The VisChem Learning Design: Visualising Chemical Structures and Reactions at the Molecular Level to Develop a Deep Understanding of Chemistry Concepts

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Broad discipline area:

Natural and Physical Sciences

- Chemistry

Year level:

- First Year Undergraduate

TRN strategy:

- Drawing on personal research in designing and teaching courses
- Conducting and drawing on research into student learning to make evidence based decisions about teaching

Teaching and learning context:

- Large group lectures
- Small group classes/tutorials
- Computer labs
- Online/blended learning
- Curriculum design
- Reflective learning

Brief description of the initiative:

Description of our research evidence-based, good practice example and the discipline context

When covering a topic in chemistry that requires an accurate mental model of the molecular world, a typical learning experience with our design in a face-to-face lecture, or online learning context would involve students:

- **observing** a surprising or unusual chemical phenomenon (chemical reaction, or substance behaviour) as a lecture demonstration, or audiovisual presentation; and **documenting** their observations in words and diagrams
- **describing** in words, and **drawing** a representation of their mental model of what is occurring at the molecular level to account for their observations
- **discussing** their representation with a peer, with the aid of the lecturer's advice to focus on the key features of the representation (or lack thereof) that

explain the observations

- **viewing** a visualisation (animation or simulation) portraying the phenomenon at the molecular level, first without, then with narration by the lecturer, and **looking** for the relevant key features
- **reflecting** with the peer on any similarities and discrepancies between their own representations and the visualisation, and then **discussing** these with the lecturer
- **relating** the molecular-level perspective to the symbolic level (e.g. chemical equations and formulas) and mathematical language used to represent the phenomenon
- **applying** or **adapting** their mental model to explain a similar phenomenon with an analogous substance or reaction

Key criteria for success of this design to promote *enduring* cognitive change are:

- the constructivist approach that focuses attention on the student's *prior* mental model
- focusing attention on looking for key features in the visualisation
- repetition of the approach throughout the teaching of the unit
- practice, application, and explicit assessment of the molecular-level visualisation skills developed so that students see this skill is valued

Institution/s Involved in the development/implementation of the initiative

Team:

Roy Tasker (*VisChem* project leader, UWS), Rebecca Dalton (PhD and Post-doc researcher, UWS), Ray Sleet (chem ed researcher, UTS), Bob Bucat (chem ed researcher, UWA), Bill Chia (instructional designer, UWS) and Debbie Corrigan (teacher educator, Monash)

Summary of how the example was developed/devised

Many misconceptions in chemistry stem from an inability to visualize structures and processes at the molecular level. It can be difficult to change a student's mental model of this level by simply *showing* a different, albeit better, one.

The *VisChem Learning Design* was developed using a multimedia information-processing model that combines a number of factors of learning identified from cognitive science and educational research. These are Johnstone's *Information Processing Model*, Sweller's *Cognitive Load Theory*, and Mayer's *Theory of Multimedia Learning*. Each of these has been successful at informing teaching practice by explicitly tailoring the pedagogy at each step – *perception* of audiovisual information, its *processing* in a working memory space of limited capacity, and effective *encoding* in the long-term memory.

- *Perception:* this constructivist learning design starts by motivating the student to "care and engage" by presenting a phenomenon that is surprising, or results in a cognitive conflict. Students are asked to communicate their prior mental model of what is going on at the molecular level using a storyboard. If they are frustrated with not being able to explain the phenomenon, then they are more likely to look for key features in an animation or simulation that provide an explanation.
- *Processing:* visualisations need to be segmented, with narration in sync with the images, and enhanced with attention-focussing elements to key features

- *Encoding:* the last, and most important step is to provide multiple opportunities to apply their refined mental model to new situations, and feel empowered in the process!

Processes for collecting data about its effectiveness and overall evaluation

The research project involves evaluating the *VisChem Learning Design* using a combination of large-scale, quantitative studies and smaller studies involving one-to-one interviews. An expert/novice comparison study was done to highlight differences in perception, processing, and encoding of key features due to depth of understanding.

Early work on the effectiveness of the *VisChem* animations has been published[1], and led to the importance of preparing the mind of the learner, avoiding cognitive overload in the working memory, and developing opportunities to apply what was learned.

Outcomes and evidence of impact

The *VisChem Learning Design* is one of a collection of learning designs selected by a panel of university educators in the Australian Universities Teaching Committee (AUTC) project titled: *Information and Communication Technologies and Their Role in Flexible Learning* as an "exemplary ICT-based learning design implemented in Australian universities", and one "with the potential to be redeveloped in a more generic form in order to facilitate the uptake of innovative teaching and learning approaches by other academics in Australian universities".

The background, rationale, implementation, reflections and sample resources for our learning design can be found on the AUTC project web site:
http://www.learningdesigns.uow.edu.au/exemplars/info/LD9/index.html
Preliminary results indicating the effectiveness of the approach have been published[1], but our present experiments are more likely to provide statistically significant results, one way or the other.

Issues, challenges and modifications experienced and faced

The widespread adoption of new approaches for teaching chemistry, particularly at the tertiary level, requires compelling evidence. In addition, our learning design is not attractive to many science educators who claim it 'wastes' precious time on developing visual models of the molecular world, at the expense of targeting the acknowledged difficulty most students have with science – a lack of quantitative understanding. The team claim that the former can address difficulties in the latter. However, evidence is needed to support this claim, and this is the focus of their current research.

Lessons for all stakeholders

- The team hold the view that the multimedia information-processing model is based on convincing educational research and cognitive science, and more importantly, can be easily applied to inform good teaching practice in any field.
- The increasing use of visualisation in many content domains requires that we understand its cognitive demands, and adapt teaching with animations, simulations, and graphics, accordingly. The *VisChem* project has developed a set of design principles for producing and using molecular-level visualisations effectively, but these principles should apply in any field.

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[1] Tasker, R. and Dalton, R. (2006) *Chemistry Education Research and Practice,* 7 (2), 141-159

For further details:

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