Fostering deep understanding in geography by inducing and managing confusion: an online learning approach

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Confusion is an emotion that is likely to occur when learning complex concepts. While this emotion is often seen as undesirable because of its potential to induce frustration and boredom, recent research has highlighted the vital role confusion can play in student learning. The learning of topics in geography such as tropical cyclone causes and processes can be particularly difficult because it requires the reconstruction of intuitive mental models that are often robust and resistant to change. This paper presents the design framework for an online module designed to enhance university students' depth of knowledge of tropical cyclones. In particular, the intervention aims to manage the level of confusion during learning. We hypothesise that in this way learners can engage with the cognitively demanding ideas in this topic and they are less likely to experience emotions such as frustration and boredom, which would be detrimental to the development of deep understanding.

Keywords: Online module; geography; confusion; conceptual change; academic emotions

Understanding complex systems

Frequently, university students face situations in which the restructuring of existing knowledge is particularly difficult and represent an important step that can influence the other steps of further learning. For example, some learning of concepts from geography can be problematic if learners possess intuitive mental models that are inconsistent with current consensus in the discipline (Lane, 2008). For example, understanding the dynamics of tropical cyclones requires a complex integration of information from different domains, and the evaluation and restructuring of alternative conceptions (Lane & Coutts, 2012).

To develop an understanding of cyclone causes and processes, learners require factual and conceptual knowledge of a range of key ideas including evaporation, air pressure and precipitation. These ideas act as threshold concepts (Meyer & Land, 2013) in this topic, enabling learners to develop a relational understanding of the links between the various causes and processes. This cognitive process known as conceptual change or conceptual reconstruction, is highly demanding and requires a significant level of engagement and metacognitive awareness from the learner (Vosniadou, 1994).

Recent research suggests that innovative instructional design can improve learners' motivation and engagement in complex learning tasks and that this can have a positive impact on learning outcomes (Moreno, 2006). Similarly, cognitive disequilibrium caused by an impasse, a contradiction, or some incongruity can also improve the engagement of students (Craig, Graesser, Sullins, & Gholson, 2004). This involves creating challenging learning opportunities that raise the interest of learners whilst building the essential skills for managing confusion.

Learners' confusion

It is now widely understood that learning is more than "cold", rational processes (Pintrich, Marx, & Boyle, 1993). Recent studies have emphasized the role of emotions in learning processes (Leutner, 2014; Mayer, 2014; Mayer & Estrella, 2014). In order to reconstruct their existing mental models students need to be both engaged and motivated. During the learning processes students often experience impasses, discrepancies, and contradictions between information from different sources. This information may come from instruction or from their prior knowledge of the topic (D'Mello, Lehman, Pekrun, & Graesser, 2014). These experiences are likely to induce a cognitive disequilibrium that will provoke a specific kind of emotion: confusion. Because this emotion is unpleasant by nature (Russell, 2003), it is expected that learners will try to resolve it. This search for a reduction of confusion can increase learner's engagement with the task, hence leading to a deeper understanding of the content.

When building learning sequences to promote deep understanding it is possible to induce confusion to increase engagement. The technique of promoting cognitive disequilibrium by comparing students' existing and new knowledge is well known by teachers, but perhaps underused in digital learning environments. The aim of the present study was to design a protocol to test the efficacy of an intervention for inducing confusion in an online learning platform used by university students. We hypothesized that, in the domain of geography, the learning of the dynamics of tropical cyclones should benefit from the induction of confusion because the processes involved are complex and students hold robust alternative conceptions about many of the core ideas (Lane & Coutts, 2012). Restructuring these mental models requires engagement and resilience of the learner.

Intervention to promote cognitive disequilibrium

The induction of confusion during learning can promote a deeper understanding of complex concepts by initiating effortful engagement and problem solving processes (Lehman, D'Mello, & Graesser, 2012). Several conditions are required to ensure that confusion is effectively managed in the learning process: (a) the cognitive disequilibrium that causes confusion must be relevant to the task and the pedagogical goals (D'Mello et al., 2014); (b) cognitive disequilibrium that causes the confusion must be resolved by learners (D'Mello & Graesser, 2014); (c) the environment must provide learners with appropriate scaffolding to help them manage their confusion and its duration.

There are two attributes of interventions that employ confusion to promote learning. The first relate to the induction of confusion itself. Confusion can be induced by provoking cognitive disequilibrium, for example with the introduction of contradictory information. The second involve strategies for managing confusion. These two thresholds of the level of confusion during learning can be represented as the boundaries of a *zone of optimal confusion* (D'Mello et al., 2014), depicted in Figure 1.

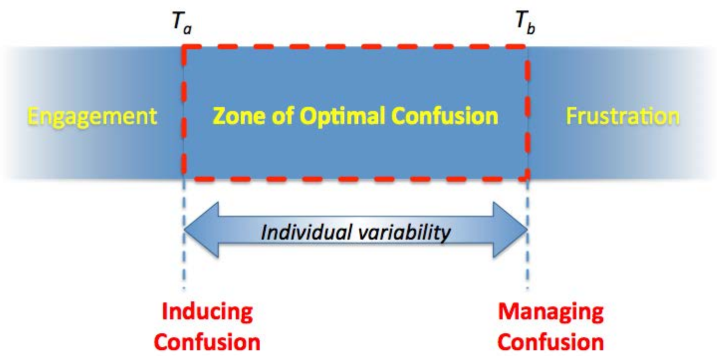

Figure 2: The boundaries of the zone of optimal confusion

If the level of confusion is too high, or if confusion is too persistent, learners might experience frustration followed by boredom. This disengagement could prevent the restructuring of students existing understandings (mental models) (D'Mello & Graesser, 2014). To prevent this strategies can be introduced for managing confusion including improving students' self-regulation skills and providing carefully targeted feedback. A student's motivation during learning can also influence their performance. Recent research has noted, for example, the positive effects of incorporating motivational features in the design of educational interfaces including appealing graphics and challenging scenarios (Mayer, 2014).

Another strategy for managing confusion and promoting its resolution is to enhance the resilience and self-efficacy of learners. Anecdotal evidence suggests learners exhibit differences in terms of academic risk taking. Some learners are adventuresome while others are more cautious and likely to avoid situations promoting confusion (Clifford, 1991). Similarly, students who have confidence in their ability to resolve complex problems are more likely to persist in resolving cognitive disequilibrium. To encourage academic risk taking and build self-efficacy in the current study, we progressively introduced students to increasingly complex problems to ensure that they built their confidence and had positive experiences of confusion resolution. The aim of this instructional strategy was to prepare students to face problems in which their engagement in resolving the cognitive disequilibrium would be required.

Materials and methods
An online unit addressing the causes and processes of tropical cyclones was developed at Macquarie University on a Moodle platform. The unit included five modules focusing on the conceptual building blocks for understanding tropical cyclones (see Figure 2) and included a range of representations such as videos, instructional text, diagrams and animations to promote conceptual change. Participants were, for example, required to respond to a quiz eliciting their initial conceptions and manipulate an interactive animation to explore scientific processes. Activities were then included to stimulate reflection and foster conceptual change.

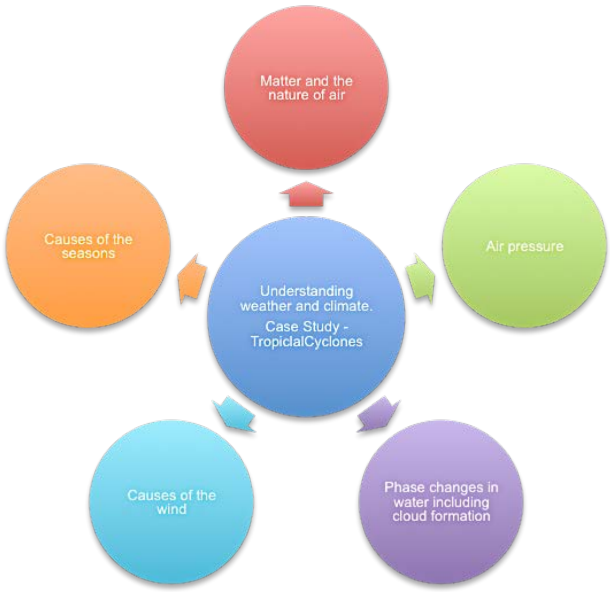

Figure 2: Content structure of the online module

After each module, students were asked to complete an online survey to self-report the frequency of the occurrence of selected emotions experienced during learning. This assessment of emotions was adapted from the *retrospective affect judgment protocol* (D'Mello et al., 2014) and consisted of nine Likert scale items relating to the emotions of anxiety, boredom, confuse/uncertainty, curiosity, delight, engagement/flow, frustration, surprise, and "neutral" for the absence of emotion. For each item, students were asked to provide a score between 1 and 10 to indicate whether they experienced this emotion "never" (score of 1) through to "all the time" (score of 10). A definition of each of these emotions was provided next to their respective rating scale.
The unit also included both a pre-test and post-test to assess changes in students' depth and accuracy of understanding. In addition content-specific quizzes were included at the end of each module.

Participants
The study was conducted at three Sydney universities and included a sample of 430 pre-service teachers (PSTs). For ethical reasons the universities are identified here as institution A, B and C. Most of the PSTs were from University A (n=228, 53%). There were 187 students from University B (44%) and a small number of students from University C (n=15, 3%).

Preliminary results
The study is ongoing and to date we have collected data from 153 of the 430 participants.

Strategies for managing confusion and promoting conceptual change

This paper presents an innovative solution for promoting the understanding of complex systems. The solution involved using confusion and self-regulation to assist with the process of conceptual change/reconstruction. In learning situations where complex content and/or a conceptual restructuration is involved, controlling the navigation of students within the boundaries of a *zone of optimal confusion* is likely to be beneficial for learning (Craig et al., 2004; D'Mello et al., 2014). Indeed, instead of designing the instructions in an attempt to protect learners from confusion, the online unit was specifically created in order to induce confusion and to foster engagement. The module included a variety of tasks, for example, videos, simulations and problem solving activities designed to expose students' existing mental models, explore scientific explanations, and reflect on inconsistencies caused by prior knowledge. The culminating task in the module encourages students to apply their new understandings to provide a rich explanation of the causes and processes of tropical cyclones. The idea of inducing cognitive disequilibrium and confusion in a progressive manner throughout the unit was hypothesized to improve learners' confidence in dealing with challenging situations and to promote their engagement for a deeper understanding.

Until recently, the benefits of inducing confusion have mainly been observed in laboratory-settings (D'Mello & Graesser, 2014; D'Mello et al., 2014; Lehman et al., 2012). In addition, few studies have focused specifically on techniques for confusion remediation despite their documented role in preventing the risks of frustration and boredom in the learning process (D'Mello et al., 2014).

The study reported in this paper addresses this gap by examining three dimensions of confusion in the learning process:

1. The relationship between confusion and cognitive disequilibrium.
2. The role of confusion as a motivator and tool for engaging learners
3. Strategies for regulating/managing confusion in the learning process.

Moreover, this study was designed to observe the effects of confusion in a real world setting, using an online learning environment and students from different universities. Unfortunately, this choice was also the source of some limitations such as the inability to control all aspects for the environment and employ a randomized controlled research. Nonetheless, we believe that the protocol presented here and the associated research will help to inform the design of digital learning environments to promote deep understanding of complex phenomena in both science and geography.

References

Clifford, M. M. (1991). Risk Taking: Theoretical, Empirical, and Educational Considerations. *Educational Psychologist*, *26*(3-4), 263–297. http://doi.org/10.1080/00461520.1991.9653135
Craig, S., Graesser, A., Sullins, J., & Gholson, B. (2004). Affect and learning: an exploratory look into the role of affect in learning with AutoTutor. *Journal of Educational Media*, *29*(3), 241–250.
D'Mello, S., & Graesser, A. (2014). Confusion and its dynamics during device comprehension with breakdown scenarios. *Acta Psychologica*, *151*, 106–116. http://doi.org/10.1016/J.Actpsy.2014.06.005
D'Mello, S., Lehman, B., Pekrun, R., & Graesser, A. (2014). Confusion can be beneficial for learning. *Learning and Instruction*, *29*, 153–170. http://doi.org/10.1016/j.learninstruc.2012.05.003
Lane, R. (2008). Students' alternative conceptions in geography. *Geographical Education*, *21*, 43.
Lane, R., & Coutts, P. (2012). Students' alternative conceptions of tropical cyclone causes and processes. *International Research in Geographical and Environmental Education*, *21*(3), 205–222.
Lehman, B., D'Mello, S., & Graesser, A. (2012). Confusion and complex learning during interactions with computer learning environments. *Internet and Higher Education*, *15*(3), 184–194. http://doi.org/10.1016/J.Iheduc.2012.01.002
Leutner, D. (2014). Motivation and emotion as mediators in multimedia learning. *Learning and Instruction*, *29*, 174–175. http://doi.org/10.1016/j.learninstruc.2013.05.004

Mayer, R. E. (2014). Incorporating motivation into multimedia learning. *Learning and Instruction*, *29*, 171–173. http://doi.org/10.1016/j.learninstruc.2013.04.003
Mayer, R. E., & Estrella, G. (2014). Benefits of emotional design in multimedia instruction. *Learning and Instruction*, *33*(0), 12–18. http://doi.org/10.1016/j.learninstruc.2014.02.004
Meyer, J., & Land, R. (2013). *Overcoming Barriers to Student Understanding: Threshold Concepts and Troublesome Knowledge*. Routledge.
Moreno, R. (2006). Does the modality principle hold for different media? A test of the method-affects-learning hypothesis VL -.22. *Journal of Computer Assisted Learning*, (3), 149–158. http://doi.org/10.1111/j.1365-2729.2006.00170.x
Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond Cold Conceptual Change: The Role of Motivational Beliefs and Classroom Contextual Factors in the Process of Conceptual Change. *Review of Educational Research*, *63*(2), 167–199. http://doi.org/10.3102/00346543063002167
Russell, J. A. (2003). Core affect and the psychological construction of emotion VL -.110. *Psychological Review*, (1), 145–172. http://doi.org/10.1037/0033-295X.110.1.145
Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction*, *4*(1), 45–69. https://doi.org/10.1016/0959-4752(94)90018-3

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