Improving Working Memory

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Improving Working Memory

Supporting Students' Learning

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I dedicate this book to Marcus, my four-year-old, who reminds me daily of the delight that learning and discovery brings.

Contents

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Preface

My journey began on a crisp October day about 10 years ago. I was surrounded by a sea of small and eager faces in neatly pressed uniforms. As part of a government-funded project, I was working with five-year-olds to understand what cognitive skills are important for academic success.

I met Andrew that day. That six-year-old boy stood out from the rest. He loved being at school and made friends quickly. In the classroom, he was always excited about participating and would raise his hand to answer questions. Andrew enjoyed 'story time' best, when Mrs Smith would ask the children to present a short story. Andrew loved telling stories and would be so animated and use such creative examples that all the children enjoyed them as well.

As the school year progressed, I noticed that Andrew began to struggle with daily classroom activities. He would often forget simple instructions or get them mixed up. When all the other children were putting their books away and getting ready for the next activity, Andrew would be standing in the middle of the room, looking around confused. When Mrs Smith asked him why he was standing there, he just shrugged his shoulders. She tried asking him to write down the instructions so he could remember what to do. But by the time he got back to his desk, he had forgotten what he was supposed to write down.

His biggest problem seemed to be in writing activities. He would often get confused and repeat his letters. Even spelling his name was a struggle – he would write it with two 'A's or miss out the 'W' at the end. Mrs Smith tried moving him closer to the board so he could follow along better. This didn't seem to work; he would still get confused.

Mrs Smith was at a loss. She always had to repeat instructions to Andrew but he never seemed to listen. It was as if her words went in one ear and out the other. On another occasion, an assistant found him at his desk not working. When she asked him why he wasn't doing the assignment, he hung his head and said, 'I've forgotten,

sometimes I get mixed up and I am worried that teacher will get angry at me'.

His parents contacted me to see if I could help. They were concerned that Andrew might have a learning disability. When I tested Andrew on a range of psychological tests, I was surprised to find that he had an average IQ. Yet, by the end of the school year, he was at the bottom of the class.

Two years later, I went back to the school to conduct some follow-up testing on the children. Andrew seemed such a different boy. He was placed in the lowest-ability groups for language and maths. He became frustrated more easily and would not even attempt some activities, especially if they involved writing. His grades were poor and he often handed in incomplete work. He only seemed to brighten up at playtime.

I was determined not to let Andrew slip through the cracks and remember his schools days as a time of frustration and failure. As I was analyzing my data, I found a clue that would change Andrew's life and thousands of students like him.

It was my encounter with Andrew that started me on this journey, a journey that I am still on today. Many of you have already come on this journey with me and I am glad for your company. As a psychologist, I am grateful to the thousands of teachers and parents who have contacted me and taken me beyond the world of theory and data to see the classroom from your perspective. Your struggles and successes have inspired and motivated me to keep searching for answers to find out what makes the difference for students like Andrew. Thank you to all the schools that have invited me to share my research with you. This book would not have been written if it wasn't for your interest in working memory.

We are on the brink of wonderful new discoveries in education and I am filled with great excitement. Over the years, I have seen so many students' lives transformed. My hope is that this book will help you support students like Andrew and turn their frustrations into success.

1 Our brain's Post-it note

This chapter looks at:

- what working memory is, and why it's important
- how working memory relates to academic success
- the differences between working memory and IQ
- quick ways to help students with poor working memory.

Working memory is our ability to remember and manage information. The best way to think of working memory is as the brain's 'post-it note'. We make mental scribbles of bits of information we need to remember. In addition to using it to remember information, we also need working memory to process or manage that information as well. Working memory is critical for a variety of activities at school, from complex subjects such as reading comprehension, mental arithmetic, and word problems to simple tasks like copying from the board and navigating around school.

One question I often get asked is whether working memory is the same thing as short-term memory. No, it is not. Here is an example of the difference. Imagine that you are driving to a new school for a meeting. You lose your way and stop at a store to ask for directions. You may repeat the information to yourself over and over again as you walk back to your car so you don't forget. At this point, you are using your **short-term memory** to remember the directions. Now you get back inside your car and start driving. As you recite the directions to yourself, you look around and match them to the road names. Is this where you make that right turn? Where do you make that second left? Now you are using your **working memory** as you are applying or using the information that you were given.

It is much the same in the classroom. When you give a student a set of instructions, they use their short-term memory to repeat it to themselves. However, by the time they get back to their desk and have to carry out the first task in the set of instructions, chances are

that if they have poor working memory, they will have forgotten what to do. The process of repeating the information and then carrying out the individual steps relies on working memory. Think of working memory as 'work'-ing with information to remember. The Try It box gives you an example of a working memory test.

How much can we remember at each age and does this amount increase as we get older? I conducted a study of thousands of indi-

Try It

Read these sentences and decide if they are true or false:

1. Bananas live in water: True or False
2. Flowers smell nice: True or False
3. Dogs have four legs: True or False

Now, without looking at those sentences, can you remember the last word in each sentence in the correct order? If you were able to remember them, congratulate yourself. Your working memory is like that of an average 10-year-old. This test is an example of the Listening Recall test from the Automated Working Memory Assessment. It measures verbal (auditory) working memory. In this book, **verbal memory** is synonymous with **auditory memory**. In tests like this, the sentences are presented orally and the student repeats the required information out loud. We will look more closely at tests to diagnose working memory problems in Chapter 2.

Working memory in childhood

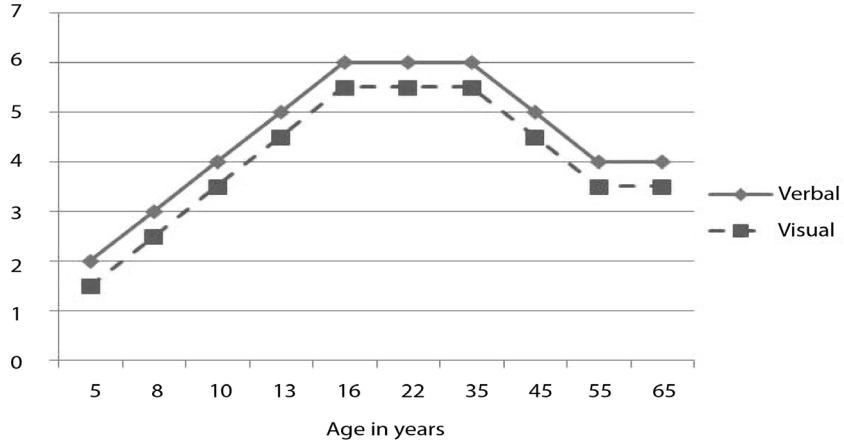

Figure 1.1 Working memory across the lifespan

individuals from 5 to 85 years old in order to address this issue. Figure 1.1 illustrates how much the average individual can remember at each age. The most dramatic growth is during childhood. These years are crucial as working memory increases more in the first 10 years than it does over the lifespan. You will notice a steady increase in working memory right up to our twenties. At this point, working memory reaches a peak and plateaus. The average 25-year-old can successfully remember about five items. As we get older, working memory declines to around three to four items. How does this relate to the classroom? The average five-year-old can hold one item in mind (list of words, instructions, etc.); a seven-year-old can remember two items, a 10-year-old can remember three items, and a 14-year-old can remember four items.

You may have noticed that there are two lines in Figure 1.1: one for verbal/auditory working memory and another for visual–spatial working memory. These two working memory skills develop at a similar rate. In the classroom, we use **verbal working memory** to remember instructions, learn language, and perform comprehension tasks. **Visual–spatial working memory** is used to remember sequences of events, patterns, images, and maths skills. My research has demonstrated that the way we use working memory to process information, whether verbal or visual–spatial, draws on some common skills. The Science Flash box details the parts of the brain that we use for different working memory tasks.

Working memory is a relatively stable construct and all working memory components are in place by four years of age. While working memory does increase with age, its relative capacity remains constant. This means that a student at the bottom 10 percentile compared to their same-aged peers is likely to remain at this level throughout their

Case Study

My name is Mary and my six-year-old daughter was tested via her school. I am not sure the name of the test, but her result in the working memory test was 63, way below average, in the borderline category. I of course started to research 'Working Memory' and have learned quite a lot … 95% of the information is due to you. The description of the symptoms fit her to a T. Every one actually. I feel I have answers now as to why she 'forgets' so many things. The school wants to have her repeat the 1st grade because of her lower grades in maths and reading. They also feel she needs more time to develop. As a mother, I feel that she is going to have the exact same issues, no matter what grade she is in. I do not see her 'growing out of it'. She hasn't thus far.

academic career. If a six-year-old with poor working memory is struggling initially, they are unlikely to catch up with their peers without intervention. By the time they are 10, the gap in learning between them and their same-aged peers will have widened. That is why early diagnosis and support is so crucial. Here is one mother's story.

The Working Memory Brain

Brain imaging has confirmed that when we perform working memory tests, like the one in the Try It box, there is electrical activity of neurons in the prefrontal cortex. We use different parts of the brain to remember verbal and visual–spatial information. Scientists suggest that the lower area of the prefrontal cortex (ventrolateral) is responsible for verbal working memory, while the higher area (dorsolateral) is linked to spatial working memory. These two areas are also linked to the different processes in performing a working memory task: the ventrolateral areas are engaged with keeping information active and the dorsolateral areas are involved in processing or managing information. Other areas of the brain are also activated during working memory tasks. When we engage in visual–spatial tasks, parts of the right hemisphere and the hippocampus are also activated. In verbal working memory tasks, there is activation in the left hemisphere, particularly in the 'language centers' such as Broca's area. What is the take home message? Protect your head, as you will need it for the rest of your life!

Limits to working memory

What can prevent us from using our working memory optimally? I will outline three limitations to working memory. Throughout the book, I will refer to these limitations that are specific to the different learning difficulties and provide strategies to support these areas.

Space

Up until the age of 15, our working memory is constantly increasing in size. It is getting bigger, which means we can scribble more information down on our mental Post-it. But some people's working memory grows faster than others, while others' working memory grows more slowly. A seven-year-old in a class of other seven-year-

olds where most students have a similar size Post-it note will not have any difficulty keeping up. But what about a seven-year-old with a bigger-than-average working memory? Imagine a 10-year-old in a class of seven-year-olds. They would be bored with what the teacher is saying and they would finish assignments before anyone else. They may even act out because they have nothing else to do. This is exactly what it is like for a student with a working memory above his peers. About 10% of your class will fall in this group.

Let's look at the other end of the scale – the student with a small working memory. Now imagine a four-year-old in that class of seven-year-olds. They would be frustrated like the 10-year-old, but for the exact opposite reason: things would be so hard to understand that they may just give up. The teacher is talking too fast for them to keep up, they can't spell all the words she is saying, they are struggling with adding up the numbers in the maths problems, they can't read all the words in their books. They will probably act out. This is exactly what it is like for a student with poor working memory.

Remember that there is a fixed limit to working memory at each age. The average seven-year-old can only remember about **three** instructions. A teacher attending a seminar I gave in Seattle commented that it made sense now why her class found it difficult to complete what she asked them to do. Here is an example of instructions she had given to her class: *Put your notebooks on the table, put coloured pencils back in the drawer, get your lunchbox, and make a line by the door.* Instead of forming neat lines by the classroom door after putting away their books, they would be wandering around the class confused. 'I know why now, I would always give them four things to do at a time and it was too much for their working memory', she said after learning about the average space we have in our working memory at each age.

Time

Another limit to how students use their working memory is how quickly information is given. When a teacher speaks too quickly, a student with poor working memory is unable to process all the information fast enough and invariably gives up on the activity. After hearing me speak, a teacher came up to me and said 'I know I speak fast. But if I don't, I'm worried that I will forget what I need to say. I think I have poor working memory!' I know exactly what she means. I've been told I'm a fast talker, usually when I am excited about a topic related to working memory. If

you are an educator who has been teaching for many years, you may not even notice how quickly you give instructions to your class. But for the students, especially those with poor working memory, they need to hear the information at a slow, steady pace.

Activities that take a long time to process can also overburden a student with poor working memory. Robert, a 10-year-old, made this comment when asked if he forgot what the teacher just talked about: 'Sometimes, I don't listen cos the teacher goes on too long'. Timed activities are especially frustrating. The student with poor working memory who has to complete 20 sums in five minutes is unlikely to attempt them. They may either sit quietly at their desk or act up in class to shift the focus away from their struggles with the activity. Another example of when time limits working memory is when homework is given out. In one classroom, homework was frequently given out in the last few minutes of a lesson when students were attempting to finish their class work and tidy up. Students with poor verbal working memory will struggle with the demands of having to finish one task, listen to instructions about their homework, and write it in their planner. John is an example of a student in this classroom. He repeatedly failed to return homework. He found it overwhelming to manage all that information in such a short period of time. The time pressure can make a manageable task too demanding.

Effort

Kelly is a happy eight-year-old that greets me with a smile. As I sit down and start talking to her, she admits that she knows that she sometimes loses concentration but cannot do anything about it. She says she tries hard at school but finds it difficult. Difficulty keeping focus is a key feature of working memory overload. If a task requires too much effort, students tune out. Kelly described it this way: 'I start floating away and then I don't get what the teacher is saying'. So what types of activities are likely to make Kelly and students like her 'float away'? Look at these two lists of words:

mat, man, map, mad

map, tan, cat, dad

Now cover them up and try to remember the words in the correct order. Which was easier? It was most likely the second list. Words that are sim-

ilar sounding require more effort to keep in mind and students are more likely to get confused. This is important to remember when you are teaching rhyming words or new vocabulary and spelling.

Students with poor working memory have to use a lot of effort when they have to juggle two or more things. If they are asked to remember a sentence ('John went to the park') and count the number of words the sentence contains, they find it too effortful. Here is what Kelly said: 'Teachers talk while we are supposed to write stuff down. I can't do it'. Teachers often view students like Kelly as bright but daydreamers or 'lacking application'.

Working memory and the environment

I imagine that you are reading this book because you are interested in working memory. You may already know that working memory is important to academic success. But did you know that working memory is one of the most important skills that predict learning outcomes. Working memory is even more important than IQ.

Let's take a step back. Before we get to working memory in the classroom, let's look at how environmental factors, such as preschool education and financial background, can impact on working memory. I was part of a government-funded study to identify the most important factors in early education. Part of this study involved testing hundreds of kindergarteners on a range of tests, including IQ and working memory. One of the things I was also interested in was how long a child had spent in pre-school before starting school. We know that children who attend pre-school learn basic 'learning blocks', like colours, numbers, letters, maybe even how to spell their name. If they had attended pre-school, were they more likely to do well in school? On the other hand, if they didn't go to pre-school, would they be at a disadvantage because they didn't know how to read or write? The parents filled in some details on how long their child had spent in pre-school. Some children hadn't attended preschool at all, while others had attended for two to three years. Would this matter to working memory? If a child has spent a longer time in pre-school, would it make their Post-it note larger? I was surprised by the results. The length of time a child spent in pre-school *did not* make any difference to their working memory size.

Now let's look at another important factor: socioeconomic status. A commonly used index to measure this is a mother's educational level.

Do you remember Andrew from the Preface? Would it matter whether his mother has a PhD or whether she didn't finish high school? Would his working memory be influenced as a result? We know that this impacts on IQ: children whose parents have a college or university degree perform better on IQ tests compared to those whose parents dropped out of high school. Here is why: parents who are well-educated are more likely to teach their children more. The more they teach them, the more they are able to learn and the more likely they will do well on a typical IQ test, which measures this knowledge.

In the same study, parents indicated how old they were when they left school and their highest educational level. Children with parents who had a college or university degree did better on the IQ tests than those who left school at 15. Does working memory follow this pattern too? Here again I was surprised. My study found that, as opposed to IQ, working memory is not linked to the parents' level of education or socio-economic status. This means all children regardless of background or environmental influence can have the same opportunities to fulfil their potential if working memory is assessed and problems addressed where necessary.

Let's look more directly at whether financial background influences working memory. Think of a classroom in rural Brazil. There is so much working against these kids. Less than 15% will finish elementary school. Most leave without learning to read. Schools can't afford to pay their teachers much and those teachers that do stick around don't always have the skills and training to do their job. But could these students have the same ability and potential of their richer urban peers? My colleagues decided to test this theory. They compared rural, low-income kids with those from wealthy, urban areas in Brazil in IQ and working memory tests. You would expect that the rural kids struggled behind their urban peers. Indeed, that was the case with the vocabulary test used to measure IQ. The urban students excelled in matching words with the correct definitions. They far superseded their rural counterparts in their knowledge, because they had more experience using the words on the test.

But here is the surprising finding: they were no better than the rural students on the working memory tests. It boils down to one thing – opportunity. The urban children had more opportunity to learn – at home, their parents have the skill and time to teach them, while at school they receive more attention from teachers. They have had a rich base of knowledge cultivated over the years. But the exciting news is that students from deprived backgrounds have the same ability to suc-

ceed. Their working memory skills are no different from their urban peers. It is not an issue of IQ. It is a matter of giving these students the same opportunity to unlock their working memory potential.

Working memory at school

Ben walks through the door, nervous and dreading the moment when his mother is going to ask the question he knows is coming. 'Can I see your report card?' He takes it out of his backpack, his hand sweaty and shaking. His mother reads the results of a semester's worth of work, and sighs. 'We'll try harder next time.' Does this sound familiar? Unfortunately, 'trying harder' isn't going to make a difference. Many children like Ben try hard every day and still struggle.

The problem isn't the effort, the problem is working memory. Working memory affects all areas of learning and hence affects grades in all subjects from language to maths, from history to art. This is the case at every level of education. The sad reality is that no matter how hard Ben tries, he will not 'catch up' with his peers. If your son or daughter has low grades in kindergarten as a result of their working memory, they will almost certainly have poor grades all the way through high school. In a recent study, I found that teenagers who were diagnosed with low working memory two years earlier were still performing very poorly in school. If we don't do something to help these students, they will continue to struggle their whole life. I regularly come across parents of college-age students who tell me with tears in their eyes how they wished they knew about working memory when their child was younger, how much it could have helped them, and how much they struggle just to pass a test now they are in college. The good news is that we can change their grades by changing their working memory.

There are many factors that contribute to academic success. Figure 1.2 illustrates key cognitive skills that are linked to learning outcomes. We will discuss each one in turn and find out how, although they are each important, if the foundation of learning is not supported, students will only experience limited success in the classroom.

The 3Rs

We all know that the 3Rs are reading, writing, and arithmetic. We all

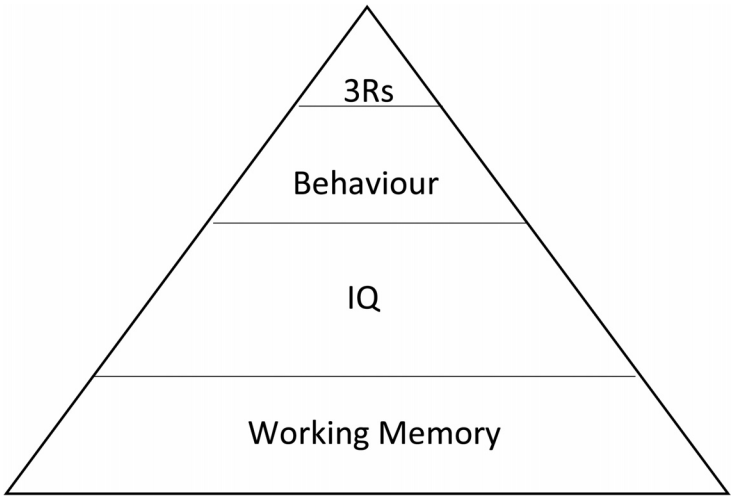

Figure 1.2 Learning pyramid

remember going to school and trying to memorise spelling words and our times tables, to write a coherent paragraph and to calculate our long division. Teachers spend a lot of time drilling the 3Rs so that students learn these important skills. But for some students, this clearly isn't enough. You know this yourself. Think about your classroom. Some students are better than others. Why is there this variation in the class? Why is it so easy for the girl in the desk in front, but so hard for the one to her right? They all sit through the same lesson, yet have very different results. Despite the focus on the 3Rs, why do we still see so many students diagnosed with learning disabilities? Furthermore, why do these students fail to improve after one-to-one instruction or tutoring?

For a long time, psychologists have attempted to find the answers to these questions, but only now is the answer clear: working memory. In a recent study that I conducted, I looked at a group of students from 8 to 11 years with learning difficulties. All the students were receiving extra educational support, like tutoring and special classes. I tested their IQ, working memory, and also looked at their grades in the 3Rs. These students received special tutoring in small groups for the next two years. Yet, when I saw these students two years later, they were still performing at the bottom of the class! Their learning outcomes had not improved and they were still struggling. Except now they were becoming more frustrated because of their learning difficulties and this was manifesting itself as behaviour problems, including truancy.

What happened to these students? Why didn't they show any

improvement? I took a closer look at their working memory scores. All of them had low working memory scores. Crucially, it was their working memory scores, and *not* their IQ, that determined their grades. If they had poor working memory, they struggled in reading, writing, and maths. It didn't even matter what their IQ was. Working memory was the critical skill linked to their learning.

What does this mean? Simply, that focusing on teaching reading and maths isn't enough. That 'hard work' without focusing on working memory is just hard work. That drilling the 3Rs without improving working memory is like entering a bike race with flat tires. This is not to say that the 3Rs are unimportant. Even a child with high working memory needs to learn the 3Rs to do well in school and life. However, if we don't develop working memory skills, the 3Rs won't make a difference.

IQ

We've all been told that IQ is related to learning – the higher the IQ, the higher the grades. Yet, there are many studies that show that students with high IQ don't achieve well in school. Think back to Andrew and his struggle in school. When I speak to educators about him, they are surprised that despite his IQ being in the normal range, he still struggled in school. Surely his IQ is important, they ask.

I had a slightly different question. We know that IQ and working memory are both related to learning. What I wanted to know is: *which is more important*? I took a group of bright, eager five-year-olds as they started kindergarten and followed them over a six-year period. I wanted to know how well IQ and working memory would predict reading, writing, and maths skills.

When I first looked at the learning outcomes at five years, I was surprised to find that some children with high IQ were achieving low grades. This seemed very odd. If IQ is so important to learning, why were some children still struggling even when they had high IQ? When I looked closer at the results, I was amazed. Working memory made *all* the difference in their grades. It was more important than IQ. Children with high working memory do well in reading, writing, and maths; while those with low working memory struggle.

I followed up with these children and tested them again at 11 years of age. My question was which would best predict learning outcomes over time – working memory or IQ? This issue is

important because as educators we need to be able to distinguish between the cognitive skills that underpin success in learning in order to best support our students. These typically developing students were tested for their IQ and working memory at five years old and again when they were 11 years old. They were also tested on their academic attainments in reading, spelling, and maths. The results were unequivocal: a student's working memory skills at five years of age was the best predictor of reading, spelling, and maths outcomes six years later. If you know a student's working memory at five, you will know their grades at 11. IQ was not nearly as reliable in predicting grades. This finding is important as it addresses concerns that IQ, still viewed as a key predictor of academic success, is not a useful benchmark of success. An individual can have an average IQ score but perform poorly in learning, as we saw with Andrew (see Preface).

The importance of working memory in learning is not just limited to children. We see exactly the same pattern right up to college and university level as well: working memory is a better predictor of learning compared to IQ. At the college and university level, working memory is a much better predictor of grades than even entrance exams. As with the 3Rs, the impact of IQ is limited. Ultimately, we need to look beyond these skills if we want to see lasting improvements in our students. This brings us to the next section.

Working memory

Figure 1.2 illustrates how working memory is the foundation of learning. It is a basic cognitive skill that we need to perform a variety of activities, and we use it in core subjects like reading and maths, as well as general topics like Art and Music. Take reading as an example: you use your verbal working memory to understand what you have read; you need to remember where you are in a sentence, the specific meanings of the words that you have already read, and the general point of the preceding passages. Visual–spatial working memory supports mathematical skills, such as arithmetic, number knowledge and strategies, as well as mental maths.

In the previous section, we saw how working memory is so much more important to learning than IQ. Why is this the case? Working memory tests measure something different from IQ tests: **working memory measures our potential to learn**. Think of the Listening

Recall test in the Try It box. You hear a list of sentences, verify them, and then recall the final word in the correct sequence. If you struggle in this test, it is not because you haven't eaten a banana or don't know about flowers. It doesn't even matter whether you know how to read. If you struggle in this working memory test, it is simply because your 'Post-it note' isn't big enough to remember three or four words. Working memory is such an accurate predictor of learning from kindergarten to college because it measures our ability to learn, not what we have learned.

In contrast, other measurements like school tests and IQ tests measure knowledge that we have already learned. If students do well on one of these tests, it is because they know the information they are tested on. Likewise, many aspects of IQ tests also measure the knowledge that we have built up. A commonly used measure of IQ is a vocabulary test. If you know the definition of say 'bicycle' or 'police', then you will likely get a high IQ score. However, if you don't know the definitions of these words or perhaps don't articulate them well, this will be reflected in a low IQ score. In this way, IQ tests are very different from working memory tests because they measure how much we know and how well we can articulate this knowledge. I was recently working in two schools: one was in an urban, developed area, while the other was in a deprived neighborhood. As part of the project, I tested the students' IQ using a vocabulary test. One of the vocabulary words – *police* – drew very different responses. Students from the urban school provided definitions relating to safety or uniforms, which corresponded to the examples in the manual. However, those from the deprived area responded with statements like 'I don't like police' or 'They are bad because they took my dad away'. Needless to say, these responses were not awarded any points according to the test manual's definitions. This example illustrates how performance on IQ tests is strongly driven by a child's background.

One important question is how common working memory problems are in the classroom. In a large-scale screening study of over 3000 typically developing students, I found that 1 in 10 students were struggling with working memory difficulties. The impact of working memory problems on learning is striking. The majority of these students is at high risk of underachieving and performs below age-expected levels in all areas of learning, including language and maths. Poor working memory leads to poor grades, regardless of the student's IQ. Studies such as these demonstrate that students with

working memory difficulties are relatively common in the classroom and have an extremely high risk of making poor academic progress. Without early intervention, working memory deficits cannot be made up over time and will continue to compromise a student's likelihood of academic success. This has a cumulative effect on learning: if working memory is not in place, the student is not able to maximise opportunities of additional support.

The exciting news about working memory is that each student has a similar opportunity for success. In this chapter, we have seen how as opposed to IQ, working memory is not linked to the parents' level of education, socio-economic status, or financial background. This means all children regardless of background or environmental influence can have the same opportunities to fulfil potential if working memory is assessed and problems addressed where necessary. We have also discussed how the traditional reliance on IQ as a benchmark for academic success is misguided. Instead, schools should focus on assessing working memory as it is the best predictor of reading, spelling, and maths skills six years later. Problems with working memory can be easily addressed in schools – an advantage over IQ, which is more difficult for teachers to influence. Targeted support at any age leads to a reduction in the number of those failing in schools, and helps address the problem of under-achievement.

Summary

1. Working memory develops throughout childhood with the most dramatic growth occurring in the first 10 years of our life.
2. There are three limits to how we use our working memory: space, time, and effort.
3. Working memory is a better predictor of academic success than IQ because it measures a student's potential to learn, not what they have already learned.

Further reading

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