How can teachers use knowledge acquisition strategies in year one science to improve spaced retrieval?

Teacher Education Advancement Network Journal

Issue 15(1) pages 18-36

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Abstract
Despite growing interest in spaced retrieval methods, a research gap has been discovered, with insufficient data to support best practises in year-one science. After analysing five systematic action cycles, four interrelated themes emerged: dual coding, cognitive load, peer communication, and feedback-driven metacognition. While literature emphasises the need to take a child's cognitive load into account, the themes of peer communication and dual coding provoked debate among participants. Despite this conflict, an agreement was reached on how limited reading abilities affect retrieval practise. While this small-scale study cannot draw definitive conclusions, I discovered that by optimising cognitive load, teachers can ensure that a task is desirably difficult using dual coding, discussion, and feedback-driven metacognition, all of which contributed to the success of knowledge acquisition methodologies. According to my research, ensuring a retrieval task is challenging, increases children's development of retention of scientific knowledge. However, minimising literacy constraints is critical to avoid thinking being exhausted by writing or reading, rather than recalling and applying. Consequently, the relevance of the study for education and society is illustrated by the findings, which emphasise the necessity to reduce extraneous load (reading and writing) during retrieval tasks and propose potential solutions to this issue.

Keywords
Cognitive science; spaced retrieval; dual-coding; knowledge acquisition; working-memory; cognitive load

Introduction

There has recently been a surge in interest in spaced retrieval practises (Ofsted, 2021), and several studies have proven the efficacy of these techniques in scientific teaching using resources such as knowledge organisers. Ofsted (2021) proposes if students practise retrieving information over prolonged periods of time, they are more likely to retain substantive (science concepts) and disciplinary (scientific inquiry) knowledge. While existing studies have recognised the effectiveness of these approaches in several KS2 and KS3 classes (Perry, et al., 2021), the Education Endowment Foundation (EEF) analysis has limited research to suggest the effectiveness in a year-one classroom. For instance, they found 'only two small studies for KS1 and no studies for children any younger' (Perry, *et al*, 2021, p35). These findings show that there is still much to learn about how young children retain science concepts in the absence of adult assistance, as well as children's poor reading abilities.

Literature review

Over the last century, the retrieval practice phenomenon was called 'the testing effect' (Roediger, Karpicke, 2006) but is currently recognised by several different terms. To avoid inconsistency, the term 'spaced retrieval' will be used in this study to refer to spaced practices that actively support children in recovering prior knowledge, from their long-term memory into their working memory to foster retention. Thus, the goal of this research is to develop knowledge acquisition strategies that will help students in extracting, structuring, and organising to improve retrieval of their 'sticky knowledge.'

Citation
Fox, P.M. (2024) 'How can teachers use knowledge acquisition strategies in year one science to improve spaced retrieval?', *TEAN journal*, 15(1), pp. 18-36.

How can teachers use knowledge acquisition strategies in year one science to improve spaced retrieval? Can retrieval strategies help improve long-term retention? This question remains to be seen. Several recent studies have short-term designs, making it difficult to apply their findings in applied classroom contexts. Churches' study found a strong positive effect on retrieval practice, though there is a lack of evidence from other studies that support this. For instance, the EEF questions how important earlier studies were based on reliability, ecological plausibility, transferability, and critical analyses. Contrary to expectations, in 2021, they suggested that only 18 of the 46 studies on interval recovery would be noteworthy. 3 out of 18 of these were classified as having “strong validity of the evidence” (Perry, et al., 2021, p164). Furthermore, the results from the impact of these studies are suggested to be inconsistent, with indefinite conclusions as to whether spaced retrieval practices positively affect learning. Additionally, most research on retrieval practise is based on content-aligned assessments in year six or secondary education, with little concern for the rest of the curriculum. One potential question that needs to be addressed, is whether consistent results will be apparent after more extensive studies within a wider range of subjects. Furthermore, the studies in KS1 are inadequate with only two ‘high-quality’ studies for this age phase (Perry, et al., 2021), which were designed and delivered by researchers, disregarding the consequences of power imbalance on outcomes. Raising the question of whether teachers will achieve equivalent results in more realistic conditions.

While the EEF (Perry, et al., 2021) is concerned about the ecological validity of several studies, other sources show that spaced retrieval is considered influential (Fazio, Agarwal, 2020; Ofsted, 2021). From my perspective, due to limitations already mentioned, a precise conclusion would be difficult to reach due to the lack of sufficient evidence for all key stages and subjects. Arguably, highlighting an inconsistency about the effectiveness of retrieval activities. In relevance to this study, little research has been undertaken in KS1 for science content. Despite past research shortcomings, it is important to highlight that lack of evidence does not imply failure of an approach.

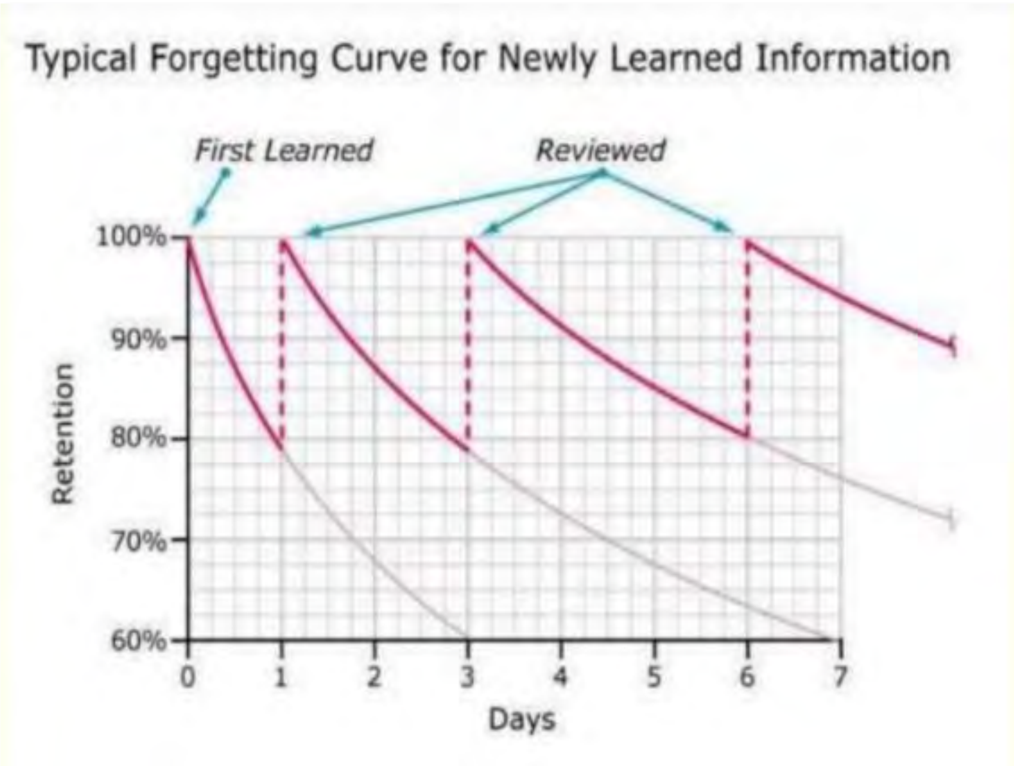


Figure 1. Ebbinghaus forgetting curve model (Ebbinghaus, 1964).

While several definitions of "working memory" have been presented (CESE, 2017; Perry, et al., 2021), this study will follow John Sweller's (1988) original notion, on the preservation and use of immediate conscious perceptual and linguistic processing. Further research on retrieval practises has shown several interconnected themes, one of which is the relationship between cognitive science, particularly cognitive load theory, and the duration of a retrieval activity (Weinstein, Sumeracki, Caviglioli, 2018; Kirschner, Hendrick, 2020). Sweller (2010) categorises cognitive load as intrinsic (new knowledge), extraneous (hinterland knowledge), and germane (storing and adapting schemata in long-term memory). Cognitive load examines the relationship between the suggested memory capacity, which Clark, Kirschner, and Sweller (2012) refer to as limited 'mental space,' and plausible retention of knowledge (CESE, 2017). Correspondingly, the Ebbinghaus forgetting Curve Model (see Figure 1) designed by Hermann Ebbinghaus (1964) depicts how the rate of memory decays over time. However, Ebbinghaus also points out that forgetting leads to a higher rate of retention in the long term. Consistent with Dehaene (2020) who argues that optimal intervals should be 20% of the intended memory duration in order to optimise future retrieval and memory strength. Along with Agarwal and Bain's (2019) assertion that spaced retrieval increases learning retention by avoiding "cramming" (learning a lot in one day). Therefore, by systematically revisiting prior concepts over prolonged periods of time, students' knowledge is given chance to 'forget,' supporting an increase in retention with each return.

According to Sweller's (2010) approach, teachers should simplify intrinsic, maximise germane, and minimise extraneous load while not surpassing working memory capacity. Effective cognitive load management will thus include consideration of various pupil characteristics and is likely to present a bigger challenge when teaching a large mixed-ability class. Establishing a relevance for teachers to consider a balance between ensuring a retrieval task is 'desirably difficult' (Dehaene, 2020). Finding this 'sweet spot' will aid with retrieval activities being challenging but successful. With relevance to KS1, this may look slightly different to KS2 due to having to consider children's reading capabilities and limited concentration span. Hence, it is suggested that young children lack self-regulative approaches to learning (Flavell, Friedrichs, Hoyt, 1970; Perlmutter, Myers, 1979) therefore teachers may need to scaffold using probing questions to elicit effective recall.

Theories tying gestures to other cognitive science strategies, such as dual coding (using a combination of words and visuals) and the Loci method (visualising facts in a logical sequence), show that multimodal learning optimises cognitive load through encoding. According to Baddeley and Hitch (1974), humans process visuals and information in two ways: 'synchronously' (seeing all at once) or 'sequentially' (looping audio information back to oneself). However, teachers in a recent study voiced concerns that dual coding had grown dependant on 'attractive icons' rather than serving educational purposes (Acha, et al., 2009; Homer, et al., 2010). While different studies have discovered positive, neutral, and negative effects (Perry, et al., 2021), investigating alternative pictorial representations and their applications may help enhance the reliability of dual coding. Therefore, by ensuring that visuals are useful rather than appealing, teachers can enhance the likelihood that they will contribute to learning rather than burden children's memory.

Since 1988, science has been included in the national curriculum. However, according to Ofsted (2019), primary schools are teaching less than 1.5 hours of science each week due to government focusing on literacy and numeracy tests instead. These documents may suggest that a balance needs to be struck between the two approaches to teaching science - mastery-based and memory-based. However, the spacing between science lessons is greater, necessitating the development of efficient recall mechanisms. The suggestion reviewed here seems to propose a pertinent role for spaced retrieval practices to build on schemas (Piaget, 1928), to work scientifically with increasing ability and advance children's disciplinary thinking.

A broad range of literature on working memory capacity seems to correlate strongly with performance in science (Yuan, *et al*, 2006; Ofsted, 2021). Science literature has found many difficulties students may experience when recalling scientific knowledge. These difficulties stem from science being cognitively demanding (Bloom, et al., 1956), the intrinsic and abstract nature of scientific knowledge (Piaget, Inhelder, 1972) and the complexity of the language (Sullenger, 1993); as well as my earlier statement referencing the limited capacity of children's working memory and thus scientific thought. According to Cognitive Acceleration through Science Education (CASE), it is 'doubtful that some children are cognitively ready to deal with the scientific curriculum's demands' (Oliver, Venville, 2019, p9). Subsequently, CASE recommend that legislators create educational interventions with long-term effects on learning, highlighting the relevance of retrieval strategies in science to improve knowledge retention.

Mercer's repeated literature on dialectic education (2004; 2009) to promote children's metacognitive awareness suggests that discussions can help children understand scientific concepts and grow as self-aware, fluent, and reflective speakers. Equally, Moore (2020) contends that encouraging children to participate in group discussions can help them improve their reading and writing abilities while also developing higher order thinking skills. Alternatively, excessive peer-communication may have a detrimental effect on retrieval practise when children rely on their partners to recall knowledge; implying that when children rely on their peers, their own memory of scientific concepts is not tested. Similarly, Ofsted (2020) emphasises the need of retrieval activities being challenging for each learner to maximise retention. Therefore, over-reliance on their peers' recollection may result in an inaccurate depiction of their individual secure scientific understandings.

Research in this field is alleged to be based on unreliable and untransferable evidence. This study intends to fill a gap in existing understanding of a rapidly developing phenomenon. There are concerns regarding the lack of evidence of impact in the classroom and how this varies by subject, context, and pupil characteristics. Having only limited consonance as to whether spaced retrieval practice impacts children's learning positively, specifically in KS1. What is needed to enhance these findings is a systematic review of classroom retrieval practices appraised with more ecological validity; to gauge a comprehensive and compelling picture of a rapidly rising phenomenon.

Methodology and ethics

This study analysed the effectiveness of retrieval practises in a primary classroom using analytical, qualitative, and reflective methodologies. Despite widespread dispute that young children lack research competence (Lundy, 2007; Coyne, 2010; Arnott, et al., 2020), I have guided, analysed, and disseminated this study with eight year-one children by adhering to my philosophical approach of valuing students as active participants and experts in their own lives. Similarly, Lundy (2007) and UNCRC (1989) argue children's freedom to express their views is not contingent on their ability to communicate mature views, but on their capacity to develop views. For the same reason, the child-researchers were carefully chosen not for their "mature views," but for their communicative confidence and conscious competence. Given Vygotsky's (1962) idea of intersubjectivity, the language used to illustrate and describe the study's endeavour was geared toward children's sphere of understanding. To demonstrate their competency, my focus group were involved in the consent process. The children's verbal consent was conditional on their knowledge of the study's purpose, their involvement, and the possible ramifications.

Figure 2.- Research agreement about participatory rules signed by participants.

Using a ‘biteable’ video to share my study’s aims and ethics protocol enabled me to elicit informed consent from my child-researchers following deep discussions about participation rights. Prior to each action cycle, my participants indicated their agreement with the participation rules using a pre-designed research agreement (See Figure 2.). The validity and reliability of my group sample was increased because of the interactive discourse this activity ignited. However, due to the uncertainty surrounding children providing consent or assent, I elected to get parental proxy consent following BERA (2018) and the school's regulations.

I sought to be eclectic in my data collection procedures with the use of triangulation (Denzin, 1989; Patton, 1999) to avoid the 'thwarting biases' associated with researcher subjectivity (Peshkin, 1988, p17-21) resulting from a single perspective. Structured and semi-structured interviews, work scrutiny, participant observations, and documentary analysis were used to collect data.

Interviews were utilised to extract in-depth personal ideas that may have been hidden attributable to the rigidity of written replies through questionnaires. Maintaining ethical integrity and sensitivity while conducting 'in-field' research, I used open-ended questions to allow variants in responses. To avoid the need for prior knowledge in this field, questions were based on the participants' own experiences and viewpoints. However, if thematic patterns emerged, participants had the potential to influence future interview questions. This is consistent with Patti Lather's (1986) definition of reciprocity as 'give and take... a mutual negotiation of meaning and power' (p267; Barbour, Schostak, 2005). Allowing myself and my co-researchers to critically reflect during interviews to generate "dialectical theory" for further data analysis and interpretation (Lather, 1986, p267).

Using a combination of continuous and event-based sampling approaches, purposeful observations were used to observe children's behaviour during activities as well as best practises in other classrooms. While these techniques can provide an invaluable perspective, it does have the drawback of being insufficient. As a teacher-researcher, I either watched attentively but neglected to record, or I took extensive notes but missed critical encounters. A practical solution taken to mitigate this issue was to employ coding by abbreviating words. However, when observing, I had to consider the Hawthorne effect, which suggests that being observed can affect individuals' natural behaviour (positively or negatively). Consequently, some observations may be unreliable, emphasising the significance of triangulation in strengthening validity.

Analysing children's work using photographs, was utilised to decide the effectiveness of an approach and the overall quality of instruction. However, because it is reliant on visual interpretations, work scrutiny alone provides only limited evidence. Therefore, through triangulation I provided photographs of work during interviews to address this issue. Conversely, it was important for me to make sure that I was not using work scrutiny to assess students' learning, but to examine the influence of my practise on their learning.

Findings and discussion

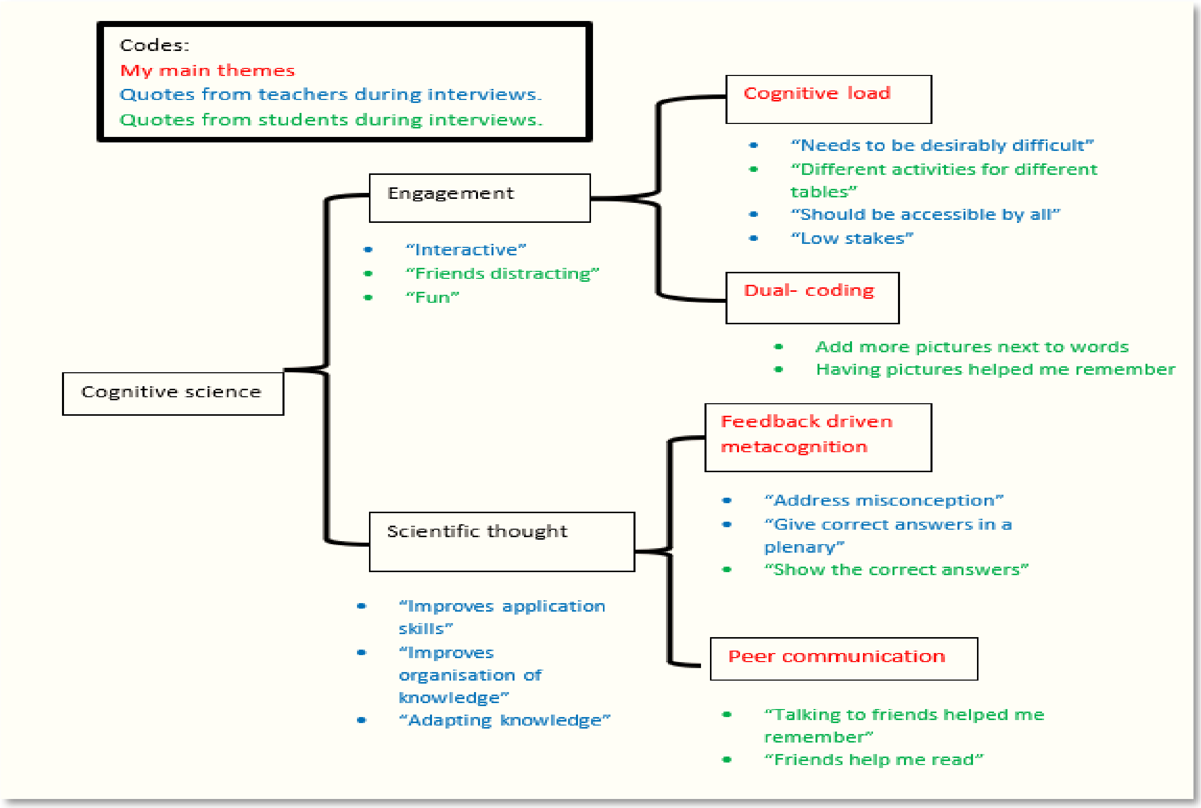


Figure 3. Thematic coding of eleven interviews revealed several potential themes.

Although a short-term study without quantitative control group comparisons makes assessing retrieval practices difficult; thematic coding of participant interviews revealed themes that could have a significant impact on knowledge acquisition strategies, as depicted in the construct mapping diagram (see Figure 3). It was noted during a staff meeting that engagement and scientific inquiry may influence cognitive science (retrieval practice). Following a triangulation of observations, interviews, and document analysis, these preliminary thoughts resulted in four primary themes that may affect (positively or negatively) these factors during a knowledge acquisition strategy.

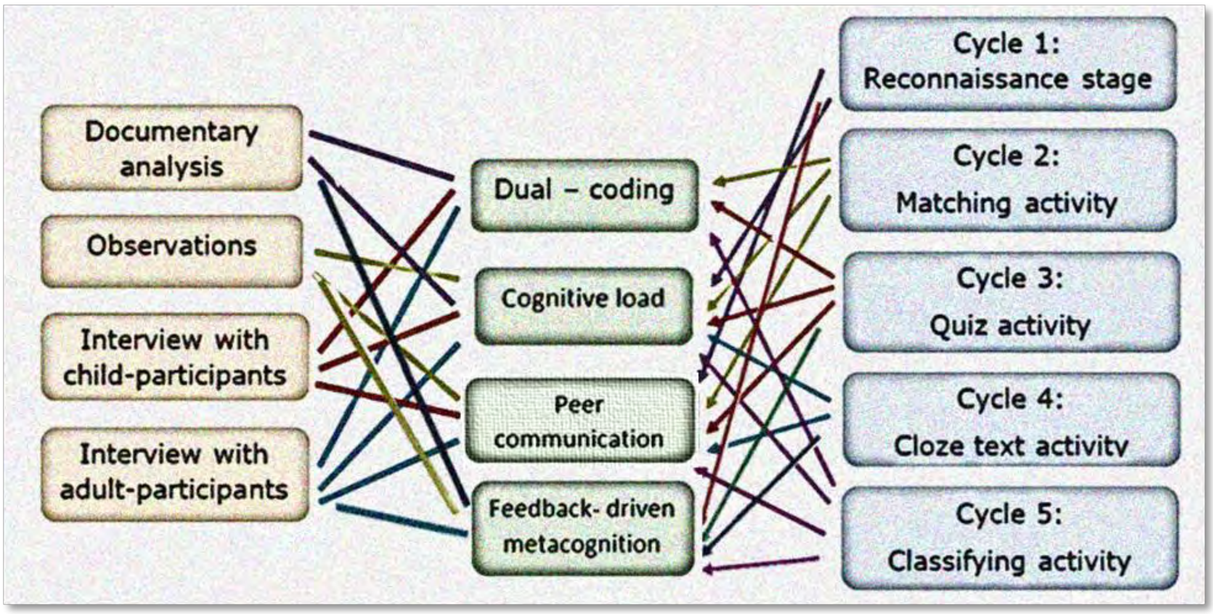


Figure 4. Systematic overview of the triangulation of my chosen methods, cycles, and themes.

The knowledge acquisition methods implemented are depicted in the cycles above (See Figure 4.), from these methods four themes emerged. Dual coding, peer communication, cognitive load, and feedback-driven metacognition are all required components of efficient retrieval practise, according to this studies analysis and interpretation. Furthermore, because of the above-mentioned literature, the findings credibility is strengthened by discovering comparable ideas to improve students' recollection and understanding of scientific concepts. While the value of dialogue was recognised, especially in situations where literacy is restricted, the value of students' peers in helping them retrieve knowledge was underestimated. Prior to gathering data, peer communication's risks ranked higher than its benefits, which this study contradicts.

Dual coding

From observational notes, during a staff meeting, teachers stressed that the usage of icons might be limited since "we do not want children to rely on a picture to recall information.” The teachers argued that removing the image will help students recall important concepts rather than focusing on hinterland knowledge. They posed the question of whether an image might hinder children's scientific knowledge when building on their schemas and applying concepts to new material. Questioning that if children rely on a single image to retain specific concepts, will their remembrance be just as strong if the image is withdrawn or replaced. Similarly, literature analysis first raised some concerns about the effectiveness of pictures on children's cognitive load when it came to applying dual coding in retrieval activities. While Mayer and Anderson (1991) demonstrate that utilising multimodal approaches to encode information increases learning, Acha (2009) and Homer (2010) demonstrate that when dual coding is used, research outcomes are inconsistent due to an emphasis on 'attractive icons' rather than educational purposes. Polemically, a triangulation of observations and interviews shows that visuals are needed to enhance students' low literacy abilities. See below the answers from my respondents when asked "what would help you with reading the matching cards?":

> *Interviewer: Some of you said last week that you had trouble "segmenting and reading the words on the cards." To help Kitty suggested I should add more pictures next to the words. Has this helped you read the cards this week?*
> *All interviewees: Yes*

Interviewer: How did it help?
Patty: because I guessed what the word said from the picture.
Andy: The pictures gave me a clue.

One surprising response was *"put more pictures near the words,"* but when questioned why, it was purely due to attraction. However, after testing this hypothesis in cycles three and five, sharing opinions during group interviews revealed that, while this suggestion was offered inadvertently, it had a greater influence on access than originally considered. The replies from an interview indicate that the students valued the additional images to assist them in deciphering the word cards. Surprisingly, dual coding was shown to be beneficial from a child's perspective. Controversially, authors and educators have expressed concern that dual coding may unduly drain memory capacity through irrelevant and distracting visuals. However, it is possible to hypothesise that dual coding may be a positive element for knowledge acquisition strategies by assisting children in extracting scientific knowledge. Consequently, by dismissing previously held beliefs that children are incapable of providing reliable information, children were able to offer the 'missing perspective'.

This discrepancy, however, might be attributed to children valuing images as a literacy aid to obtain information, rather than utilising visuals to recollect scientific concepts. Although the replies of participants first led to inquiries on how dual coding aids memory recall, it finally led to the conclusion that using multimodal strategies can improve accessibility. Consequently, arguing that dual coding is beneficial in KS1 for retrieval practise to increase the accessibility of an activity. Despite these optimistic findings, there are still questions regarding whether dual coding in the form of using an image to recall is still unclear, thus further study is needed to prove the feasibility of these data findings. However, dual coding is a realistic technique for overcoming the barrier indicated above, by reducing children's reading and writing demands.

Cognitive load

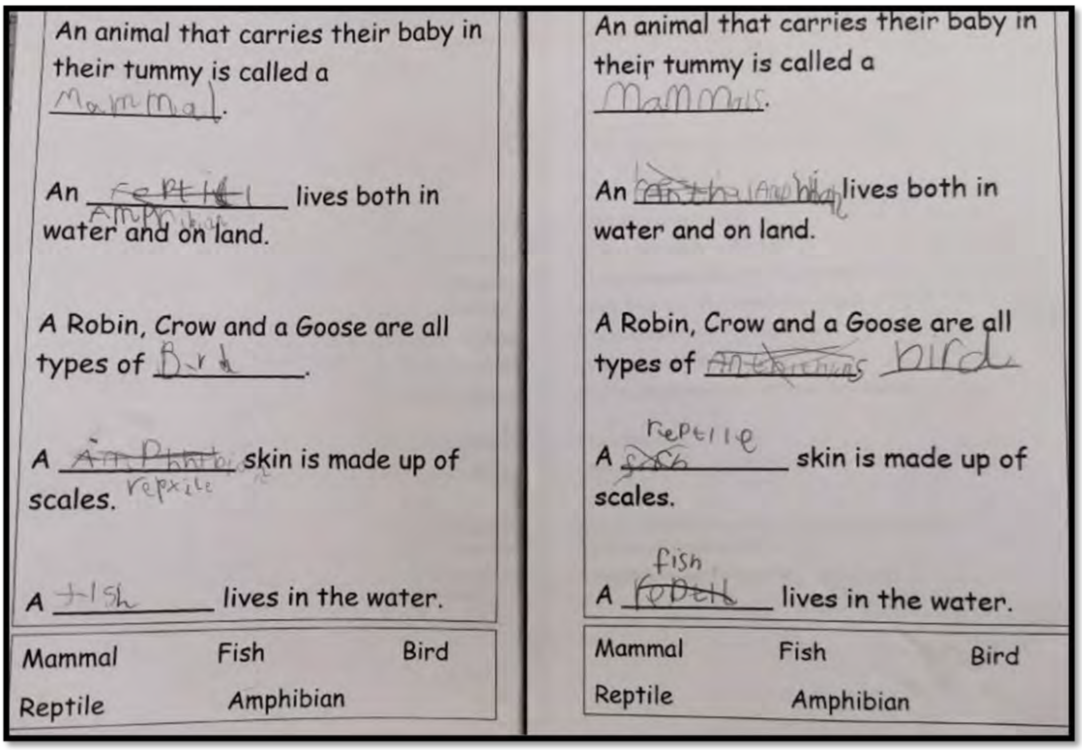
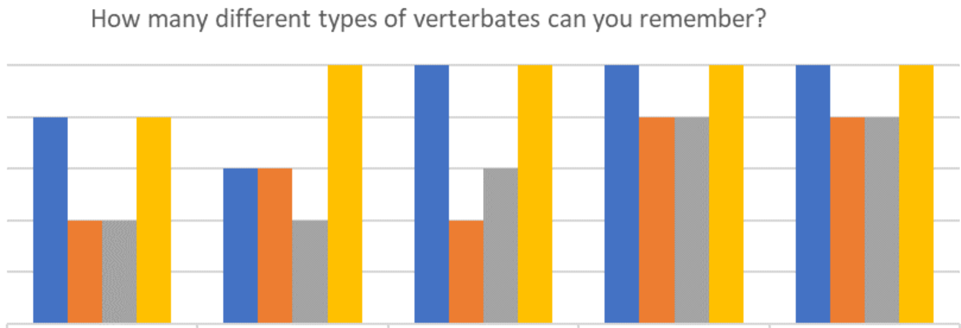


Figure 5. Cloze text activity.

Naturally, this leads to the importance of analysing the impact of an activity on a student's cognitive load. Despite the difficulty in measuring a child's cognitive load due to its abstract nature, a triangulation of observations and interviews revealed the need to consider that an activity is desirably difficult and low staked. During a staff meeting, best practises were shared, which suggested that contrary to popular beliefs, *"Information should not come quickly or feel fluent to demonstrate effectiveness in knowledge retention. Instead, when knowledge comes quickly to memory and feels natural, it is easy to forget."*

Recommending that the more challenging the retrieval exercise, the more effective it is for long-term learning. However, reflections on action cycle four with child participants revealed that, while some initially stated that the activity (see Figure 5) was difficult because it required them to "think hard," it is debatable whether the activity was cognitively challenging or difficult due to limited literacy skills. Although it was intended to use ability grouping to reduce the barrier associated with insufficient reading skills, this initially was unsuccessful. Prior to cycle four, a synthesis of responses indicated that when children partnered with their friends, it was occasionally the case that both children lacked reading aptitude and thus "struggled to read the sentences." After experimenting with various ability groups, a solution was developed, which will be addressed more in the following theme. However, these findings demonstrate that making retrieval tasks desirably difficult aids children in acquiring and recalling scientific knowledge. The optimal difficulty level of an activity was determined by ensuring that retrieval activities were dependent on the children's prior knowledge. However, as reiterated above, minimising literacy constraints was critical to avoid thinking being exhausted by writing or reading rather than recalling and applying.

When asking the science coordinator *"what would you propose teachers include in a retrieval activity to minimise memory overload?"* Assuring that teachers are clear about the fundamental knowledge they want children to recover, and that the knowledge is accessible to everyone was highlighted as critical. Validating this suggestion, during student interviews it was proposed that, *"every table could have a mixture"* of activities based on the level of application of scientific concepts. However, after interviewing teachers, they raised concerns about the difficulties of differentiating each activity because of the time restrictions they currently face. Therefore, policymakers should investigate ways to differentiate knowledge acquisition processes to make them accessible to everybody while staying challenging. Similarly, looking into various solutions for how teachers might manage this increased workload while maintaining their already-hectic schedules. External programmes such as Phlickers and Kahoot may be utilised to address this issue by ensuring that questions are available to all children while also alleviating teachers of the added burden of customising and hand-making each activity.



	Action cycle 1	Action cycle 2	Action cycle 3	Action cycle 4	Action cycle 5
Andy	4	3	5	5	5
Patty	2	3	2	4	4
Rosie	2	2	3	4	4
Callum	4	5	5	5	5

Figure 6. Recording of how many vertebrates (bird, fish, amphibian, reptile, mammal) four children could name over five action cycles.

Given the above-mentioned variance in memory capacity, this variation was observed and tracked through spacing of retrieval activities and children's retention of knowledge of the five different types of vertebrates. Shown in Figure 6., the four children's knowledge retention differs, however their individual retention appeared to grow in a linear fashion the more a concept was recalled. Thus, memory capacity appears to affect cognitive load, since the quantity of information that a child's working memory can retain may influence the difficulty of a retrieval task. Consistent with literature, this study found that individuals may have large variations in their working memory capacity. Though, my findings may also lend credence to the notion that regular exposure to structure and organisational knowledge enhances and accelerates memory performance. Patty's memory of vertebrates, on the other hand, fluctuates while the other children's memory develops linearly, her memory declines throughout action cycle three. This might be because, unlike previous cycles, there was a half-term break between cycles two and three. Patty's memory may have decreased due to her inability to transfer long-term memories to her working-memory because of the prolonged time interval between reciting scientific concepts. In agreement with Robert (1998) and Ebbinghaus (1964), I would infer that spacing retrieval intervals can help students retain knowledge since it allows students' to 'forget,' resulting in an increase in retention with each return.

However, some of the difficulties raised by this study are specific to my methods, notably the consequences of group interviews with children. Although I indicated above children initially stated an activity was difficult, I believe children's anxieties with judgement suppressed or changed their responses. As depicted below, it might be claimed that Alice assumed her position in the research 'hierarchy' and that her worry over delivering what was expected led in her adjusting her reaction and behaviour to make it like Kitty's.

> *Alice: It was a bit difficult because some questions I got right and some I didn't.*
> *Kitty: It was good because it was easy and challenging and it helped me looking at the words at the bottom.*
> *Alice: I have changed my mind, I kind of liked it because it was a bit hard, and it was kind of good.*

Considering my ethical responsibilities, both of Alice's replies were analysed to inform my results and methodology. However, the validity of my findings may be questioned, as children's responses may have been influenced by their peers and their fear of answering incorrectly. A combination of individual and group interviewers was used to address this dilemma, yet individual interviews had their own drawbacks. One disadvantage was that many participants declined to participate in individual interviews, reducing the number of replies available for analysis.

Peer communication

The largest theme that appeared from my research was the positive affect of peer communication. Communication between peers aided the reduction of potential literacy barriers and enhanced concept recollection, according to a triangulation of observations, interviews, and document analysis. During an observation, it was noted that the students appeared to make effective use of their partners' expertise, as I overheard pairs debate about several vertebrates and their distinct characteristics. The dialogue below illustrates a debate between two students of varying abilities discussing classifying vertebrates.

> *Callum: I think the Bearded dragon is a reptile because it has scales.*
> *Rosie: I think the Newt is a reptile because it looks like a Bearded dragon.*
> *Callum: But the Newt's skin is wet like the frog and the Bearded dragon's is dry.*
> *Rosie: The frog's skin is wet from the water.*
> *Callum: Amphibians live in water and land; I think the Newt is an amphibian.*

Rosie: And Reptiles just live on land, I think the Newt is an amphibian too.

By encouraging discourse, the children were able to organically broaden the thinking of one another. This observational data implies that discussion partners may be an effective knowledge acquisition approach for supporting children in recalling the intrinsic and abstract nature of scientific content and its complex scientific language. Offering opportunities for students to build on one another's schemas and scientific reasoning.

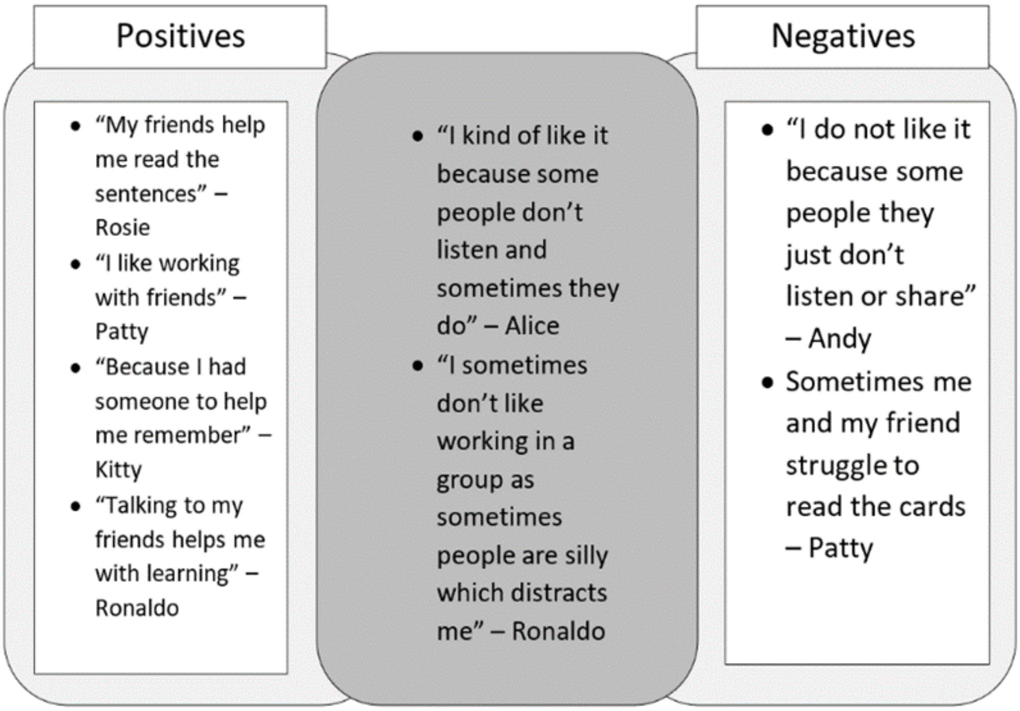


Figure 7. An accumulation of responses when asking children "do you like working with a friend?"

Emphasising this suggested effectiveness, Figure 7 depicts an accumulation of responses during interviews where children expressed their opinions about group work. Prior to gathering data, I ranked peer communication's risks higher than its benefits, which this study contradicts. While the positives out-weigh the negatives, it is questioned that a lack of modelling, engagement, or partner selection can have a detrimental effect on learning. Jo Moore, in her latest Primary science article (2020), adds to this data by stating that research conducted by Mercer (2009) revealed that children rarely understand how to interact in groups. She did, however, find that children are motivated and engaged when their ideas are solicited and acknowledged during discourse. Therefore, valuing peers' responses through peer-to-peer communication may increase their engagement and motivation to retrieve scientific concepts. Additionally, carefully pairing students' abilities and behaviours may alleviate any issues detected during interviews by matching them with someone who can read fluently and avoiding "silly" combinations. However, considering Mercer's advice, one could argue that by pairing the students, I am reducing their motivation and engagement due to the anxiety associated with working with new individuals. Further study is thus required to determine how various partner groups contribute to or detract from retrieval practise, and whether this is contingent upon a knowledge acquisition technique.

Additionally, while some theorists argue that young children are incapable of self-regulating their learning, teachers could argue that through group work, children support one another by scaffolding and probing retrieval of specific concepts by building on one another's schemas. However, there is a risk that students will inadvertently evoke misconceptions or hinterland knowledge instead of core knowledge. In turn, making it the teacher's responsibility to make core knowledge explicit whilst also modelling expectations for effective dialogue. For instance, based on an interview with the science coordinator, teachers may plan "cocktail parties" during which key scientific terms are shared around the classroom. Following that, the child's task is to team up and quiz one another on their terms and meanings. They then swap cards and part ways, with the intention of repeating the exercise with other partners. Alternatively, "meet the expert" exercises could be used in which a tick sheet holding essential concepts, vocabulary, or phrases is provided to a group of three children. The roles of expert, interviewer, and observer are shared, and the interviewer asks the expert to recollect key ideas about a science topic. Therefore, even if the teacher cannot offer personalised feedback to each group, these suggested exercises may help them recall core knowledge while reducing misunderstandings.

Feedback-driven metacognition

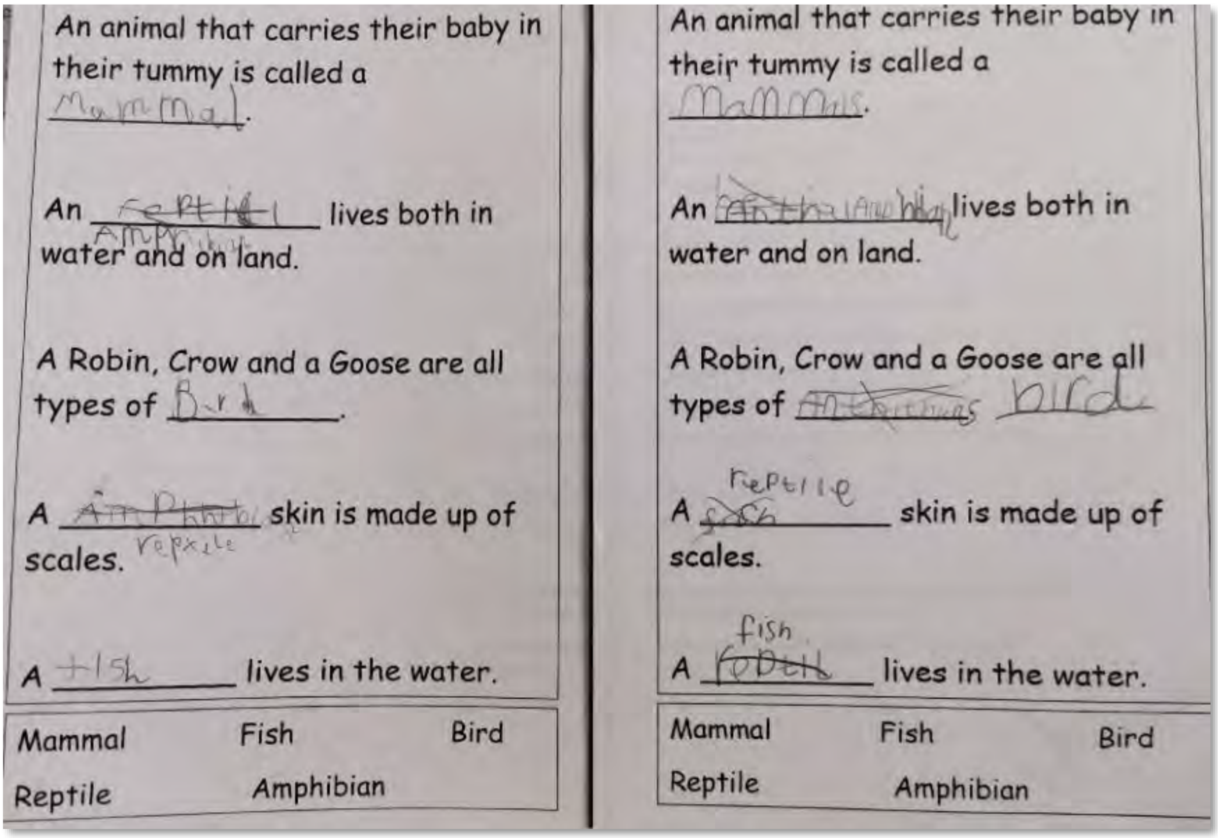


Figure 8. Cloze text knowledge acquisition activity prior to the main activity.

Linking pleasantly to the final theme; how feedback-driven metacognition might improve retrieval practise when utilised after a knowledge acquisition strategy. During a teacher interview, the notion of giving feedback after retrieval was suggested. A year one teacher claimed feedback will support pupils in *"remembering what they have learnt and clear up any misunderstandings."* Similarly, a year 4 teacher asserted that *"feedback allows students to recognise their misconceptions",* in turn increasing their *"awareness and comprehension of their cognitive processes."* Children agreed on the need of feedback during action cycle three, when they emphasised the necessity of a quiz that revealed the correct answer in response to Ronaldo's question, *"what is the point of doing a quiz if it* *does not give the correct answer?"* The success of implementing feedback after a retrieval activity is apparent in Figure 8. Following sharing of feedback, children edited their answers to ensure they had the correct vertebrate explanations during the main science class. Children were able to check if an answer was correct from subject-specific feedback after a targeted knowledge activity. Following this retrieval task, the children utilised the correctly filled cloze text sentences to support their comprehension during the main activity.

As previously mentioned, teachers believe that supporting students in recognising their misunderstandings might help them become more conscious of their cognitive processes. However, I believe that young children struggle with metacognitive thinking because they lack the ability to independently self-reflect and actively engage with feedback. Results from cycle four and five caused this hypothesis when children were able to offer examples of what they could recall in science related to the topic, but when asked what they needed help remembering, they struggled to independently identify gaps in their understanding. During cycles four and five, two five-minute brain dump (free recall) exercises were employed to support children with comparing their retention of knowledge over two consecutive weeks. (See Illustrations' 1. and 2.). However, even after presenting the school's knowledge organiser as a stimulus (see appendix 1), children were unable to utilise what they recalled independently to uncover gaps in their understanding. This finding is supported by research demonstrating that when children make predictions or judgments about their own learning capacity, they frequently overestimate it. According to literature, this might be due to an 'illusion of fluency' (Arwargul, Bain, 2019), in which children believe that because their retrieval was fluid or effortless, future learning and retention will also be effortless, resulting in an 'illusion of confidence' (Brown, Roediger, McDaniel, 2014). These findings appear to be connected to the age of the children and their ability to connect "A" to "B". In other words, the children may have struggled to understand that by recalling one idea but not another, could suggest a gap in their learning.

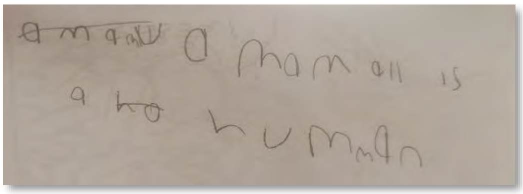


Illustration 1. Callum's first free recall during cycle 3.

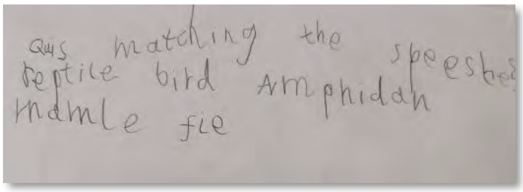


Illustration 2. Callum's second free recall during cycle 4.

These results may be due to the vagueness of the question and the description of the exercise's purpose, as well as the children's unfamiliarity with the "brain dump" activity. Based on the children's past understanding of the term "facts," it was concluded that they were competent to participate in the study. However, as seen in Illustration 2, Callum wrote "matching the speeshes" (species) and "quis," suggesting that he did not remember the fundamental science facts from the previous retrieval activities. These results may indicate that core knowledge was not explicit in past lessons, which impaired accurate memorisation. Therefore, there is much room for improvement in determining whether children this year can think reflectively in response to feedback. Future studies may examine whether children can think metacognitively by using structural cues and explicit presentation.

Conclusion:

Despite the study's modest sample size, the above-mentioned findings provide new light on this rapidly developing phenomenon; validating earlier research while providing a fresh perspective on practice and how it differentiates depending on subject, context, and pupil characteristics. Prior to this study, it was challenging to identify successful retrieval practises in year-one. Earlier research utilising cognitive science strategies in classroom settings was limited, with ambiguities and gaps on the applicability across subjects and age phases. While this small-scale study cannot draw definitive conclusions, it was discovered that by optimising cognitive load, teachers can ensure that a task is desirably difficult through dual coding, peer communication, and feedback-driven metacognition.

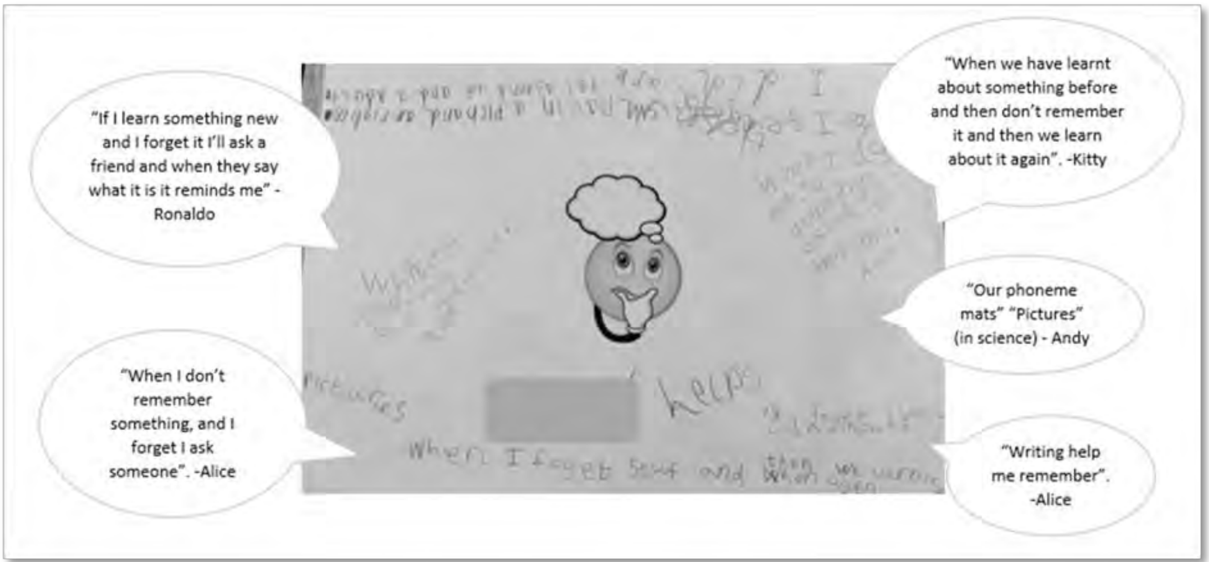


Figure 9. Children's replies to the question "what helps you remember things in science?".

Figure 9. also highlights children's conclusive thoughts at the end of research regarding what supports a retrieval activity. Taken together, these findings suggest that ensuring a retrieval task is challenging supports children's development of retention of scientific knowledge. However, minimising literacy constraints is critical to avoid thinking being exhausted by writing or reading rather than recalling and applying.

One of the study's most intriguing findings is that, while these themes were highlighted in my action cycles, various participants offered different interpretations for these aspects. The implementation of dual coding and feedback-driven cognition sparked debate over efficacy among teachers and children. Both teachers and children were offering different perspectives of effectiveness based on their experiences, time, and success. Despite this conflict, an agreement was reached on how limited reading abilities affect retrieval practise. Particularly when ensuring a retrieval task is challenging to increase retention of scientific knowledge. In agreement, minimising literacy constraints is critical to avoid thinking being exhausted by writing or reading, rather than recalling and applying.

The cycles above provide various strategies, but there is still more to be uncovered in a larger-scale study. Since peer communication was an unexpected trend in this study, further research could focus on how to model effective metacognitive strategies using discussion partners to aid retrieval practises. Contributing to filling this gap Scott has researched for two consecutive years that discussion is crucial in science (Mercer, Scott, 2007; Scott, 2008). Although students are often uninformed of the expectations of discussions (Moore, 2020) particularly when it comes to obtaining knowledge from their partner. Additionally, this study raises new questions concerning the nature of extrinsic advantages from retrieval practise during feedback-driven metacognition, and how success shows itself differently at different key stages. However, despite the limitations of my investigations, it is vital to emphasise that a lack of data does not always imply that my techniques were ineffective.

As a result of the newfound understanding, when teachers create knowledge acquisition strategies in the future, they may consider the children's learning needs and develop exercises that are demanding whilst considering their literacy capabilities. As educators, I think that teachers must be researchdriven to propel and guide student development using evidence-based practises. In conclusion I agree that the national curriculum should be structured in the same manner as high-achieving countries construct their science curricula to create "curriculum coherence" (Schmidt, Wang, McKnight, 2005). This entails prioritising students' acquisition of critical concepts, which corresponds to the hierarchical organisation of scientific disciplines. By promoting curricular consistency, retrieval techniques can attempt to strengthen memory of scientific knowledge that can be more effectively utilised in secondary education.

Given the scarcity of applied classroom research in this field, a blend of research-based and classroom-proven principles was critical for this study. Though, when interviews were conducted during lessons, the disruption to the classroom was caused by intrusion. Although consideration of participants wellbeing was considered, this study may have overlooked the welfare of those who were passively involved. Consequently a student may see missing learning as an enticement, especially if it is during a topic they dislike. In consideration, it could be argued that my ethical stance is unbalanced due to the absence of some considerations. An absence of consideration is possibly evident when Andy demonstrated playful dissent, by finding ways to 'act beyond the boundaries outlined' by our participatory rules (Gallagher, Gallagher, 2008, p507), while reaping the potential benefits of the interview over his peers. When asked if he wanted to continue with the interview, he often said "yes" but continued to dissent playfully. In the future, as a teacher-researcher, I will need to differentiate between dissent when children adjust the boundaries of their study participation or when they refuse to participate. From this transparency it causes an openness to researcher vulnerability, which is reinforced through an 'immature attitude of creative experimentation' (Gallagher, Gallagher, 2008, p512 513), which could be described when students navigate through the complex consent process. Given the multiple indicators of dissent discovered by Kitzinger and Fitch, such as delays in answering, pauses, fillers, or excuses, I need to address dissent concerns respectfully in the future.

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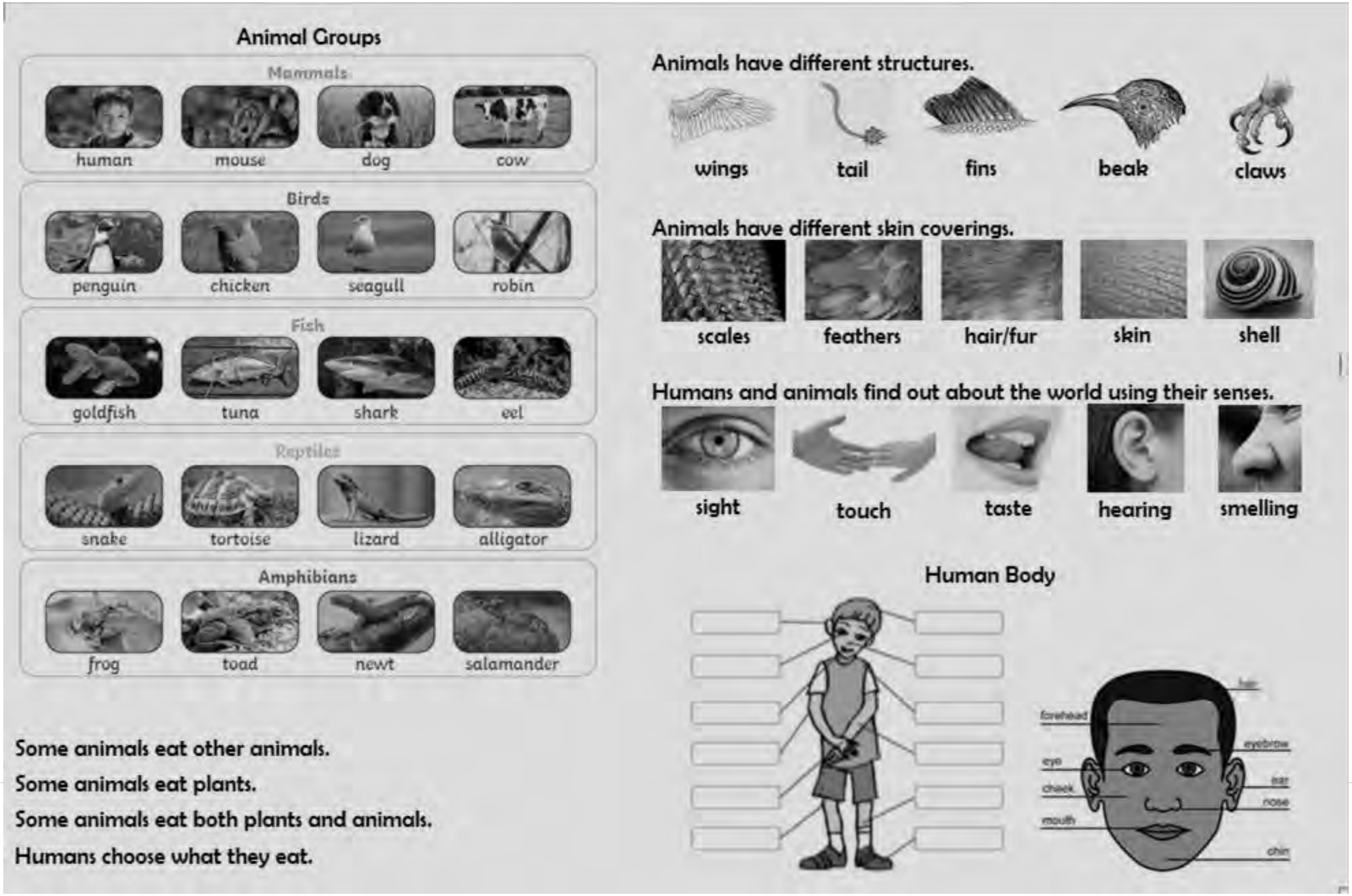
Appendix 1.


Animal Groups
Mammals
human
mouse
dog
cow
Birds
penguin
chicken
seagull
robin
Fish
goldfish
tuna
shark
eel
Reptiles
snake
tortoise
lizard
alligator
Amphibians
frog
toad
newt
salamander
Some animals eat other animals.
Some animals eat plants.
Some animals eat both plants and animals.
Humans choose what they eat.
Animals have different structures.
wings
tail
fins
beak
claws
Animals have different skin coverings.
scales
feathers
hair/fur
skin
shell
Humans and animals find out about the world using their senses.
sight
touch
taste
hearing
smelling
Human Body
hair
forehead
eyebrow
eye
cheek
ear
nose
mouth
chin