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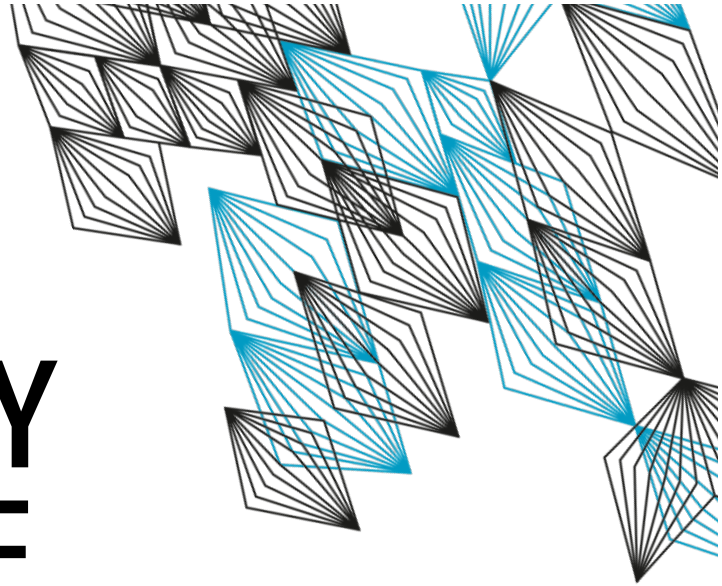

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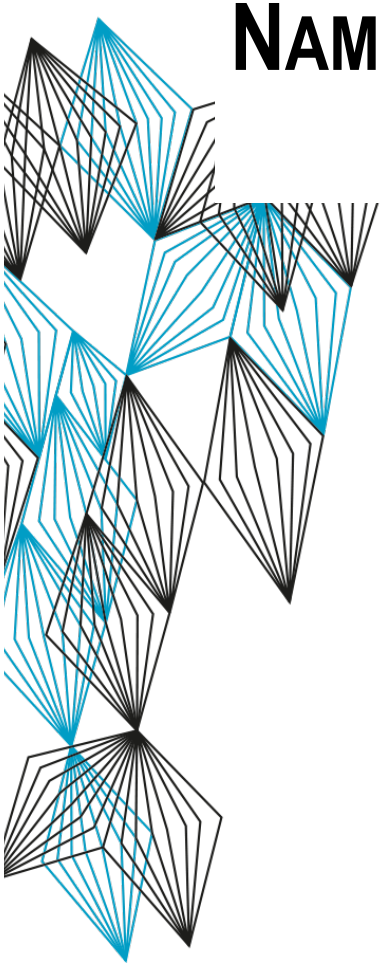
Learning Electrochemistry Through Scientific Inquiry: Conceptual Modelling as Scaffolding

Educational Research Project

Mariana Orozco

NAMEPLATE



Project Title	Learning electrochemistry through scientific inquiry. Conceptual models as scaffolding.	
Lead Researcher	Dr. ir. Mariana Orozco	(BMS-WIJS)
Supervisor	Prof. dr. ir. Mieke Boon	(BMS-WIJS)
Support	TNW-CSE Programme, esp. Teachers Team Module 4	
Period	April – December 2021	
Funding	University of Twente	
Ethics Committee Approval	Request 210292 approved on 21.03.21	
Data Management Plan	available	
GDPR Registration	29.03.21	
BMS Lab Support	Project-ID-1616661384	

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Abstract

- This presentation concerns an action research project in Engineering Science Education.
  The project (running in 2021) aims at pedagogical innovation in CSE Module 4, and beyond.

- This project is a joint effort of teachers and researchers from the TNW and BMS faculties.
  Dr. ir. Mariana Orozco is the lead researcher. Doctor in Educational Sciences, she has an academic background in Chemical Engineering, and professional experience in various industrial sectors.

- The purpose of the presentation is to inform the steering team of the learning programme hosting the pedagogical intervention and the empirical investigation.

- The further purpose is to inform the students, learning assistants and teachers concerned.
  After this, the prospective participants will be requested to complete an informed consent form.

- This project is fully dependent on the engagement and voluntary participation of students, learning assistants and teachers.

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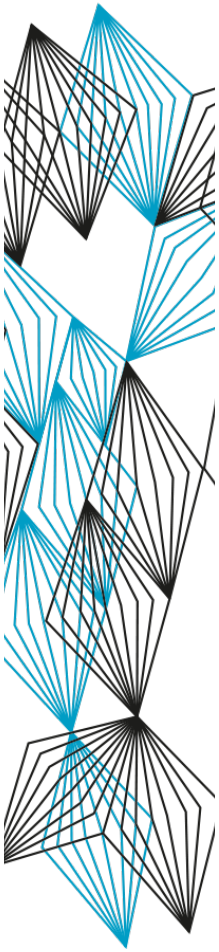

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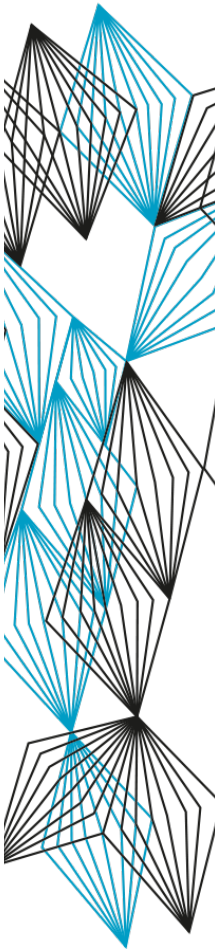
Problem Formulation

- In the past, the CSE bachelor programme
  did not provide an extensive electrochemistry course

- Teachers at the master level observed
  students' insufficient understanding of electrochemical concepts and phenomena
  - Necessary to introduce new topics → i.e. connecting to new concepts
  - Necessary to generate new knowledge → e.g. adaptive transfer & use in scientific problem-solving

- A new course was required
  - To contribute to students' building deep insight into electrochemical phenomena
  - To promote students' mastery of electrochemical concepts

The Approach: Action Research in Education



- Action research
  - Combines
    - Pedagogical intervention → its design, implementation, execution, evaluation
    - Educational research → explorative, descriptive, evaluative
  - Joint effort of teachers & researchers from the TNW and BMS faculties
- The intervention → extensive electrochemistry course
  - For Module 4 of the bachelor programme
  - Innovative pedagogical approach → the instructional design integrates Chemical Science, Philosophy of Science in Practice, and Education Sciences
    - Tapping on ideas of inquiry-based learning
    - Guided by the use of conceptual modelling
- The educational research
  - Intervention study
  - Phenomenological approach

Use of qualitative methods of data collection and analysis, seeking description of the phenomenon of learning, focussing on the students, learning assistants and teachers' experiences.

Theoretical Framework & Methodological Guidance

- Electrochemistry → (e.g., Fuller & Harb, 2018)
- Conceptual modelling → (Boon & Knuuttila, 2009)
- Models as mediators → (Morgan & Morrison, 1999)
- Learning progression for scientific modelling → (Schwarz et al., 2009)
- Scaffolding → (e.g., Davis & Linn, 2000)
- Inquiry-based learning → (e.g., Madhuri et al., 2012)
- Action research & Intervention studies in education → (e.g., Cohen, Manion, & Morrison, 2011)

Intervention Purposes

- The aim of the new course is to assist students in building deep insight into electrochemical phenomena and extended mastery of concepts. In particular for the selected topics:
  - Potentiometric meter
  - Electrochemical cell
  - Solubility
  - Acid-base potentiometric titration
  - Cyclic voltamperometry (final project)

- More information
  - Learning objectives (ILOs)
  - Handout Conceptual Modelling
  - Handout Electrochemical Practicum
  - Electrochemistry manual

Educational Research Purposes

- Explore
  - Understand how M4-students learn electrochemistry under the pedagogical intervention
- Describe (in an integrative fashion)
  - Behavioural aspects of learning → e.g., indicators of progress in reasoning
  - Assessment results → i.e., process & product evaluation, by LA & teachers
  - Contextual conditions → e.g., sequencing of learning activities, groups working
- Evaluate
  - Find out whether the new approach has any effect (& to what extent)
    - on the near and far-reaching learning outcomes in M4 → using the learning objectives as criteria
    - on transfer of electrochemical concepts in M5 → terms of mastery of concepts

Context of Study

CSE Programme 2021

- Module 4 → Electrochemistry Course
  - Conceptual modelling workshop
  - Laboratory practicum → Electrochemical Cell & Final project
  - Process & product evaluations
  - *Participants: students, learning assistants (LAs), M4-teachers*
- Module 5 → Kinetics & Industrial Chemical Processes
  - Process & product evaluations
  - *Participants: same students, M5-teachers*

Educational Research Methods

- From research purposes to research design
  → description of the data sources, and data collection & analysis to respond to each research question (RQ)
  - Explore → RQ1
  - Describe → RQ2
  - Evaluate → RQ3

- Overview of participants
  → individual students (S), students' groups (G), learning assistants (LA), teachers (T)

- Overview of data collection
  - Data sources (e.g., practicum reports, groups discussions)
  - Time dedicated to this study (none to max. 2 hours for a few selected participants)
  - Kind of data → (e.g., qualitative, quantitative, documents, recordings)

Explore → Research Question 1

- RQ1 → How do students learn electrochemistry under the intervention?
- Focus on
  - Students' reasoning & hands-on activity, during lab practicums
    - Observation of behaviour followed by recall interviews
    - Content analysis (rather than motor skills), in terms of CM learning objectives
  - Students' progress in reasoning, during the construction of conceptual models
    - Lab journals & practicum reports (including students' reflections)
    - Content analysis (rather than writing and presentational skills), in terms of CM learning objectives
  - Students' reasoning & discursive activity, during meetings with their Las
    - Observation of preparatory & feedback meetings
    - Content analysis (rather than conversational), in terms of CM learning objectives
- Contribution → Fundamental understanding on the interaction of the intervention with the process of learning

Describe → Research Question 2

- RQ2 → In what ways is student learning embedded in the learning environment?
- Focus on
  - Building on the findings related to RQ1
  - Relation to the LA & teachers' evaluation
    - Collect exams, quizzes, practicum reports and lab journals
    - Analysis in terms of ALL learning objectives
  - 'Thick description' of the contextual conditions
- Contribution → Contextualisation of the findings to provide tools for generalisation (i.e., hints on how to implement in other modules & programmes)

Evaluate → Research Question 3

- RQ3 → To what extent does the intervention have any effect on the learning outcomes?

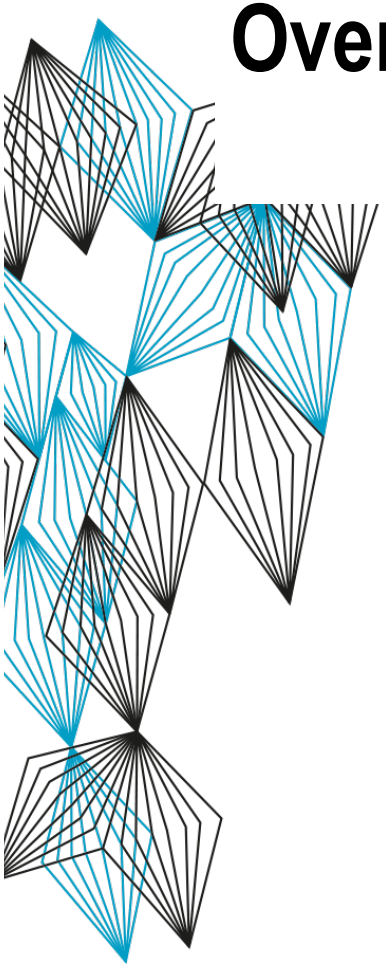
- RQ3a
  - Near-reaching outcomes (e.g., solving well-structured problems) & far-reaching outcomes (e.g., solving ill-structured problems)
  - Focus on comparison of this and last year's results of the assessments
    - Collect teachers' perceptions in M4
    - Collect last and this years' exams → evaluate the feasibility of comparison
    - Analyse the exams comparatively → (1) in terms of ALL learning objectives, (2) in the light of teachers' perceptions

RQ3b.

  - Mastery of concepts in terms of connections to new and/or more encompassing concepts & in terms of their use in scientific problem-solving
  - Focus on transfer
    - Follow-up students from M4 to M5
    - Collect teachers' perceptions in M5

- Contribution → evidence of the effectiveness of the intervention
  to the extent that it is defendable to attiribute effects to the intervention

Overview of Participants



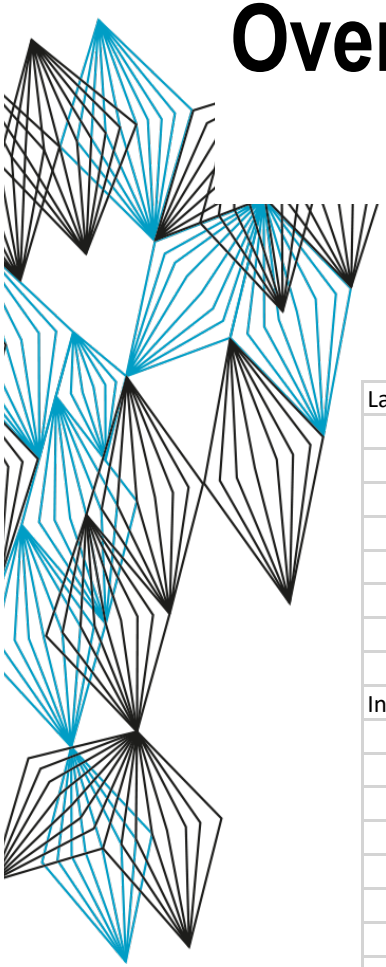
	Number of participants			
	Students	Groups	LA	Teachers
Pool of participants	24	8	5	2
Volunteers*	24	8	5	2
Attrition*	0	0	0	0
After random sampling	12	4	5	2

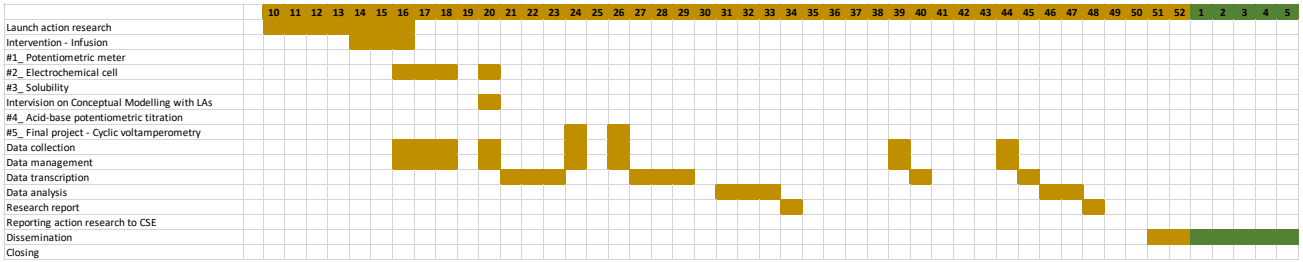
** assumption*

Overview of the Data Collection

Data sources	Participants				Time [h/pers]	Freq.	Kind of data	Comment
	S	G	LA	T				
Test electrochem. + Assessment	x					1	quaL/quaN	existing, anonym. to do
Survey - Informed consent	x					1	doc.	
Lab journals	x	x				3	doc.	
Practicum reports							doc.	
Practicum electrochem. cell	x	x				1	video rec.	1 student/ group
Recall interview	x	x			1,5	1	audio rec.	the same student
Groups - LA meetings	x	x	x			2	audio rec.	plus visuals
Intervision group discussion			x			1	audio rec.	
Plenary feedback meetings	x					1	audio rec.	
Exam electrochem. + Assessment	x					1	quaL/quaN	
Quizzes electrochem.	x					1	quaN	
Interview				x	1	1	audio rec.	
Mini focus group discussion				x	1	1	audio rec.	
M5 - Task / Quiz / Project	x					1	tbd	tbd

Overall Plan





- Launch action research
  - Intervention design
  - Intervention proposal to CSE
  - Intervention preparation
  - Research design
  - Ethical review
  - Research proposal to CSE
  - Research preparation
  - Informed consent
- Intervention - Infusion
  - Workshop Conceptual Modelling for LA, part I
  - Briefing LA (specific experiments)
  - Workshop Conceptual Modelling for LA, part II
  - Instructions for LabA
  - Introduction to Conceptual Modelling for S
  - Introduction to Electrochemistry for S
  - Preparation Conceptual Modelling
  - Discussion & Feedback
- #1_ Potentiometric meter
- #2_ Electrochemical cell
  - Theoretical introduction
  - Preparing the practicum + CM_0
  - Meeting the LA before the practicum
  - Conducting the practicum
  - Processing and interpreting the data + CM_1
  - Meeting the LA
  - Short recap of previous week
  - Theoretical self-instruction
  - Reporting + CM_2
  - Feedback on reports & CM_2 to all S
- #3_ Solubility
- Intervision on Conceptual Modelling with LAs
- #4_ Acid-base potentiometric titration
- #5_ Final project - Cyclic voltamperometry
- Data collection
- Data management
- Data transcription
- Data analysis
- Research report
- Reporting action research to CSE
- Dissemination
  - Conceptual Paper
  - SEFI Conference 2021
  - Workshop for 4TU-CEE
  - Empirical Paper
  - EARLI SIG 4/6/17/20 Conference 2022
  - Publication - Review process
- Closing

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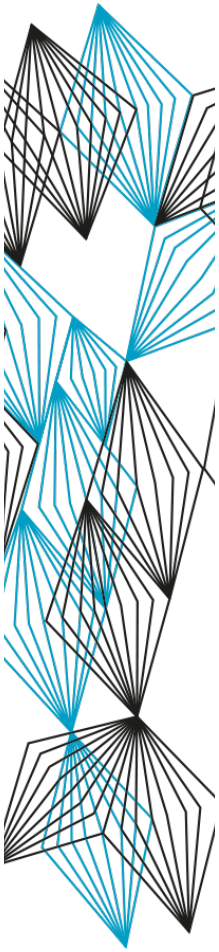
Participation in this Educational Research

- Voluntary → on individual basis
- Informed consent → information & active consent during a plenary session
- Benefits for the participants → opportunities
  - Reflection about own epistemological conceptions & understanding others'
  - Questioning the understanding of the learning objectives
  - Making assumptions and expectations explicit
  - Particularly for learning assistants → professional development
- Limited time spent
  - A small number of selected participants will dedicate max. 2 hours to purposive research activities
- Privacy & Personal data protection → according to UT Data Policy
- Participants who indicate their interest will receive a summary of the research results.

Conclusion & Expected Implications



- Primary goal →
  To enhance students' deep understanding of electrochemical phenomena,
  with a view on scientific problem-solving within and beyond the initial learning context.
- Further goal →
  To introduce an evidence-based and innovative pedagogical approach
  that can be rolled out to other learning programmes in engineering science education.

- This project is expected to contribute to:
  - Engineering educational practice
  - Educational research
  - Philosophy of Science in practice

- This is only possible with:
  - High participation and engagement of all actors (students, LA, teachers)
  - Research support

Contact

Mariana Orozco

m.orozco@utwente.nl