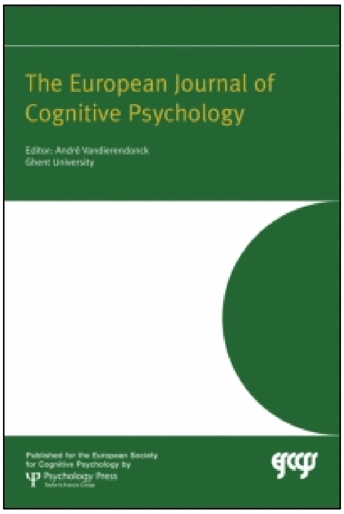

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Introduction: A metacognition bridge

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Introduction: A metacognition bridge

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> We are told never to cross a bridge until we come to it, but this world is owned by men who have "crossed bridges" in their imagination far ahead of the crowd. (Anon.)

John Dewey, a well-known education theorist and pragmatist, said the following: "Without insight into the psychological structure and activities of the individual, the educative process will, therefore, be haphazard and arbitrary" (1897, p. 77). For a long time, the two disciplines, *cognitive science* and *education*, have worked hard to discover effective principles of learning with the goal of improving educational achievement. And although each has made significant advances, there has been a gap between the two disciplines, a gap that remains a reality today. In this introduction, I provide a brief synopsis of the historical paths towards the understanding of learning in both the cognitive field and educational realm, with the aim to show that there is a need, now more than ever, to throw a bridge between the two fields. In this special issue, *Bridging Cognitive Science and Education: Learning, Memory, and Metacognition*, we have organised and integrated some of the recent cognitive data that can provide some new insights on the complexities of learning in the classroom.

The question of how people learn, be it inside or outside the classroom, has been a major theme in cognitive science. Although the cognitive revolution is thought to have arrived in the mid-1900s, *cognitive science*,

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which is defined by empirical investigation, was instigated much earlier. Francis Bacon, who lived from 1561 to 1626, was the first to develop the practice of "observe and experiment" as the method of scientific inquiry. Later, in 1879, Wilhelm Wundt set up the first psychology laboratory, giving him the title "founder of experimental psychology". And soon thereafter, Hermann Ebbinghaus (1885/1962) performed the first empirical studies on remembering and forgetting, using himself as his own guinea pig. Around the same time, and continuing into the twentieth century, work of the behaviourists, as well as a list of more contemporary pioneers of the cognitive revolution—Hebb (1949) with his insight into the neural mechanisms of brain activity, Miller with his discovery of our "magic" short-term capacity (1956), and Chomsky (1959) with his influential theories of linguistics and mental states, to name but a few—paved the way for decades of continued investigations into how the process of learning functions (and malfunctions).

Throughout this extensive history of empirical investigation, as summarised in the quick and easy synopsis above, terms such as *encoding*, *short-* and *long-term storage*, *transfer appropriate processing*, *rehearsal*, and many others, became household names to cognitive scientists. Years of data collection in the laboratories made researchers aware of what types of strategy could potentially improve learning, as well as those types that could hurt learning. For example, it was recognised that we should *space*, and not *mass* our learning sessions (e.g., Melton, 1970); that we should actively *generate*, and not passively *read* the items that we wanted to learn (e.g., Slamecka & Graf, 1978); if possible, we should *cluster* or *chunk* a list of items that needed to be remembered (e.g., Simon, 1974), and we should exercise interactive *imagery* rather than *rote* maintenance for enhanced learning (e.g., Craik & Lockhart, 1972). And finally, a new subfield emerged, one where researchers focused on a framework of "metacognition", which included *monitoring* and *control* of one's own learning. Still, research was largely limited to the laboratories, and it was not until only recently that cognitive researchers focused on learning inside the classrooms.

Within the education realm, of course, understanding and improving learning has been a high priority. In America even as early as the 1600s, for instance, everyone was expected to learn to read, if at the least for religious reasons, and it was not long before an organised place where children would go to learn evolved—a *school*. In 1635, the Boston Latin School, considered to be the first school in the US, opened for boys. The next few decades saw a nationwide expansion of schools. In most of these early "one-room" schoolhouses, students were encouraged to behave in a way that was composed and respectful, especially to the teachers. In the classroom, teachers were meant to be in charge. It was still a century too early for the idea that *student-centred* learning might be more effective than learning that was *teacher centred*.

With the expansion of organised learning facilities came the development of *educational psychology*, a branch aimed to improve learning and, in particular, school performance. Like the goals of cognitive psychologists, educational psychologists also aimed to better understand how learning occurred and how the process could be improved. Friedrich Frobel, who lived from 1782 to 1852, was one of the first educational psychologists, and the first to believe that children should not be reserved, that *activity* was key in the learning of a child. These ideas went directly against the practices of the early schoolhouses, where students had been expected to be inactive. Soon thereafter, John Dewey published "My Pedagogic Creed" (1897), and became a major critic and reformer of the earlier school philosophies throughout the early 1900s. In his pedagogic creed, Dewey wrote that the teacher's task was not to impose certain ideas, but instead to merely stimulate and guide the learner. Already, the notion was rising that students, not teachers, should be the centre of learning.

It was also apparent that success in the classroom meant that students had to perform at some criterion level on a variety of tests. As a result, educators became concerned with evaluation and assessment in the schools, and hoped to be able to diagnose all students, including those who might have had particular learning problems. In 1905, Alfred Binet developed the first *IQ test*, a testing method that became extremely influential in education (although years later, in the 1980s, the meaningfulness of the IQ test was challenged by Howard Gardner's *theory of multiple intelligences*; 1983). Standardised testing became a common practice, and by the 1970s and 1980s, even primary grade children were tested. Although many were opposed to such educational policies, there was a clear understanding that school learning and performance would have a dramatic impact on a child's life, and thus, it was vital that we develop the type of classroom atmosphere that would be most amenable to successful learning.

Throughout the twentieth century, educational psychologists, in collaboration with developmental psychologists and educators, investigated the types of practices that had the potential of improving learning in a classroom setting. And they, like cognitive researchers, also had their own set of household names and methods. Many of these methods were described as *metacognitive* strategies, although again, the definition of "metacognition" used by educators was different (and distinct) than that used by cognitive researchers described above. Here, techniques such as *note-taking*, *outlining*, and *summarising* became important issues to examine (e.g., Anderson & Armbruster, 1984). Other manipulations such as c*larifying* and *predicting* also were thought to be beneficial metacognitive devices (e.g., Brown & Campione, 1990). The relationships between members of an entire classroom, rather than the processes of simply one individual, were also observed as a metacognitive activity. For instance, *reciprocal teaching*, or the method in which teachers and students have a back-and-forth dialogue about a particular text, was found to facilitate learning (e.g., Palincsar & Brown, 1984). Similarly, *cooperative learning*, which encouraged students of different levels to work in small face-to-face groups, was acknowledged both in the US and internationally (e.g., Cohen, 1994). Finally, the effect of *feedback*, defined as teacher responses that affect student learning, was also a significant issue (e.g., Brophy & Good, 1986).

Both cognitive researchers and educators had accumulated a sizeable amount of information. However, many feel that the two fields, along with their independent findings, remain separate for the most part (e.g., Kuhn & Dean, 2004). In order to further knowledge on the issue of learning and performance, there is a strong need for communication between the two fields, and this is precisely the aim of this special issue.

CROSSING BRIDGES

Although cognitive research and education were distinct, there are a number of individuals who might be credited for designing and crossing the earliest bridges between the two fields. And interestingly, although the term "metacognition" had been defined already in different ways by the separate fields, it was also via another general description of metacognitive processes—the ability for an individual to reflect on his or her own thinking (Flavell, 1979)—that early bridges were crossed.

Several well-known individuals and their theories paved the way for the emergence of a new metacognitive field. These individuals were tremendously influential for both cognitive psychologists (and the devising of laboratory experiments), as well as for educators (and the structure of learning in the classroom). Jean Piaget was perhaps the most influential, particularly through the 1970s and 1980s. Piaget (1972) is best known for classifying the stages of cognitive development, starting with infancy, and continuing through to adolescence. The idea behind his stages was that a child learned as a result of reorganising and reflecting on the knowledge gained at each level, including knowledge of errors. Piaget's theories had a long-lasting effect on educational policy such that learning became more student centred, but also affected cognitive science in that age-comparison studies could provide valuable methods by which to capture the various step-by-step mechanisms that are required for learning and self-reflection.

Perhaps influenced by Piaget, another recognised "bridge builder" was Lev Vygotsky, made most famous with his contributions on the *zone of proximal development*. In his book *Mind and Society: The development of* *higher mental processes* (1930/1978), Vygotsky focused on student-centred learning, but in collaboration with guidance from the adult who would act as a "scaffold". He believed that there was a "zone", defined by a difference between what a child could learn on his own and what the child could learn with meaningful help from an adult. Both interested in student-centred learning, Piaget and Vygotsky were key figures in the emergence of how children think about their own learning.

Although Piaget and Vygotsky had laid the groundwork, the study of metacognition in both the laboratories and the classrooms became front and centre largely because of another researcher, John Flavell. Flavell was a psychologist who had long been interested in Piaget's work, and in the understanding of a child's mental states. In fact, his book *The Developmental Psychology of Jean Piaget* (1963) was the first most comprehensive evaluation of Piaget's work in English. In the 1970s and 1980s, Flavell focused his research on evaluating children's role-taking abilities, or the abilities that children had to understand what another person knew. He was also interested in the development of memory in children, and found that children needed to understand the concept of memory before they could actually develop skills for applying or improving memory processes. This higher knowledge, of understanding memory, he officially called *metamemory* (1971).

Since Flavell's introduction of the term, metamemory and metacognitive research continued to expand. Answers to questions that had been posed centuries earlier about how to improve learning and memory are being sought, and more importantly, are sought in forms that are realistic and effective for learning in the classrooms, not just in the laboratories. Researchers and educators together are now motivated to discover the most optimal practices for learning, memory, and metacognition.

This special issue shows that a growing number of researchers are interested in crossing the "metacognition bridge", and are devoting a good part of their investigations to understanding strategies that enhance learning and memory, and the awareness of those strategies, particularly in real-world educational situations. The main purpose for this collection of papers is to have, in one place, an encyclopaedia of information that will provide researchers and educators with new findings about how people learn and remember information. In organising the issue, I have categorised the papers into two broad categories that aim to answer a few general questions. The first is "What types of strategy improve learning?" and is addressed by the first five papers. And the second is "Are people aware of such strategies?", addressed by the next seven papers in this issue. This set of seven papers will also relate to issues such as what kinds of people are aware as well as the relation between awareness and learning. The final paper in the series suggests that when an appropriate "metacognitive" scaffold is used—one that incorporates a variety of effective cognitive strategies—learning in the student will improve enormously. Below, I summarise briefly the topic in each paper.

The first paper uses a method of research that bridges directly cognitive research and the classroom. In their paper, the authors McDaniel, Anderson, Derbish, and Morrisette investigate the *testing effect* in an everyday college course. Typically, people think of testing as a device that merely measures performance (e.g., Kornell & Bjork, in press; Kornell & Son, 2006), but recently, people have shown that testing has benefits for the process of learning too (e.g., McDaniel & Fisher, 1991). In this research, students took weekly quizzes made up of multiple choice (MC) tests or short answer (SA) tests. Their results showed that quizzing (as compared to those not quizzed at all) improved performance, and that short answer quizzes improved performance the most, especially when accompanied by corrective feedback.

In the next paper, Butler and Roediger examine the testing effect and how it affects performance over the long term. Participants were given initial exposure to a classroom lecture via a video. Then, participants either took an MC test or an SA test, or simply studied a summary of the lecture. A final SA test was administered after 1 month. The results indicated that an initial SA test produced final test performance that was superior to that resulting from either an MC test or additional study. Kang, McDermott, and Roediger also study the effects of testing in the next paper, and in this case, had participants learning papers on their own. After reading the papers, participants received an MC test or an SA test, or a list of statements to read, or a filler task. Their question was: Do MC or SA tests differentially improve performance on later tests, and if so does the type of final test matter? The results showed that when feedback was available, there was an advantage for the SA test which yielded the most benefits on later tests, regardless of the type of final test.

An important issue in the investigation of learning is feedback. How much feedback is effective for learning and does feedback matter? Rawson and Dunlosky focus on this question in their paper, where they test people's learning of text passages. They also asked whether people's metacognitive knowledge improved when feedback was given versus when it was not given. In their experiment, college students read passages, each of which included key terms. After reading each text, each key term was presented, and participants attempted to recall the corresponding definition. Then, they were given the opportunity to "score" their own answers. Some were given feedback before scoring their answers—that is, they were shown the correct answer, in the "standard" condition; others were not able to see the correct answer—the "no standard" condition. The results showed that both recall performance and metacognitive accuracy improved when participants were able to compare their own answers to the correct answer during the "self-scoring" stage. And, although all participants were overconfident in the correctness of their answer, the "standard" participants were less so.

Carroll, Campbell-Ratcliffe, Murnane, and Perfect then ask if a higher level of expertise could protect against forgetting. In order to test forgetting, they used the *retrieval-induced forgetting* paradigm (e.g., Anderson & Spellman, 1995). Retrieval-induced forgetting occurs when memory for items that are not rehearsed are remembered less well than items that were rehearsed in that same category as well as items from other non-rehearsed categories. For instance, if people rehearsed *banana* and *plum*, then memory for *pineapple* and *melon* would be worse than memory for *banana* and *plum*, as well as for *chair* and *table*. This "forgetting" of *pineapple* and *melon* has been thought to be a type of unconscious forgetting. The question the authors addressed here was: Are people aware of retrieval-induced forgetting? If so, can something be done to compensate for that forgetting? For instance, might a student spend extra time trying to study the *connection*s between items within one particular category? In one experiment, comparing experts versus novices (who would have less awareness of connections between items in one category), they found that, indeed, experts were somewhat protected from retrieval-induced forgetting, especially when there was not enough time during study to form new connections. In addition, the expert participants were more aware of what they would remember and not remember. That is, the experts thought there would be less inhibition than the novices did. In the second experiment, they follow up similar investigations on the influences of test format.

A few of the early papers, while investigating the types of strategies that enhance learning, have also examined how aware or attentive people are of what they know and don't know. Groups have different levels of attention, for a variety of reasons. For instance, some have attentional disorders, others have high levels of anxiety. And it is certainly likely that students in school will have different levels of attention or anxiety when it comes to testing and performance. One question of interest then is: How will these differences manifest in learning and metacognitive processes? Moreover, is there a developmental component to the metacognitive process? For instance, do younger children have more difficulty with knowing what they know and do not know? And for that matter, are there differences in monitoring abilities between people of different levels of experience or expertise? The following set of papers all address these issues.

In their paper, Ballesteros, Reales, and Garcia examine recognition and priming of attended and unattended stimuli at encoding in two different ages (second and fifth grades) of both normal children and those with attentional deficits (AD). In the recognition phase, children were asked to name an object that was presented in a particular colour and overlapped with another object in a different colour. The named objects were the attended items while the ignored overlapping objects were “unattended”. In the test phase, they performed a picture fragment completion task (PFCT) that included both attended and unattended objects. For instance, they were shown gradually more filled in pictures until they were able to identify the item. Results showed while the AD children suffer from expressing their unattended or “implicit” memory in general, they show similar patterns of attention development as normal controls.

Meneghetti, De Beni, and Cornoldi also examine adolescents, and their use of effective and less effective strategies. From a sample of 354 students, aged 11 to 15, two groups of students were selected based on their performance on a reading comprehension task. The goal of the study was to compare knowledge in the two groups, anticipating that the high scoring reading comprehension group would show coordination between knowledge and use of strategies, the low scoring group a greater discrepancy between the two ratings. And indeed, this is what they found. Such findings implicate the importance of metacognition in strategy use and consequent academic performance.

Miesner and Maki follow up with the question of how anxiety influences metacognitive monitoring. Many feel that anxiety is a negative emotion. Feeling too nervous or anxious might distract from your attention or your learning. Meisner and Maki investigate whether anxiety might help or hurt your monitoring performance as well. For instance, if you are anxious about your knowledge, does that mean that you are a worse or better predictor of what you believe you know? After rating people using the Test Anxiety Scale, people were given texts to read for a later test. Before taking the test, they were also asked to judge how well they thought they would do on the test as a measure of monitoring accuracy. Results showed that high anxiety did hurt performance, as well as decrease confidence. Interestingly, people high in anxiety were more accurate on metacomprehension, particularly on MC tests.

De Bruin, Rikers, and Schmidt also test monitoring accuracy in learners at different expertise levels—experienced and inexperienced chess players. In their study, all participants were presented with a variety of chess rules, and had a learning phase where they saw a particular move. Then they made judgements about how well they would be able to predict such moves in the future. They were given a final test in the format of a new game. Results showed that experienced chess players not only learned faster and performed better, but also had higher monitoring accuracy.

Kelemen, Winningham, and Weaver split their participants as a function of SAT scores, and compare monitoring ability. Subjects were given foreign vocabulary pairs to learn and then make judgements about how well they thought they would remember the pairs later on the final test. Then they were given the final test. Those with higher SAT scores had higher performance on the test, and were less overconfident. In addition, training across trials only benefited the students who had higher SAT scores. In a series of additional experiments, they investigate how monitoring accuracy might be improved. For instance, they find that practice can improve monitoring accuracy, without any explicit instructions or added feedback, and that mere exposure to study and recall procedures, without having to make metacognitive judgements, also improved monitoring accuracy.

Higham and Arnold investigate people's awareness of their knowledge during MC tests using a *signal-detection* approach. On MC tests, learners need to know which answer is correct and which answers are incorrect. If some particular option has reached some criterion of confidence as correct, then that answer is chosen as the correct one. If none of the choices reach criterion, then one could choose to withhold a response and not answer the question. Using signal detection, the authors were able to see who has a conservative criterion and who has a liberal criterion—which could be used a metacognitive monitoring measure. Their results showed that in general, people were underconfident—that is they withheld too often—and that there was no improvement across time. More importantly, the lowest-scoring groups of students did not respond in a manner that was consistent with their actual performance. Those who monitored well performed better than those who monitored more poorly. These results, in combination to the previous findings in this special issue, suggest that awareness of one's own learning, or the enhancement of metacognitive accuracy, can improve learning itself.

In the final paper of this special issue, my co-authors Metcalfe and Kornell, and I, show that when a computer acts as an effective "metacognitive" scaffold for a student by introducing practices that use cognitive principles to enhance learning, learning in the student will improve enormously. In the research, students in both middle school and college either studied on their own, or on a computer program in which spacing strategies, generation strategies, and contextual processing strategies were enforced. And one of the most valuable aspects of the study was that the procedure took place over a long term, across a total of 7 weeks. The final results show a huge improvement on the final test following computer study over self-study. One could interpret these results as showing that individuals are indeed, bad at learning. On the other hand, one could rest assured that even when students use suboptimal strategies, and even when they do not have accurate metacognitive knowledge, we can still rely on educational implementations (and teachers) that are knowledgeable about effective learning strategies and can appropriately guide students during learning. These data, and the information gained in all of the papers in this issue, show that the bridge between cognitive science and education is crucial for an individual's success in school.

TRAFFIC ON THE BRIDGE

Historically, both cognitive researchers and educators have invested huge amounts of energy and time to our understanding of learning. Strategies that enhance learning both in the laboratories and in the classrooms have been tested and applied in many ways, and continue to expand. And metacognition, what I describe here as an early bridge between the two fields, has grown to be a theme that, at the moment, seems to have numerous empirical answers for the improvement of real-world learning. Perhaps a question that remains is this: How long will researchers investigate real-world learning paradigms, and similarly, how long will educators be interested in the research? In other words, can we expect a lot of traffic across this bridge?

I offer this question for several reasons. First, there has already been a long history of a largely divided path of research—one for cognitive researchers and another for educators. And it is likely that there are several causes of the creation of this divide. One is that there are still few opportunities for researchers and educators to speak to each other. Over the past semester, I was able to visit a local private school, and survey anonymously a group of 20 teachers (who teach a variety of subjects and a variety of grades in elementary and middle school). One of the questions on that survey was: "Have you ever spoken before with any cognitive researchers (besides me) who conduct research on learning strategies?" Out of 20, only 4 said that they have spoken about some research findings. On the other hand, all 20 answered "Yes" when asked: "Do you think that your teaching strategies would improve if you were made aware of various cognitive strategies?" and "Do you think that it is important to understand the psychological mechanisms that underlie the different learning strategies?"

Also on that survey, the teachers were asked if they knew of such practices such as the *generation effect*, the *spacing effect*, and *levels of processing*. Out of all of their answers, only 15%, 20%, and 50%, respectively, knew that these methods had been found to enhance learning in the laboratories. After describing each of these practices in some detail, I asked the teachers whether they ever used these tactics in the classroom, and how many of their students would use these strategies on their own, in their opinion. On average, about 80% said they used these strategies in the classroom (each of the above strategies were used at around the same frequency), but felt that only about 20% of their students would use such strategies on their own. And all of the teachers agreed that learning could be much improved at the level of the individual learner, rather than in the classroom.

Another reason for why the two fields have stayed fairly divided is that educators have long felt that the data collected in the laboratories have not been applicable to their own classrooms and the subjects that they teach. For instance, many of the teachers expressed that they are not interested in having their students learn a list of words. When asked in the survey "Do you think that connecting with cognitive researchers would be helpful for the teaching strategies in your subject area?" one teacher said "not at all", two teachers said "a little", four said "not sure", ten said "probably a lot", and only three said "definitely". Given these answers, it seems that there would be a varying range of how valuable this bridge of data and the classroom would be.

A few teachers expressed to me that researchers should realise that the types of material that need to be learned in school are often complex, especially to a child. When asked on the survey "Do you think that cognitive researchers could learn from speaking with you and your teaching strategies?" seven teachers said "definitely", eight said "probably a lot", but five said that they were "not sure". (None of the teachers chose "not at all" or "a little".)

Surprisingly, 19 out of the 20 teachers surveyed had read some number of scientific papers that addressed learning prior to or during their teaching careers. However, a few said that cognitive scientists write in a way that was "boring" or "cryptic". And the larger problem was that the learning scenarios were not realistic, and the materials were not typical of what a student in their class would have to learn. One even said that "it's obvious that cognitive researchers who collect data in the lab have very little knowledge of what goes on in the classroom". When the teachers were asked "Do you think that reading scientific papers would be helpful for your teaching strategies?" there was a range of answers: One teacher said "not at all", two said "a little", eleven said "not sure", five said "probably a lot", and five said "definitely".

Even though there may be some uncertainty about whether traffic on this bridge between cognitive science and education will continue to increase, I believe that it will. Fortunately, many cognitive researchers, including those who have contributed to this special issue, have put effort into asking teachers and educators questions about learning and materials in their classrooms. And using that knowledge, they have designed new and applicable experiments. I also feel that the main reason that teachers have found some scientific papers to be "boring" or "cryptic" is simply because they have not been successfully applicable to classroom learning. In this special issue, I hope this will not be the case. The researchers have, I feel, successfully tested the various means of learning in highly realistic and valuable ways.

Since the beginning of cognitive research and the beginning of education, even as separate fields, we have not done too badly. Given what Dewey might have seen as a "haphazard and arbitrary" educational process, children and adults have been able to perform fairly well in the hundreds of exams that they take in their lifetimes. But he is correct to believe that improved communication between the two fields can only advance the state of our knowledge. The contributors to this special issue have made valiant efforts in testing learning as it pans out in the real world, and, through this special issue, we hope to disperse that information with the goal of continued links between cognitive scientists and educators. In short, I am looking forward to an unbreakable, and congested, bridge.

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