

Ultimately, we believe that careful consideration of the measurement issues identified in this commentary will encourage even more high-quality research into the complex interplay between emotion and a range of diverse psychosocial constructs in medical education.

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Learning from erroneous examples in medical education

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The article by Domuracki *et al.*¹ published in this issue fits into a long tradition of research on observational learning, also known in educational research as example-based learning, which is subject to increasing investigation in medical education. Given the aim of improving central line insertion skills, the authors¹ understandably focus their discussion of prior research mainly on the observational learning of (psycho)motor

skills. Nevertheless, this study also has interesting parallels with research on training in cognitive tasks through example-based learning. Therefore, I will start by placing this study in the broader context of research on example-based learning in the educational sciences. Subsequently, I will discuss some factors that may play a role in learning from erroneous examples, which may also provide inspiration for future research on this topic.

Example-based learning has been studied from the perspectives of two different research traditions.² Research inspired by social learning theory³ has mostly focused on modelling examples, which provide students with opportunities to observe an adult or a peer model performing the learning task, either live (face to face) or on video. Research inspired by ACT-R (*adaptive control of thought–rational*) theory⁴ and cognitive load theory⁵ has mainly focused on worked examples, which typically provide students with a step-by-step written account of how to complete the learning task. Despite these origins in different research traditions, there are many interesting

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This study has interesting commonalities with research on training in cognitive tasks through example-based learning

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parallels in the research on learning from modelling examples and worked examples.²

In the context of medical education, both types of example-based learning have proven effective, such as in studies on the effects of videotaped modelling examples on simple surgical skills learning,⁶ live modelling examples on procedural skills training,⁷ worked examples on diagnostic knowledge,^{8,9} and worked examples of reflective reasoning on diagnostic competence.¹⁰

There are many interesting commonalities in the research on learning from modelling examples and worked examples

Moreover, with both modelling and worked examples, quite some research has been conducted on the issue of whether observing a mix of correct and erroneous examples helps or hinders learning compared with the observation of correct examples only.

However, with regard to motor learning tasks, very little research has investigated the effects of a mix of correct and erroneous examples. One study that did so found positive effects of using a mix of expert and novice examples.¹¹ However, that study included a very large number of example trials, during which novices were seen to gradually improve performance, and thus it is difficult to compare its design with that used by Domuracki *et al.*¹

Quite some research has been conducted on whether observing a mix of correct and erroneous examples helps or hinders learning

The study by Domuracki *et al.*¹ is in some respects more similar to studies that have compared the learning of *cognitive tasks* using a combination of correct and erroneous examples with the same tasks learning using correct examples only. Results from those studies suggested that both students' prior knowledge and the explicit instruction to compare examples determine learning outcomes. Students with low prior knowledge were found to benefit more from correct examples than from a mix of correct and erroneous examples, even if errors were highlighted, whereas students with more prior knowledge did benefit from a mix of correct and erroneous examples.¹² However, even novices seem to benefit from a mix of correct and erroneous examples compared with correct examples only when they are explicitly instructed to compare (or contrast) the correct and incorrect examples.¹³

Both students' prior knowledge and the explicit instruction to compare examples determine learning outcomes

Studies in medical education suggest that studying only erroneous examples may also foster the acquisition of diagnostic knowledge better than the study of only correct examples, provided that the erroneous examples are accompanied by elaborate feedback that explains *why* a step was wrong, instead of feedback that indicates *only* that a step was wrong.^{8,9}

So why does the contrasting of correct and erroneous examples, or the receipt of elaborate feedback on erroneous examples, foster learning? Bandura stated: '...people cannot learn much by observation unless they attend to,

and accurately perceive, the relevant aspects of the modelled activities'.³ Because novices have little, if any, prior knowledge of how a task should be performed, they also lack knowledge of the criteria and standards for what constitutes good performance (a phenomenon that has been dubbed 'the double curse of incompetence'¹⁴). When contrasting correct and erroneous examples, or receiving elaborate feedback about what constitutes correct and incorrect performance, the correct example or the feedback can act as a reference for performance standards that can then be applied to evaluate or learn from the flawed performance.

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Participants in the study by Domuracki *et al.*¹ appear to have been novices, and it would seem that they were not encouraged and would have found it difficult to compare a flawless and a flawed example because the examples were not presented in close proximity (i.e. participants observed one example per day over the course of 4 days). In one condition, however, they were given feedback on their ratings of the models' performance in the form of a set of reference scales. As expected, this feedback fostered learning outcomes as measured by expert ratings of participants' performance, although only on global ratings of performance. However, the question of why participants in this condition did not become better at evaluating the models' performance remains open. Moreover, in the condition in which participants were given a mix of examples without feedback,

subjects performed better at rating the models' performance (again only on global ratings). The authors¹ do not really address this issue in their discussion and I must also admit to having a hard time thinking of a potential explanation.

The correct example can act as a reference for performance standards that can then be applied to learn from the flawed performance

In sum, although some of the findings are difficult to interpret and should definitely be replicated in a study with a larger sample size, Domuracki *et al.*¹ provide a new contribution to the scarce research on learning (psycho) motor tasks from a mix of correct and erroneous examples. Studies on cognitive tasks suggest that a promising direction for future research in this area would involve an exploration of the effects of instructing students to contrast competent and flawed task performance. Another promising avenue for future research lies in investigation of the effects of additional practice. In this study,¹ participants performed the task themselves the day after observing the example and their performance was taken as a measure of learning. An opportunity to practise directly after the study of examples has been shown to strengthen performance on a subsequent test compared

with the lack of such practice.¹⁵ It will be of interest to explore whether this would interact with the effects of observing and evaluating a mix of erroneous examples with or without reference standards.

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