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Learners' confusion: faulty prior knowledge or a metacognitive monitoring error?

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Research often treats confusion as a turning point of the learners' cognitive-affective dynamics in digital environments (e.g. D'Mello, Grasser and colleagues). The origin of confusion, however, is a topic of a debate. Could inaccurate prior knowledge serve as a source of confusion, or does confusion relate to metacognitive processes? In this paper we are attempting to address this question by employing case study analysis with fourteen participants who worked through simulated learning problems with feedback in a digital environment. Physiological and self-reported data were combined to examine problem-solving patterns. Preliminary findings highlighted the role of metacognitive monitoring in confusion development and its interrelation with inaccurate prior knowledge.

Keywords: prior knowledge, metacognitive monitoring, confusion, self-regulated learning

Background

To effectively learn in technology-enhanced courses and digital learning environments students have to effectively process new complex information, know how to handle technical difficulties, and how to deal with the lack of immediate teacher's feedback. Learners may get confused trying to balance these multiple demands and end up frustrated and disengaged after reaching multiple impasses. Indeed, an unresolved confusion can easily turn into its non-constructive variety, in which case the learner's interest will be completely lost (D'Mello & Greasser, 2014). At the same time, research demonstrates that cognitive disequilibrium, manifested by constructive confusion, plays a positive role in learning, promoting deep elaborative processing of the new information and transfer of learning (D'Mello et al., 2014). The problem lies in understanding of the origin of confusion.

The four-tiered model of cognitive-affective dynamics described in details by D'Mello, Lehman, Pekrun and Graesser (2014) summarizes the findings of previous research and presents confusion within a network of the linked states. All four states — engagement, confusion, frustration and boredom — play an important role in learning according to these authors. Specifically, in this model, learners are initially in a state of engagement that can lead to confusion when an impasse is detected. If the impasse is resolved, learners will return to the original engagement state. Otherwise, with the failure to resolve the impasse learners may experience frustration. If learners stay confused for too long, for example while experiencing persistence failures to resolve an impasse, they may become bored and disengage from the learning task. Prolonged state of confusion, or joint confusion and frustration may have negative consequences for learning (D'Mello & Greasser, 2014; Liu et al., 2013).

Confusion is likely to occur when students experience an impasse while processing new information that is inconsistent with their prior conceptions (Graesser, Lu, Olde, Cooper-Pye, & Whitten, 2005). *Cognitive disequilibrium* that triggers confusion is seen as an essential element in learning about complex systems, for which a shallow processing of information would potentially lead to critical errors of understanding and long lasting misconceptions. An alternative situation when the inaccuracy of prior conceptions is not detected, and learners engage in shallow processing could then be characterized by the *Illusion of Understanding* (Rozenblit & Keil, 2002). With *Illusion of Understanding* (IOU) learners have conviction of knowing or understanding something while in reality the knowledge or understanding is missing.

Returning to the model of cognitive-affective states, the prior knowledge is not included in the model, although the authors of the model and the other researchers mention it throughout their work. The common assumption stating that a large knowledge base and good technical skills might help learners avoid confusion in online environments has never been challenged by considering the cases of inaccurate prior knowledge. In fact, if a learner experiences incongruences and a mismatch between prior conceptions and a new information, leading this learner to a cognitive disequilibrium

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(e.g. Graesser et al., 2005), it calls for a reflection on the role of the prior knowledge in an "impasse" leading learner to confusion. Logically, the presence of a misguiding prior knowledge would contribute to the episode of impasse.

Cases of inaccurate prior knowledge are quite common in learning math and science, and are tightly related to the notion of conceptual change. Specifically, conceptual change occurs when learners' prior knowledge contains misconceptions and is inconsistent with the new upcoming information (Vosniadou, 1994). Inaccurate prior knowledge could lead to confusion, and some of the conceptual change literature encourages educators to seek a potentially conflicting for a learner situation when contradictions caused by the learner's irrelevant conceptions are exposed and examined (Limón, 2001). Such method should potentially lead to re-evaluation of these outdated conceptions and foster a conceptual change.

Inaccurate prior knowledge was also recently reviewed by self-regulated learning researchers in relation to the metacognitive monitoring accuracy. Van Loon et al. (2013) found that inaccurate prior knowledge not only leads to larger overestimations of the future performance in comparison with the cases in which no prior knowledge existed, but also that these overestimations were not corrected by actually taking the test (i.e. learners also hugely overestimate their on-test performance after taking the test). Finally, in line with previous research on metacognitive regulation, learners were not considering to re-study the materials they thought they knew (Thiede, et al., 2003; Van Loon et al., 2013), which would have also led to a better learning performance (Thiede, et al., 2003). Taking that metacognitive monitoring is often considered to be the most important part of self-regulation process (Thiede, et al., 2003; Winne, & Hadwin, 1998), these findings demonstrate how tightly self-regulatory processes are linked with prior knowledge.

The present study is aimed at uncovering linkages between metacognitive processes, prior knowledge, and confusion.

The present study

The study was a part of a larger project which investigates confusion, feedback and self-regulation in digital learning environments. The study used insight problems (problems that require a shift of perspective or an 'aha' moment to reach a solution) in form of puzzles: this type of problems is notorious for activating non-relevant prior knowledge (Knobich, Ohlsson, & Raney, 2001). The problems presented to participants were transformation puzzles, in which the pieces could form two different layouts depicting different pictures. The specific shapes used for the pieces were causing a kind of visual illusion during the transformation. For Problem 1, both initial and final layouts looked similar but a gap between two pieces appeared for one of them. Problem 2 was of the same nature but was showing the disappearance of a graphic element[1]. Both problems were presented as on-screen simulations with learner control: learners could manipulate a scrollbar to move the puzzle pieces. Fourteen participants recruited via on-campus advertisement were tested individually. Their gaze trajectories were recorded via a Tobii-T120 eye tracker, two hints were provided and the solution times recorded. Then, individual gaze trajectories were shown to participants who retrospectively rated their confusion on a scale for each 1-minute interval of the problem-solving phase. They were also invited to report on their problem-solving approaches (think-aloud method). Thus, data from the reporting of confusion were triangulated with problem solving steps and trajectories obtained from eye tracker.

Data analysis and results

The data were coded by one rater, and the coding sheet was developed based on research questions and the emerging themes. Consequently, 35% of cases were coded by the second rater using a coding sheet. The inter-rater agreement was 90%. The remaining 10% were negotiated and the corresponding changes were made to all similar cases.

Records were analyzed as a collection of case studies. Confusion ratings were higher for Problem 1 than for Problem 2: M_{p1} = 7.24 and M_{p2} = 4.97 on a 10-point scale, and a larger number of participants

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[1] http://en.wikipedia.org/wiki/Missing_square_Puzzle#/media/File:Missing_Square_Animation.gif and http://www.archimedes-lab.org/workshop13skulls.html respectively.

did not solve Problem 1 (7 non-solvers for Problem 1 and 3 for Problem 2). Hence it seems that Problem 1 would have served as a pre-training for the more challenging Problem 2 (which was confirmed by audio records analysis). Finally, patterns of *cognitive disequilibrium* and *illusion of understanding* were assessed for all the participants (Fig. 1). Single or recurring[2] instances of cognitive disequilibrium were recorded in 31% of cases for Problem 1 and 45% for Problem 2. We have operationalized *cognitive disequilibrium* as an increase in confusion ratings (often leading to a change of strategy as seen in gaze trajectory) after hint or after a wrong solution. Such changes in both confusion ratings and a gaze direction could have been a result of thinking about an incorrect solution of the problem, and then, realizing that it was a wrong solution path. Cognitive disequilibrium plus an illusion of understanding were recorded in 38% of cases for Problem 1 and 33% for Problem 2. An *illusion of understanding* (IOU) was operationalized as a decrease in confusion ratings/low confusion ratings before the hint or a wrong solution is delivered, increase after. IOU was often (86% of cases) followed by cognitive disequilibrium. While a case with the wrong solution clearly illustrates that participants were under the impression they knew the answer, a case with hints is not that straightforward. Often participants asked for a hint when they already had something in mind (as evident from audio records), in case of IOU this something or their existing ideas were rather misleading that why the primary decrease was followed by an increase in confusion ratings. If the participants did not ask for hints, hints were delivered 2 and 4 minutes after the start of the problem-solving, and similarly, if participants had something misleading in mind the primary decrease was followed by increase in confusion ratings. As we have already mentioned, these detected states were recurrent (as per D'Mello et al., 2014 model): one instance of *cognitive disequilibrium* could have been followed by the other when an additional impasse has been reached.
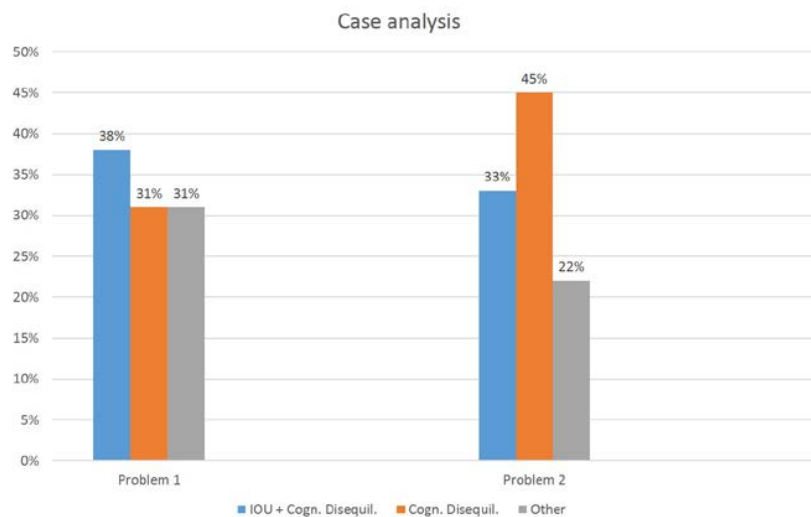
Figure 1. Patterns during problem-solving with hints.

"Other" cases (Fig. 1) are referring to the instances when the participants did not change their confusion ratings until the solution was reached or explained to them, or, alternatively, they were rating their confusion as decreasing through problem-solving process.

Discussion

While *cognitive disequilibrium* is discussed in the literature as the trigger for confusion (D'Mello & Graesser, 2014), incidents of IOU refer to the literature on metacognitive monitoring. IOU is especially harmful for learning because it influences the restudy efforts (e.g. Thiede, et al., 2003): learners who are convinced they know a vocabulary word, or an answer to a question, choose not to focus on this word or question anymore. Learners prone to IOU will try to reduce the time needed for the task and to deliver a rushed (often incorrect) answer, as it was observed with our participants. It is interesting to note that, although learners reported to be less confused with Problem 2 and produced a higher solution rate, the percentages of IOU instances were relatively similar amongst the problems (Fig. 1). Indeed, an increased familiarity with the task has been shown to increase participants' confidence in

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[2] As two instances of cognitive disequilibrium experienced by the same subject while solving Problem 1 or 2.

ability to perform well on a test although it was not warranted by the test results (Baars et al., 2013). If Problem 1 was regarded as a pre-training for Problem 2, learners could feel increased confidence in their ability to solve this problem and, as a consequence, IOU was present at the same rate in Problem 2 as in Problem 1.

Besides, learners were suggested to derive their monitoring judgments from the amount (but not the quality) of accessible information that comes to mind (Koriat, 1993). It equally explains the comparable IOU rates for both problems, and the presence of IOU at the first place. Since our pilot problems were insight problems learners were confident they possessed a certain prior knowledge. In reality, this prior knowledge was misleading, and its activation negatively reflected on metacognitive monitoring and, potentially, on performance (these data are being currently analysed) in line with the findings of Van Loon et al. (2013).

Conclusion

It could, then, be argued that the incorrect assessment of one's potential or past performance (i.e. IOU) comprises a metacognitive component of confusion while inaccurate prior knowledge represents its cognitive component. "What learner *believes* to know […] influences his learning, not only directly" via prior knowledge, "but also indirectly by affecting metacognition and regulation of learning" (van Loon et al., 2013, p. 24). In this case any intervention aimed at reducing non-constructive confusion (via self-regulatory techniques) has to address the monitoring side of the process. Our recommendations for creators of and educators working with digital learning environments would then stress the importance of faded scaffolding (similar to Baars et al., 2013 techniques), asking students to self-explain or to draw concept maps of textual materials (e.g. Thiede et al., 2010). Overall, the above techniques were proven to improve both performance and monitoring accuracy for learners and to help them avoid *illusion of understanding*. Further research could also investigate additional techniques particular to technology-enabled environments.

References

Baars, M., Visser, S., van Gog, T., de Bruin, A., & Paas F. (2013). Completion of partially worked-out examples as a generation strategy for improving monitoring accuracy. *Contemporary Educational Psychology*, *38*, 395-406. https://doi.org/10.1016/j.cedpsych.2013.09.001

D'Mello, S. K. & Graesser A. C. (2014). Confusion and its Dynamics during Device Comprehension with Breakdown Scenarios. *Acta Psychologica, 151*, 106-116.

D'Mello, S. K., Lehman, B. Pekrun, R., & Graesser, A. C. (2014). Confusion can be Beneficial for Learning. *Learning & Instruction, 29*(1), 153-170. https://doi.org/10.1016/j.learninstruc.2012.05.003

Graesser, A. C., Lu, S., Olde, B. A., Cooper-Pye, E., & Whitten, S. (2005). Question asking and eye tracking during cognitive disequilibrium: Comprehending illustrated texts on devices when the devices break down. *Memory & Cognition, 33*(7), 1235-1247.Knoblich G., Ohlsson S. & Raney, G.E. (2001). An eye movement study of insight problem solving. *Memory and Cognition, 29*(7), 1000-1009. https://doi.org/10.3758/BF03193225

Knobich, G., Ohlsson, S., & Raney, G.E. (2001). *An eye movement study of insight problem solving*. *Memory & Cognition, 29*(7), 1000-1009. https://doi.org/10.3758/BF03195762

Koriat, A. (1993). How do we know what we know: the accessibility model of feeling of knowing. *Psychological Review, 100*, 609-639. https://doi.org/10.1037/0033-295X.100.4.609

Limón, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: acritical appraisal. *Learning and Instruction, 11*(4), 357-380.

Liu, Z., Pataranutaporn, V., Ocumpaugh, J., & Baker, R. (2013). Sequences of Frustration and Confusion, and Learning. In D'Mello, S. K., Calvo, R. A., and Olney, A. (eds.) *Proceedings of the 6th International Conference on Educational Data Mining Conference* (Memphis, TN, July 6 - 9, 2013), 114-120.

Rozenblit, L., & Keil, F., (2002). *The misunderstood limits of folk science: an illusion of explanatory depth. Cognitive Science 26*, 521–562.

Thiede, K.W., Anderson, M. C. M., & Therriault, D. (2003). Accuracy of metacognitive monitoring affects learning of text. *Journal of Educational Psychology, 95*, 66-73.

Thiede K.W., Griffin T., Wiley J., & Anderson M. C. M., (2010). Poor Metacomprehension Accuracy as a Result of Inappropriate Cue Use. *Discourse Processes, 47*(4) 331-362.

van Loon, M., de Bruin, A., van Gog, T., & van Merrienboer, J. (2013). Activation of inaccurate prior knowledge affects primary-school students' metacognitive judgments and calibration. *Learning and Instruction*, *24*, 15-25. https://doi.org/10.1016/j.learninstruc.2012.08.005

Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction, 4*, 45-69. https://doi.org/10.1016/0959-4752(94)90018-3

Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. J. Hacker & J. Dunlosky (Eds.), *Metacognition in educational theory and practice (pp. 277-304).* Mahwah, NJ: Erlbaum.

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