideas:** 1) Plants use energy from sun/light to do photosynthesis reaction, \( \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{glucose} + \text{oxygen} \), 2) Energy from the sun gets to animals when they eat photosynthetic plants.

**Rationale:** Jigsawing based on KI score allows students to develop the particular skill they need (1/2: gather ideas to support claim, 3: gather evidence to refute claim, 4/5: identify ways to clarify claims). The mixed groups encourages all students to learn from each other either new ideas, how to coherently link ideas, or how to clarify/elaborate ideas.
Evaluation of TAP

- Multiple actions performed
- Students’ performance was revealed in TAP
- Significant actions by Teacher 1
- But no significant changes in short term
  - A large proportion of students in all three teachers’ classes did not have shifts in their scores

A study on longer term effects showed that
  - Teacher 1 achieved a significant enhancement in all learning dimensions (e.g. concepts and skills), probably due to her alignment with the KI framework
Conclusions of illustrating study (I)

- **Importance of**
  - LD-LA alignment
  - use of learning theory
  - inter-stakeholder communication

- **For design decisions on**
  - elements of the LD that should be analyzed
  - data to be collected
  - indicators to be calculated
  - form that insights are communicated and interpreted
  - connection of LA to LD redesign and orchestration action.
Conclusions of illustrating study (II)

- Importance of theory - implementation principled approach (KA and LAID)
- Influence of all stakeholders in DBR research
- Usefulness of the Data Storytelling in visualization
- Alignment with teachers’ beliefs and attitudes
- Advantages of embedded and checkpoint analytics
- Enhancement of teachers’ agency
- But also need for
  - greater transparency in understanding how LA indicators are computed
  - even longer trials in authentic and scaled up contexts
Some take-home messages (I)

- Technology-enhanced learning (TEL) ecosystems
  - especially hard to design and orchestrate

- Various elements (social architectures, tasks, environment)
  - can be designed in media-res in constantly evolving authentic context

- Teachers are essential stakeholders
  - LD and LA are about learning and teaching

- Human-Centered design is necessary in spite of its cost
  - Move from “demonstrators in a greenfield” to embedded tools and practices in authentic contexts

- Teachers can work as designers and orchestrators
  - based on their own tacit and explicit knowledge (TPACK)

- Tools are necessary to support stakeholders
  - balanced use of AI agents and human expertise and actions
Some take-home messages (II)

- LA for understanding and optimizing learning
  - oriented to pedagogical interventions based on actionable insights

- LA benefits from
  - Data Science, Learning Theory and Design

- LA and LD are intrinsically interconnected
  - They should be jointly employed

- Inter-stakeholder communication is essential
  - using multiple design techniques and approaches

- Bring the human in the loop
  - of these human processes of teaching and learning

- Support them with
  - technological and conceptual tools
References (I)

- Mor, Dimitriadis, Köppe (2019), *Hybrid Learning Spaces – Design, Data, Didactics*, Workshop @ EC TEL 2019, [https://hls-d3.iucc.ac.il/](https://hls-d3.iucc.ac.il/)


References (V)


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