Proposal for eye tracking research in MAPS

This document outlines a theoretical framework and practical process for carrying out eye tracking research in MAPS. The intention is to support the broader strategic aim of the faculty education team to “embed evidence-based pedagogical approaches within all programmes, using and learning from best practice in the sector."

Background

This project was originally inspired by a MAPS research seminar in January 2022 presented by Dr Ginger Schulz from the University of Michigan entitled “Capturing and Cultivating Reasoning in Chemistry”. In this seminar Dr Schulz explained how a combination of eye-tracking, semi-structured, think-aloud interviews, and textual analysis of student writing was used to investigate students’ reasoning and subsequently redesign teaching (Connor et al, 2019[1]). This powerful and proven technique seemed an ideal fit for the MAPS faculty’s ambition to develop a stream of research into STEM education, so we committed to purchasing the same eye tracking equipment as that used by Dr Schulz and her team.

Why eye tracking?

Eye tracking allows researchers to gain insight into how learners interact with educational materials, such as charts, force diagrams, molecular structures, and mathematical proofs. By tracking the movements of a learner's eyes, researchers can analyse where the learner's attention is focused, how they process visual information, and how they engage with the content. Eye tracking can be thought of as a proxy that together with other tools has the potential to reveal the cognitive processes that underline learning.

[1] Constraints on organic chemistry students’ reasoning during IR and 1 H NMR spectral interpretation - Chemistry Education Research and Practice (RSC Publishing) DOI:10.1039/C9RP00033J

Overall, eye tracking provides a valuable tool for pedagogical research by allowing researchers to better understand how learners engage with educational materials and to develop more effective teaching strategies that can improve learning outcomes.

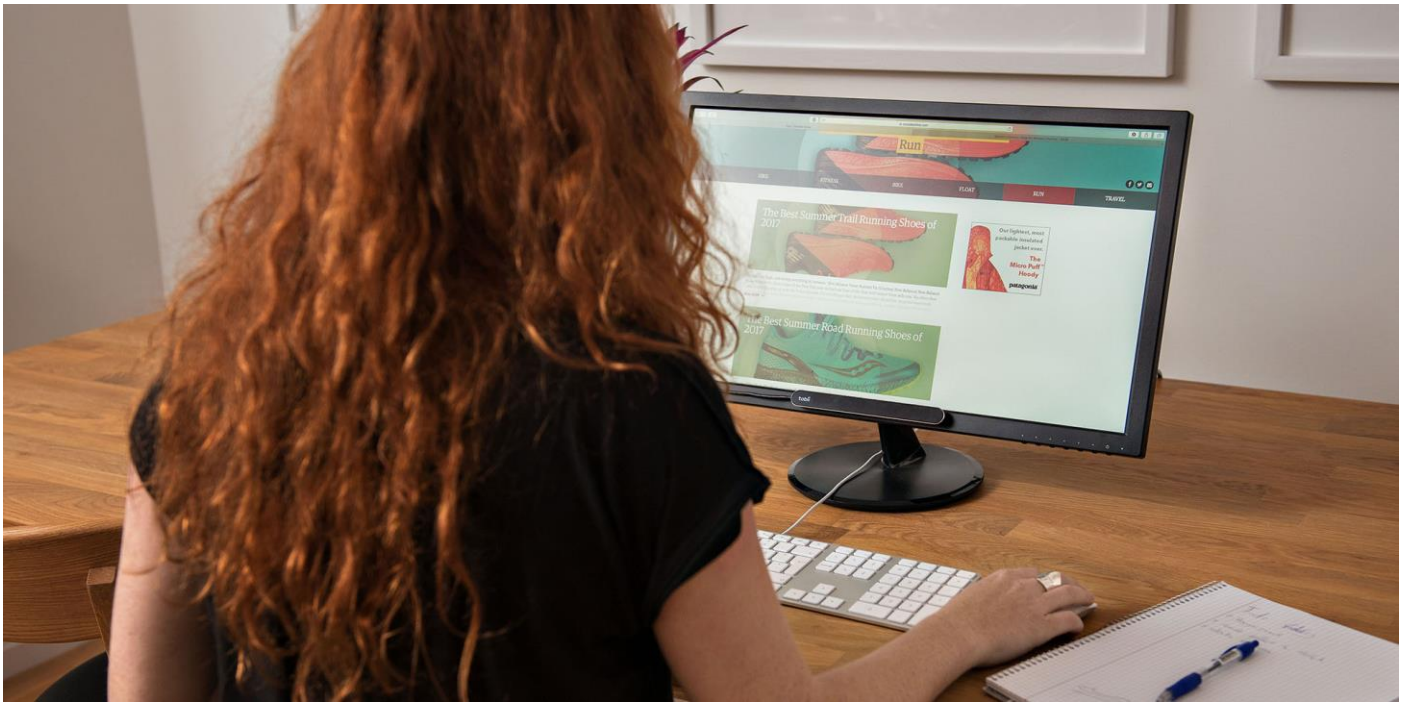

Figure 1: A typical eye tracking set-up. The eye tracker is the thin black bar at the bottom of the monitor (Source: Tobii)

Theoretical frameworks

A framework for teaching: Pedagogical Content Knowledge

Whilst the main activity proposed in this document is the use of eye tracking technologies and complementary methods to study how students learn from visual materials, the overall objective of the research is to improve teaching. It is important, therefore, to first have an agreed and shared understanding of what it means to teach effectively. For this, the theory of Pedagogical Content Knowledge is proposed (Shulman, 1986[2]).

The theory of pedagogical content knowledge (PCK) is a framework that describes how teachers' knowledge of subject matter and teaching methods interact to promote effective teaching and learning. Developed by educational researcher Lee Shulman in the 1980s, the theory argues that

[2] Those Who Understand: Knowledge Growth in Teaching - LEE S. SHULMAN, 1986

effective teaching requires a unique blend of both content knowledge and pedagogical knowledge, and that this combination of knowledge must be integrated into a teacher's practice. This framework has since become widely influential in the field of education, providing a lens through which to view the complex relationship between content knowledge, pedagogy, and student learning outcomes.

Shulman's theory of pedagogical content knowledge (PCK) is based on the idea that teaching is more than just the transfer of information from teacher to student. Rather, effective teaching requires a deep understanding of how to best present and convey subject matter to learners in a way that is accessible and meaningful to them. PCK, as Shulman defines it, is the specific type of knowledge that teachers need in order to successfully bridge the gap between their content knowledge and their ability to effectively communicate that knowledge to their students.

To develop PCK, teachers must engage in a process of reflection and analysis that involves examining their own content knowledge, their pedagogical strategies, and the specific needs and abilities of their students. By doing so, they can develop a deep understanding of the content they are teaching, as well as the most effective ways to communicate that content to their students.

A framework for learning: Variation Theory

Variation theory (Marton, 2014[3]) is a pedagogical framework that seeks to explain how students learn by focusing on the role of variation in their learning experiences. It states that for students to learn a new concept or idea, or “Object of Learning”, they need to encounter multiple examples or instances of that concept each of which varies in some important way. These variations help students to discern the underlying structure (or invariance) of the concept, and to develop a more sophisticated and nuanced understanding of it.

Central to the variation theory of learning is the concept of "discernment". Discernment refers to the process by which students become aware of the underlying structure or invariance of a concept or idea and develop a deeper understanding of its essential invariant features. Discernment occurs when students are able to distinguish between different examples or instances of a concept, and to identify the key similarities and differences between them.

[3] Necessary Conditions of Learning | Ference Marton | Taylor & Francis e

Explaining the "Object of Learning"

Central to variation theory is the "Object of Learning", the concept, idea or phenomenon that a teacher wishes a student to learn. Variation theory suggests that this object of learning exists in three states: what the teacher wants the student to learn (the "Intended Object of Learning"), what the student experiences whilst learning (the "Enacted Object of Learning"), and what the student actually has learned (the "Lived Object of Learning"). These three states are displayed visually in Figure 2, below.

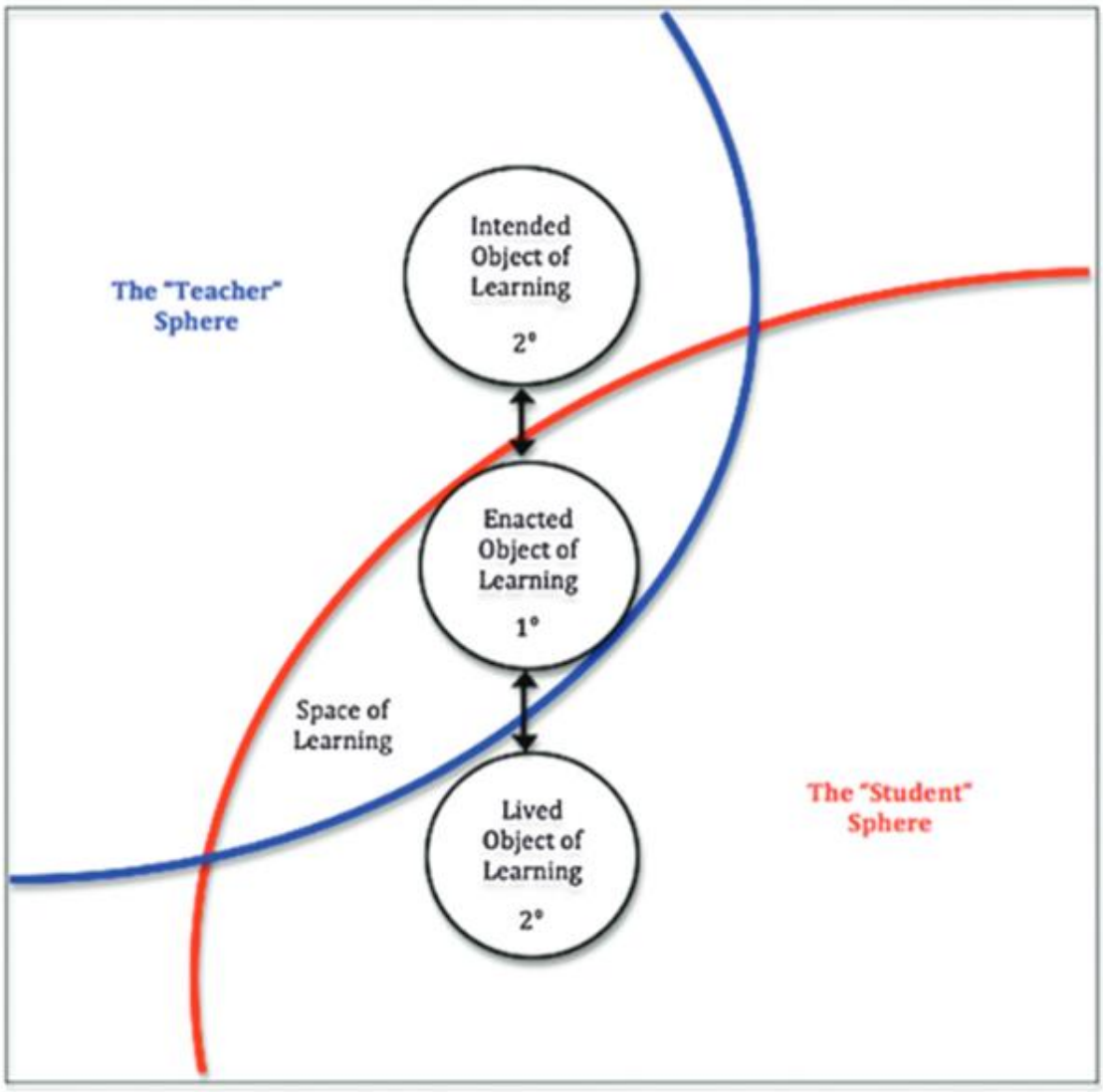

Figure 2: Object of Learning States Visualised (from Bussey et al., 2013)

Intended Object of Learning

The Intended Object of Learning (IOL) refers to the specific aspect of a concept or phenomenon that a teacher wants students to learn. It is the desired learning outcome that guides the teaching and learning process.

The IOL is the focus of the teacher's instruction, and the teacher uses different forms of variation to help students notice and understand the critical features of the IOL. By presenting examples and non-examples, similarities and differences, and different contexts, the teacher aims to support students in developing a deep and flexible understanding of the IOL. For example, if the IOL is the concept of "fraction," the teacher may use different types of fraction representations, such as visual models or symbolic notation, and provide examples and non-examples to help students understand the key features of fractions.

Overall, the IOL plays a central role in variation theory, as it guides the teacher's instruction and the students' learning process.

Enacted Object of Learning

The Enacted Object of Learning (EOL) refers to the way the Intended Object of Learning is ‘operationalised’, how specific teaching strategies and/or instructional design materials are created to ‘enact’ the Object of Learning and what this means in terms of student interaction.

The Enacted Object of Learning may differ from the Intended Object of Learning, and therefore the intended learning outcome that the teacher had in mind when planning the instruction. This can happen due to various factors such as students' interpretation of the teacher's instruction, or the effectiveness of the teaching and learning strategies used. The goal is to ensure a close match between the EOL and the IOL, so that students can achieve the intended learning outcomes.

Lived Object of Learning

The Lived Object of Learning (LOL) refers to the actual experiences and understanding that learners have during and after engaging with teaching and learning activities. The LOL is shaped by the students' interpretations, perspectives, and prior knowledge, as well as the learning opportunities and challenges that they encounter.

The LOL takes into account the complexity and diversity of learners' experiences and recognizes that learning is a dynamic and ongoing process.

These influences of the Object of Learning and its states are represented visually in Figure 3, below.

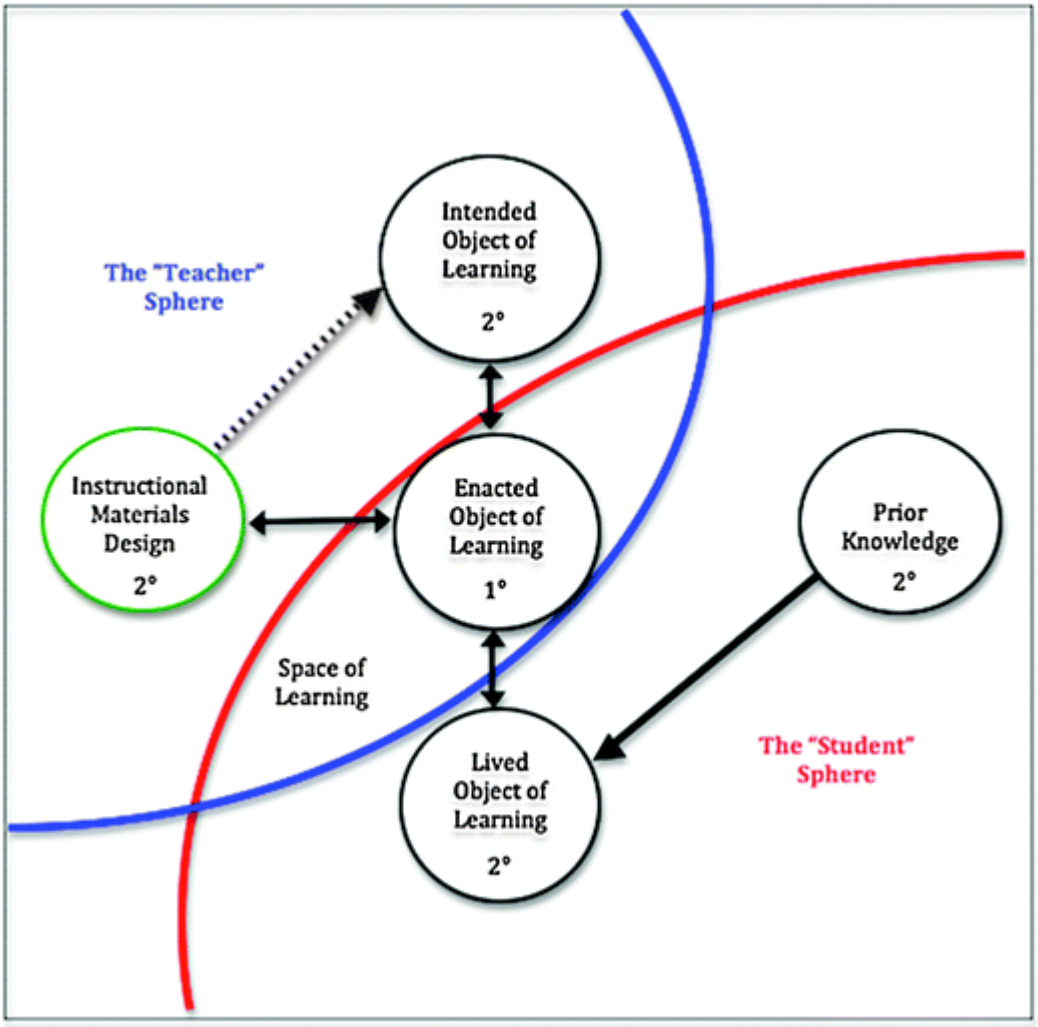

Figure 3: Influences on the Object of Learning (from Bussey et al., 2013)

A framework for research: Design-Based Implementation Research

Design-Based Implementation Research (DBIR) (a derivative of Design-Based Research) is an approach to educational research that aims to improve educational practices by developing and testing new interventions in real-world settings. DBIR is a collaborative and iterative process that involves multiple stakeholders, including researchers, educators, and administrators, working together to design, implement, and evaluate educational interventions.

The DBIR process typically involves several phases, including:

1. Problem Identification: The first step in DBIR is to identify a problem or issue in educational practice that requires attention. This might involve identifying a gap in student learning

outcomes, a need for new instructional approaches, or a need to improve teacher professional development.

2. Intervention Design: Once a problem has been identified, researchers and practitioners work together to design an intervention that addresses the problem. The intervention might involve developing new curriculum materials, implementing new instructional strategies, or providing new professional development opportunities for teachers.
3. Iterative Implementation: In DBIR, interventions are implemented in real-world educational settings, and the implementation process is iterative and collaborative. Researchers and practitioners work together to monitor the implementation of the intervention, identify challenges and barriers, and make adjustments to the intervention as needed.
4. Data Collection and Analysis: Throughout the implementation process, researchers collect data on student learning outcomes, teacher practices, and other relevant variables. This data is analysed to determine the effectiveness of the intervention, and to identify areas for further improvement.
5. Knowledge Mobilization: The final phase of DBIR involves disseminating the results of the research to relevant stakeholders. This might involve presenting findings at conferences, publishing research articles, or developing practitioner-focused resources to support the implementation of the intervention in other contexts.

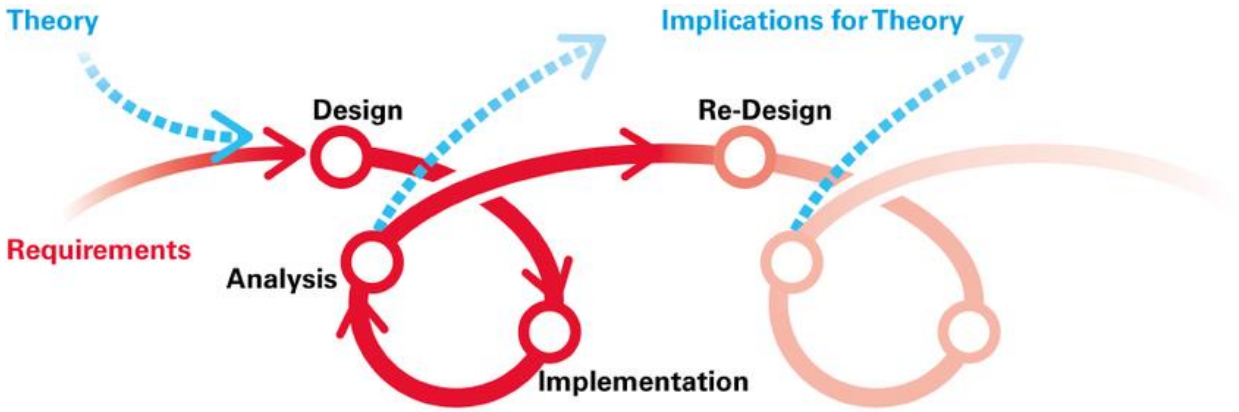

Figure 4: A Typical Design-Based Research model (from Fraefel, 2014[4])

[4] https://www.researchgate.net/profile/Urban-Fraefel/publication/275040746_Professionalization_of_pre-service_teachers_through_univer-sity-school_partnerships_Partner_schools_for_Professional_Development_development_imple-mentation_and_evaluation_of_cooperative_learning_in_s/links/553104d30cf2f2a588ab9517/Professionalization-of-pre-service-teachers-through-univer-sity-school-partnerships-Partner-schools-for-Professional-Development-development-imple-mentation-and-evaluation-of-cooperative-learning-in.pdf

Overall, DBIR is a collaborative and iterative process that seeks to bridge the gap between research and practice by developing and testing educational interventions in real-world settings. By working together to design, implement, and evaluate interventions, researchers and practitioners can improve educational practices and outcomes for students.

Possible Research Design

Many different research designs might be developed to study teaching & learning using eye tracking, but following the DBIR approach a relatively straightforward process can be outlined as below:

A. Identify an Object of Learning that is in some way problematic, perhaps one that often generates misconceptions or one that is particularly challenging to teach.
B. Create a learning scenario that uses various visual stimuli to teach the Object of Learning.
C. Select students as research participants.
D. Run the scenario:
    a. Select a sample of students, use eye tracking and interviews to gather data on how those students are engaging with the Object of Learning, which aspects of variation they are paying attention to and which they are not.
    b. Analyse the data from a PCK / Variation Theory perspective to determine effectiveness and identify improvements.
    c. Redesign the learning scenario using the data; rerun the scenario with new students.
E. Extrapolate from the iterations how varying the learning scenario impacted student learning and helped to develop teachers' PCK
F. Publish results.

Ethical Considerations

Although within the proposed research all personal data will be anonymised, it is possible that the ability to understand and utilise biometric data in particular may become more accurate over time, hence there will be a need to keep all eye tracking data generated secure and compliant with regulations such as GDPR.

References

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Disclaimer

Although the overall concept or this research is novel, parts of the text which are mostly descriptive in nature were originally generated by ChatGPT.