

*Automating Multimodal Data Storytelling  
for Embodied Team Learning*

by *Gloria Milena Fernández Nieto*

Thesis submitted in fulfilment of the requirements for the degree of

**Doctor of Philosophy**

*in*

Learning Analytics

under the supervision of

Dr. Roberto Martínez Maldonado

Prof. Simon Buckingham Shum

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## ABSTRACT

There is a growing interest in creating Learning Analytics (LA) interfaces that support students and teachers directly. Thus far, many of these solutions have been materialised as dashboards and visualisations. However, although a growing number of prototypes and commercial products aimed at supporting students/teachers exist, their limitations are coming under careful scrutiny. For instance, many visual LA tools are failing to provide meaningful and relevant insights that can support students reflections on their embodied teamwork activity.

Moreover, there are additional challenges in visualising and communicating the wide variety of *multimodal sensor data* captured from physical spaces, in a way that supports educational stakeholders (e.g. teachers or students), who as casual users, have limited training in data analysis and interpretation. Thus, this thesis engages research in Information Visualisation (InfoVis) and specifically the **Guidance** visualisation paradigm that aims to support casual users, or those users with low analysis expertise, to narrow the gap of data visualisation interpretations. **Data Storytelling** is one way to provide guidance, as a compression technique to help an audience effectively understand what is important in an visualisation, communicating key messages combining *data*, *visualisations*, and *narratives*. ‘Telling stories’ with data in these ways should enable the elicitation of deeper reflections in an effective manner.

This thesis tackles the above challenges by investigating: “*How can salient aspects of embodied team activity be automatically identified and derived insights be communicated to support timely, productive reflection?*” Four research questions were derived: (1) What **modelling techniques** can enable identification of salient aspects of multimodal embodied team activity according to the learning design (i.e. teachers’ pedagogical intentions)? (2) How can insights be extracted from multimodal sensors and **communicated to students and teachers** to support teaching and reflection on embodied team activity? (3) To what extent can students and teachers **reflect** on embodied team activity using MMLA interfaces? and (4) To what extent can MMLA interfaces for students and teachers be **automatically generated**?

This research adopted a **mixed methods** approach using quantitative and qualitative analyses to provide evidence in response to these research questions. Empirical studies of teamwork were conducted in **authentic higher education settings** in the context of *healthcare* (simulations) and *science* (physics lab) education. Automated multimodal Data Stories were co-designed, evaluated, and implemented to support students and teachers to reflect on different aspects of their embodied practice (patient-care, or

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co-teaching).

This research makes three types of contribution: modelling, prototypes (MMLA interfaces), and implementation. Regarding **modelling**, two contributions are presented: (i) a methodology to map from teachers' pedagogical intentions to salient aspects of multimodal embodied team activity, and (ii) the exploration of a set of five multimodal data modelling techniques. In terms of **MMLA interfaces** two contributions are presented: (iii) a set of seven multimodal data interfaces were created, and (iv) the analysis and evaluation of them to understand their potential for reflection. Finally, in terms of **implementations**, this research contributes a (v) functional architecture description and documentation and (vi) a *reference implementation* to automatically generate multimodal LA data stories.

Results from this research point to the potential of creating alternative ways to communicate multimodal data insights to teachers and students, by combining visualisation, narrative and storytelling, driven by teachers' pedagogical intentions. Multimodal data stories of embodied team activity are effective tools to support: (a) teachers as they reflect on student progress; (b) students as they reflect, recall and improve their future practices; (c) teachers in providing timely feedback according to their pedagogical intentions; and (d) teachers as they reflect on their co-teaching practice. In addition, this thesis identifies that LA designers should identify representations that best fit teachers' and students' needs, by contextualising and aligning pedagogical intentions with the visual analytics.

**Keywords:** guidance, data storytelling, embodied team learning, learning by reflection, multimodal data, pedagogical intentions, learning design.

## AUTHOR'S DECLARATION

I, *Gloria Milena Fernández-Nieto* declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy in Learning Analytics, in the *Connected Intelligence Centre* at the University of Technology Sydney, Australia, is wholly my own work, unless otherwise referenced or acknowledged.

In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution. In addition, I received direct authorisation from the main authors to include their images to document previous research in Chapter 2. This research is supported by the Australian Government Research Training Program under the International Research Training Program Scholarship (IRTP).

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Signature removed prior to publication. \_\_\_\_\_

[Gloria Milena Fernández Nieto]

DATE: 21 July, 2022

PLACE: Sydney, Australia





## DEDICATION

*To my beloved husband and my Colombian and Aussie families which have always been there giving me support and motivation. My heart is with you all and will always be with you ...*



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[Spanish alert!] Principalmente, gracias a mi familia en Colombia. Los amo y aprecio todo el apoyo y acompañamiento durante estos años lejos de casa. Durante este tiempo aprendí grandes lecciones no solo como profesional sino como ser humano. En primera instancia, aprendí a no dar las cosas por hecho, la distancia me demostró que no estar cerca de las personas que amas puede ser muy doloroso, aprovecharlas al máximo es ahora parte de mi motivación de vida. Además, aprendí que la familia esta siempre para ti, en los buenas y en los malos momentos. A mi madre bella (Gloria Stella), por supuesto, sin su apoyo, su motivación y sus sacrificios, yo no estaría disfrutando de este nuevo logro, ¡gracias por todo madre! A mi padre (Ramón Fernández), porque su berraquera, su empuje y su constante trabajo me permitieron estudiar y cumplir sueños. A mi hermanito (Camilo Fernánadez), porque, el ser humano que soy hoy, es en parte por su influencia en mi, siempre has sido mi ejemplo.

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## LIST OF PUBLICATIONS

### JOURNAL PAPERS:

1. **Gloria Milena Fernandez-Nieto** et al., "Storytelling With Learner Data: Guiding Student Reflection on Multimodal Team Data", in *IEEE Transactions on Learning Technologies* (2021), doi: 10.1109/TLT.2021.3131842
2. **Gloria Milena Fernandez-Nieto**, Roberto Martinez-Maldonado, Vanessa Echeverria, Kirsty Kitto, Pengcheng An, and Simon Buckingham Shum. 2021. What Can Analytics for Teamwork Proxemics Reveal About Positioning Dynamics In Clinical Simulations?. *Proc. ACM Hum. Comput. Interact.*5, CSCW1, Article 185 (April 2021),24 pages. doi: 10.1145/3449284
3. Martinez-Maldonado, R., Gasevic, D., Echeverria, V., **Fernandez-Nieto, G.**, Swiecki, Z., and Buckingham Shum, S. (2021). What do you mean by collaboration analytics? a conceptual model. *Journal of Learning Analytics*, 8(1), 126–153. doi: 10.18608/jla.2021.7227
4. Martinez-Maldonado, R., Echeverria, V., Mangaroska, K., Shibani, A., **Fernandez-Nieto, G.**, Schulte, J., and Buckingham Shum, S. (2022). Moodoo the tracker: Spatial classroom analytics for characterising teachers' pedagogical approaches. *International Journal of Artificial Intelligence in Education*, 8(1), 1–27. 10.1007/s40593-021-00276-w

### CONFERENCE PROCEEDINGS:

1. **Gloria Milena Fernandez-Nieto**, Pengcheng An, Jian Zhao, Simon Buckingham Shum, and Roberto Martinez-Maldonado. 2022. Classroom Dandelions: Visualising Participant Position, Trajectory and Body Orientation Augments Teachers' Sense-making. In *CHI Conference on Human Factors in Computing Systems (CHI'22)*, April 29-May 5, 2022, New Orleans, LA, USA. ACM, New York, NY, USA, 17 pages, doi: 10.1145/3491102.3517736. 2022.

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2. **Gloria Milena Fernandez-Nieto**, Simon Buckingham Shum, Kirsty Kitto, and Roberto Martinez-Maldonado. 2022. Beyond the Learning Analytics Dashboard: Alternative Ways to Communicate Student Data Insights Combining Visualisation, Narrative and Storytelling. In LAK22: 12 th International Learning Analytics and Knowledge Conference (LAK22), March 21 –25, 2022, Online, USA.ACM, New York, NY, USA, 16 pages. doi: 10.1145/3506860.3506895
  3. **Gloria Milena Fernandez-Nieto**, Roberto Martinez-Maldonado, Kirsty Kitto, and Simon Buckingham Shum. 2021. Modelling Spatial Behaviours in Clinical Team Simulations using Epistemic Network Analysis: Methodology and Teacher Evaluation. In LAK21: 11th International Learning Analytics and Knowledge Conference (LAK21), April 12–16, 2021, Irvine, CA, USA.ACM, New York, NY, USA, 11 pages. doi: 10.1145/3448139.3448176
  4. Lixiang Yan, Roberto Martinez-Maldonado, Beatriz Gallo Cordoba, Joanne Depeler, Deborah Corrigan, **Gloria Fernandez Nieto**, and Dragan Gasevic. 2021. Footprints at School: Modelling In-class Social Dynamics from Students’ Physical Positioning Traces. In LAK21: 11th International Learning Analytics and Knowledge Conference (LAK21). Association for Computing Machinery, New York, NY, USA, 43–54. doi: 10.1145/3448139.3448144
  5. Martinez-Maldonado, R., Gašević, D., Echeverria, V., **Fernandez-Nieto, G.**, Swiecki, Z., and Buckingham Shum, S. (2021). What Do You Mean by Collaboration Analytics? A Conceptual Model. *Journal of Learning Analytics*, 8(1), 126-153. doi: 10.18608/jla.2021.7227
  6. Roberto Martinez-Maldonado, PhD; Vanessa Echeverria; Katerina Mangaroska; Antonette Shibani; **Gloria Fernandez-Nieto**; Jurgen Schulte; Simon Buckingham Shum. *International Journal of Artificial Intelligence in Education (IJAIED’21)*. Moodoo the Tracker: Spatial Classroom Analytics for Characterising Teachers’ Pedagogical Approaches. doi: 10.1007/s40593-021-00276-w
  7. Roberto Martinez-Maldonado, Vanessa Echeverria, **Gloria Milena Fernandez-Nieto**, and Simon Buckingham Shum. 2020. From Data to Insights: A Layered Storytelling Approach for Multimodal Learning Analytics. In CHI Conference on Human Factors in Computing Systems CHI’20. 15 pages. doi: 10.1145/3313831.3376148.

#### **WORKSHOP PAPERS:**

- 
6. **G. Fernandez-Nieto**, K. Kitto, and R. Martinez Maldonado, Four Challenges in Crafting Multimodal Collaboration Analytics for non-Data experts, 2019. In CSCL 2019, Collaboration Analytics. available here
  7. Miguel A. Ronda, Olga C. Santos, Roberto Martinez-Maldonado and **Gloria Fernandez-Nieto**. Exploring Emotional Reactions in Teamwork using Multimodal Physiological Data. MAIED'21. 12 pages.

#### **WORKSHOP:**

8. Vanessa Echeverria, Lu Lawrence, Yi-Shan Tsai, Shaveen Singh, **Gloria Fernandez-Nieto**, Roberto Martinez-Maldonado. A Tutorial on Data Storytelling for Learning Analytics Dashboards. LAK21 Workshop.
9. Roberto Martinez-Maldonado<sup>1</sup> and **Gloria Fernandez-Nieto**. Multimodal Analytics for Classroom Proxemics. ALASI 2019.

#### **ETHICS:**

The studies presented in this thesis were conducted under ethics approved by the University of Technology Sydney's Human Research Ethics Committee, and are based on projects ETH17-1411: Learning Analytics for understanding small-group collaborative processes; ETH17-1415: Measuring Adoption and Acceptance of Learning Analytics Tools and ETH17-1502: Learning Analytics in clinical simulation. A revised version of the ethics project ETH17-1502 has the protocol number ETH18-2278. The most recent participant information sheets and consent forms can be requested by email.

One of the studies was run at Monash University as part of the research project "Teamwork analytics in clinical simulation", project ID: 28026. Students and academics consented to participate in both, data collection and follow-up interviews.

#### **SOURCES AND ORIGINAL WORK:**

Original material of my own from the above publications has been included in this thesis. Such prior publications when used in the thesis are explicitly cited where appropriate and are not used in entirety. Publications of external authors are credited throughout the thesis with citations in text and reference at the end of the thesis. Figures from external sources where author granted permissions for usage are cited in their captions.





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