# An evaluation of retrieval-based learning through active organisational processing techniques

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# Introduction

In the evolutionary history of humanity, the cognitive revolution can be argued as the most significant turning point. Bigger brains granted us superior communication, learning, and an overall advantage in adapting to novel situations. In the great experiment of evolution this was an overwhelming success (Harari, 2011). From this evolutionary perspective it can be said that the brain evolved to educate and be educated. Therefore, it should hold a central position within educational interests (Blackmore & Fruth 2005). In this paper, I will discuss the design and implementation of a retrieval-based learning intervention based primarily on combined readings surrounding the field of educational neuroscience and cognitive psychology.

The school this research enquiry was conducted in is an 11- to 16-year-old voluntary-aided comprehensive school in Cardiff that serves a wide catchment area covering almost half the city. Even though they are ranked 19th out of twenty secondary schools in terms of budgeting per pupil, the latest Estyn report indicated that prospects for improvement are good, signifying many strengths, with no important areas of significant improvement. One of the main areas for recommendation in the report was to raise the standards in science at the key stage 4 level (Estyn, 2015). Wales' new curriculum emphasises the importance of teachers setting high expectations for learners (Donaldson, 2015). Expectations at key stage four and five are explicitly set by predicted exam scores. To meet these expectations pupils need effective revisionary tools that facilitate these ends. My inquiry addresses this by focusing on a top set year 10 triple science class in preparation for their GCSE examinations. Through experiences in teaching this class and conversations with my mentor it was clear that this triple class was highly capable and intelligent; however, they lacked confidence and almost uniformly suffered from anxiety when confronted with past paper questions. The high ability of these students often comes with high expectations. With the added stress of the high stakes testing environment, I felt it was important to confront this barrier to learning by developing an effective solution.

As a result, in this paper, I discuss the development and implementation of an intervention that focuses on building efficient schemas of semantic knowledge through implementing strong memory and retrieval learning techniques. I will summarise a small sample of relevant articles within cognitive psychology and applied educational neuroscience. From these articles, I will justify a retrieval-based learning activity that collectively encompasses what I have termed active organisational processing techniques. I will discuss the implementation of these activities in class and through anonymous feedback and questionnaires I will evaluate the effectiveness of my intervention. Furthermore, I will compare the results of pupil's performance on past paper questions to expected GCSE scores. The aim of my investigation is to develop effective teaching practices that will empower my pupils with the tools to retain and retrieve information across various contexts and over longer lasting time frames. This promotes the development of ambitious confident and capable learners who are building up a body of knowledge and have the skills to connect and apply that knowledge in different contexts (ACL2). This intervention also drives at the develop of healthy, confident pupils who face and overcome challenge (HCI9) and in this building their mental and emotional well-being through the development of their confidence and resilience (HCI2).

## Literature Review

A pupils' ability to perform on GCSE and A-level examinations directly impacts their future opportunities within further education. It is then critical that pupils are prepared adequately and given the best tools to succeed on these high stake's examinations. Although the exam content is largely known, the exam questions are not and therefore success on these exams is largely dependent on the pupil's ability to retrieve learned information and apply it under various contexts. The general fields of cognitive psychology and educational neuroscience apply a transdisciplinary approach to understanding learning and teaching that can be directly applied to the benefit of students in this regard. In this literature review I have compiled information on a range of revision strategies and categorised them by general effectiveness. I then further justify this evaluation and discuss the characteristics of effective revision using

information pulled from the fields of cognitive psychology and educational neuroscience. Although my area of research lends itself well to cognitivism, I still felt it was important to take a more holistic approach. Where appropriate I aimed to branch out and find opportunities to incorporate other general areas of educational philosophy. This research guides the development of my own research informed intervention and educational philosophy discussed later.

## The Growth Mindset

In my own opinion, the public overemphasises the relationship between high academic performance and innate cognitive advantages. While genetic advantage certainly exists; any sufficiently talented individual can be outperformed with sufficient training and resources. At the heart of this argument lies the importance of educators and pupils in embracing a growth mindset. The growth mindset, popularised by Carol S.Dweck is a positive psychology philosophy that embraces the malleability of intelligence (Dweck, 2006). This stands in opposition to a fixed mindset that views intelligence as innate and rigid Kapasi & Pei, 2021). Contextualised within educational research, evidence strongly supports the contention that pupils with growth mindsets are heavily correlated to positive outcomes regarding neuroplasticity, motivation, and academic performance across all areas of learning (Kapasi, 2021; Tirri, 2016; Kujala, 2010). Part of the growth mindset is characterised by seeing mistakes not as a lack of ability but rather as opportunities to learn and improve. As I will discuss later, creating an environment and opportunity to cultivate this growth mindset was an important factor when designing and delivering my intervention. This philosophy also ties in nicely with Wales' new curriculum. According to Donaldson, an influential figure in Wales new curriculum design: “Teaching should proceed on optimistic assumptions about its ability to make a difference as self-limiting beliefs about fixed potential are difficult to alter and can have a profoundly negative effect on learning” (Donaldson, 2015: p64). The growth mindset abolishes these negative effects of self-limiting beliefs and sets a learning environment that promotes mental resilience while maximising the potential for achievement and wellbeing.

## General Revision Strategies

The first stage in my review of the literature was to compile information on a range of revision strategies and categorise them by general effectiveness. Keeping in mind the scope of this project I summarised my findings in table 1 found below. The general effectiveness of revision strategies used within my intervention will be justified further in the following sections.

| Revision Technique | Effectiveness | Summary of Technique |
|---|---|---|
| Elaborative Interrogation | Moderate[1,2,8] | Pupils explore connections within knowledge schemas by asking why, how, and what happens under varying conditions. |
| Spaced/Distributed Practice | High[1,3,8] | Consistently scheduled practice over large periods of time. |
| Self-Explanation | Moderate[1,8] | Explaining the interrelation of information as well as verbalising the steps required in problem solving. |
| Summarization | Low[1,8] | Creating summaries of material. |
| Highlighting/underlining | Low[1,8] | Selecting text deemed important for future retrieval. |
| Keyword mnemonic | Low[1,8] | Chunking keywords with mental imagery. |
| Imagery for text (Dual Coding) | Low[1,8] | Forming images physical or mental of material in text. |
| Rereading | Low[1,8] | Revisiting text following initial reading. |
| Practice Testing/Quizzing (With Feedback) | High[1, 3,8] | Independent testing/re-testing. |
| Interleaved practice | Moderate[1,3,8] | Scheduled practice that combines differing sets of problems and or materials within a single session. |
| Peer supported Retrieval | Moderate[1,2,8] | Pupils work together to recall information and answer questions. |
| Using Knowledge Organisers | Low-Moderate[2,4,6] | Typically, a one-page document that summarises factual knowledge and technical terms alongside visual representations. |
| Generative effect | Moderate[4,5,7] | Where pupils create revision materials such are practice tests (reverse quizzes) or knowledge organisers. |

**Table 1:** Summary and rating of compiled revision techniques. (1) Dunlosky, J. Rawson, K. (2015). (2) Sherrington, T. Caviglioli, O. (2020). (3) Roediger, H. Butler, A. (2011). (4) Bjork, R. Dunlosky, J. Kornell, N. (2013). (5) Rosner, Z. Elman, J. Shimamura, A. (2013). (6) Sherrington, T. Caviglioli, O. (2021). (7) Voss, J. Galvan, A. Gonslaves, B. (2011). (8) Dunlosky, J. et al. (2013).

## Cognitivism, Neuroscience & Knowledge Schemas

In cognitive psychology schemas are widely defined as knowledge structures; a cognitive framework involved in the organisation of knowledge (Neisser, 1967). Educational neuroscience defines a schema more specifically as a framework of knowledge within a network of connected neurons. These neurons form memory traces that associate information allowing for increased efficiency in retrieval (Kesteren, 2013). In the following paragraphs I will briefly summarise the process of memory formation in relation to knowledge schemas. Throughout, I will comment on how this information can inform effective revision strategies. This will ultimately inform the justification for the design of my intervention.

Superficially, memories are stored through the strengthening of synaptic connections between neurons. This is established through a process called long term potentiation (Kesteren, 2013). Colloquially this neurobiological process is taught as “what fires, together, wires together” and represents the basis of memory traces. Under this hypothesis it may seem that repetition is key to effective revision, and while repetition is important, successful memory retention is more complex (Tulving & Kroll, 1995). When presented with information memories must first be encoded. The brain region responsible for this (the medial prefrontal cortex) has been shown to serve as a novelty detector (Tulving & Kroll, 1995; Matsumoto et. al., 2007). As such, familiar information is thought to be less well encoded than novel information (Kesteren, 2013). This is termed in the literature as novelty encoding theory. Novelty encoding theory is based on predictive coding theory (Friston, 2005). Predictive coding theory describes deviation or prediction error as the driving force in memory encoding. These predictions are made of pre-existing schemas, if deviations exist between predictions and the schema's output, then encoding occurs (Kesteren, 2013). Therefore, both novelty and feedback serve as an important criterion for effective revision as both aid in driving memory encoding. This understanding can also be used to help explain the general ineffectiveness of revision strategies such as re-reading and highlighting (Dunlosky et al, 2013) as these strategies do not foster novelty, deviation, or feedback. Another closely related theory, the supply-demand model of neuro-plasticity, describes the major driving force of brain adaptation

as a “mismatch between functional supply (ability) and demands (education) (Wenger & Lövdén, 2016). Under this theory if mismatch is too large then the system will not respond, and plasticity does not evolve. In contrast if the system is already capable of responding to the environmental stress and no mismatch occurs then plasticity is not required and therefore adaptation does not occur. In educational practice the supply demand model of plasticity implies the importance of effortful practice that challenges students based on their current ability.

Following memory encoding is memory consolidation. This occurs mostly outside of the classroom, over long ranges of time, concentrated primarily within sleep (Wilson & McNaughton, 1994). Although getting good sleep is a critical step towards effective revision it is for obvious reasons beyond the scope of this intervention. After consolidation comes memory retrieval, a variable that is often discussed in terms of retrieval strength (Sweller, 2016). This is a critical variable to improve and monitor as it is the main end point that is tested in exams. Spaced/distributed practice is a critical variable in fostering greater retrieval strength as it allows the extended time required for the re-encoding and re-consolidation of information (Dunlosky & Rawson, 2015; McKenzie & Eichenbaum, 2011).

### Expert Reversal & Guidance Fading effect

One way to approach setting goals for effective revision is to develop the characteristics of pupils' thought processes from novices to experts. An interesting caveat of this process is the expert reversal effect. Not only do differences in knowledge exist between novices and experts but also how their knowledge is organised (Chi, et.al, 1979). This deviation affects how these two groups approach novel problems. Novices, with underdeveloped schemas, approach problem solving by working backwards (i.e., What could the answer be?). Thereby requiring novices to remember individual elements. This requires a greater cognitive load. In contrast experts chunk elements and work forwards (i.e., What is the question asking?). This reduces cognitive load freeing up space for higher order thinking (Chi, et. al, 1982). To approach problems in this way requires a more developed schema. A requirement of this is exposure to re-

encoding and re-consolidation events (i.e. spaced practice). Re-consolidation events require extended periods of time and teaching time allocated to revision within the classroom is limited. As such effective revision should extend beyond the classroom. However, with a shorter timeline for my intervention, I looked to find a way to bridge the gap in the divide between novice and expert thinking. To do this, I aimed to leverage the guidance fading effect. The guidance fading effect is a pedagogical tool that can aid in facilitating the transition from novice to expert (Kennedy, 1995). This requires a gradual reduction in guidance or scaffolded support as pupils develop expertise within a focused area. An example of this fading procedure could include questioning that starts as closed ended questions with support and guidance to a gradual shift to open ended questions where pupils are entirely reliant on their knowledge schemas alone. This will be discussed further in the following section.

## Justification of intervention

The primary goal of my intervention was to address the general lack of confidence with past paper questions within a class of year 10 triple award students. To meet these ends I designed and implemented ‘active revision booklets. These active revision booklets are a focused retrieval-based learning resource that collectively represents a combination of characteristics I have described as ‘active organisational processing techniques. This designation is based on the interventions focus on active retrieval practice that is scaffolded and designed to facilitate the efficient organisation of schemas of semantic knowledge. These newly organised and focused schemas are then directly applied to exam questions.

Each active revision booklet is constructed to holistically cover one unit. Designing the booklets begins with collecting a set of past paper questions from the WJEC test bank. These questions are carefully selected to cover the range of topics presented within the given unit as well as any misconceptions or areas of improvement from previous mock exams results. Next, by leveraging school resources I collect all Bangor revision sheets available on the unit. These sheets serve as pre-made knowledge organisers for all the

specification content within each unit. By using the marking schemes from the selected past paper questions I proceed to verify that the information is presented clearly within the revision sheets and adapt and edit the sheets where required. Once this is complete, I then create a two-page active retrieval map (Lesson 1C, 2B, 3B). The active retrieval map is a targeted question sheet containing various styles of questioning. Once these three sections are completed (retrieval map, revision sheets & past paper questions) I combine them into a completed active revision booklet (Lesson 1C-D, 2B-C, 3B-C).

In this paragraph I will briefly explain how the active revision booklets were implemented within the classroom. During implementation students are given time to complete the map either by retrieving information from their existing schemas or by actively retrieving the information within the adapted revision sheets. Once completed students then move on to completing the past paper questions. At this point pupils are no longer allowed to reference the revision guides. The last stage of the lesson involves feedback on the past paper question answers. These are corrected and graded by the students using designated green pens (Lesson 2E). The active revision guides set up the lesson to be primarily student driven. As the teacher in the room, my primary goal is to foster a positive learning environment by promoting the growth mindset philosophy to students as they make progress.

The design of the active revision booklets has been informed and justified the information presented within the literature review. Seeing as the active retrieval map questions are reverse engineered from both the past paper answer keys and the revision guides, all the information encoded from completing the retrieval map can be applied to the past paper questions. This is done intentionally to leverage the guidance fading effect discussed earlier (Kennedy, 1995). This design is targeted at building pupils' knowledge schemas of the focused material in the first part of the lesson. This then creates a reduced cognitive load when confronted by the past paper questions allowing for a greater amount of cognitive load allocated to higher order thinking. In this case specifically focusing on what the questions are asking and how to use the

information to answer them appropriately rather than worrying about whether they have all the information required. The active retrieval map has also been designed to incorporate a variety of questioning styles that reflect effective revision techniques compiled from table 1. This was done to maximise memory encoding as a variety of questioning styles produces novelty, an important driving factor in predictive coding theory (Kesteren, 2013; Tulving & Kroll, 1995; Matsumoto et. al., 2007). Additionally, the questions span a wide area of knowledge and have been set at a variety of difficulties to help ensure that filling out the revision maps is an active and effortful process helping drive the neuroplasticity described by the supply demand model of neuroplasticity (Wenger & Lövdén, 2016). Lastly, past paper questions were chosen as the endpoint of the intervention as they reflect the exam conditions pupils are preparing for. Furthermore, practice testing was commonly advocated as the most effective revision strategy within the literature.

Regarding the core four purposes this intervention targets elements of ACL, ECC and HCI. The active revision booklets, when framed correctly, are an enjoyable problem-solving activity (ACL1). They provide a challenge where pupils are required to build a body of knowledge that is then applied in different contexts (ACL2). Naturally questions within topics cover elements of numeracy and literacy along the way (ALC6). This presents an opportunity for pupils to both use numbers effectively in different contexts and foster an understanding of how to interpret data and apply mathematical concepts (ACL7). The questioning within the revision maps also links nicely to ECC2 where pupils can think creatively to reframe, and problem solve.

My interventions success is primarily depended on the development of pupil's confidence. This intentionally links towards developing healthy, confident individuals (HCI). This is especially so regarding building mental and emotional well-being through the development of confidence and resilience (HCI2). Lastly, the active revision booklets provide opportunities for pupils to face and overcoming challenge (HCI9). In this they develop the confidence to perform well on their exams (HCI7).

# Results & Discussion

## Pilot active revision booklet

The topics covered by the year ten class at the start of the intervention were cells, digestion, respiration, and circulation. Being the first topic learned, I produce the pilot active revision booklet on the cell's topic (Lesson 1C-D)**.** To gather feedback on students' current confidence with the material I had them rank the topics from most to least confident anonymously on sticky notes. Following this I had them RAG rate each topic individually (Lesson 1B). The RAG rating system designates red topics unconfident, amber as fairly-confident, and green as confident. Of the 22 responses, cells, digestion, and respiration had an average ranking of 2 while circulation had the lowest average ranking of 3 with 55% of correspondents ranking it as their least confident topic. The data obtained from the RAG rating is visualised in figure one below. The intervention was carried out three times over three lessons meaning the digestion topic was not covered by the intervention and therefore was omitted from the data.

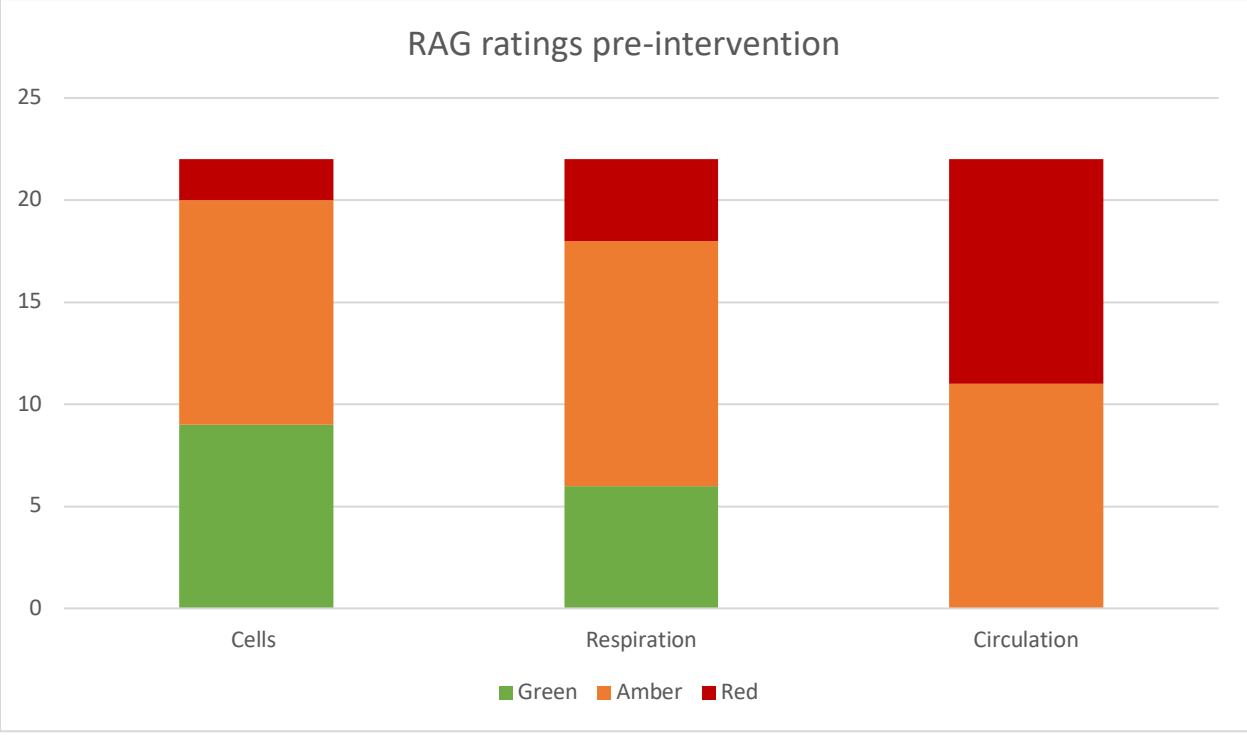


**Figure 1:** RAG ratings pre-intervention (n=22). Pupils designate colours that represent their confidence with the material. Red represents unconfident, amber is fairly-confident, and green is confident.

Following the lesson, I collected anonymous feedback from the students regarding the active revision booklet in the form of a WWW/EBI (what went well / even better if) exit ticket (Lesson 1G). The following table (table 2) summarises the feedback provided, and action taken in response. From the cell booklet intervention, a random sample of pupil booklets were collected and scanned, any names were omitted from the scanned images to maintain anonymity of pupils (Lesson 1E, 1F). From these scanned books it was clear that pupils would require more time to complete the number of questions originally set out in the booklet. This was also reflected in the feedback provided from students. To address this the next active revision booklets (Lesson 2, 3) were created with fewer questions in order to increase completion rates and feedback time within the lesson.

| What went well | Even better if | Notes/Actions taken on EBI |
|---|---|---|
| "All the resources/questions were available in one place" | "Please make the text a little bit bigger" | Text was made bigger for the next two booklets produced. |
| "Useful information to be able to answer questions" | "Too much info on one page" | This was good feedback as the time required to complete the retrieval map was longer than expected as well. The next two booklets addressed this with less questions and a more specific focus to the past paper knowledge required. |
| "Good to quiz yourself on memory" | "Better picture quality" | This was an issue with the photocopier. I spoke to the technician about the photocopier, the next run of booklets was printed with new toner and more detail. |
| "Fun engaging/Good material" | "Task is clearer" | A few students thought they were unable to use the revision notes when filling in the retrieval map. Although it was explained to students, I will make sure to have them explain the task back to me before beginning. |
| "Helps me take in a lot of information at once" | "More tips on how to revise better" | Was unable to address this with the time allocated however providing time or resources on effective revision strategies within the lesson structure is an area for future development. |

**Table 2:** Summary of feedback following pilot run of active revision booklet intervention (Lesson 1G).

## Circulatory and Respiratory system active revision booklets

Based on the feedback from the pilot run I made several adjustments to the booklets and delivery of my intervention (see table 2). The next active revision booklets produced covered the circulatory system and the respiratory system (Lesson 2, 3). Following intervention of all three topics I used the RAG rating system to get a general assessment of confidence in the material post-intervention (Lesson 4A).

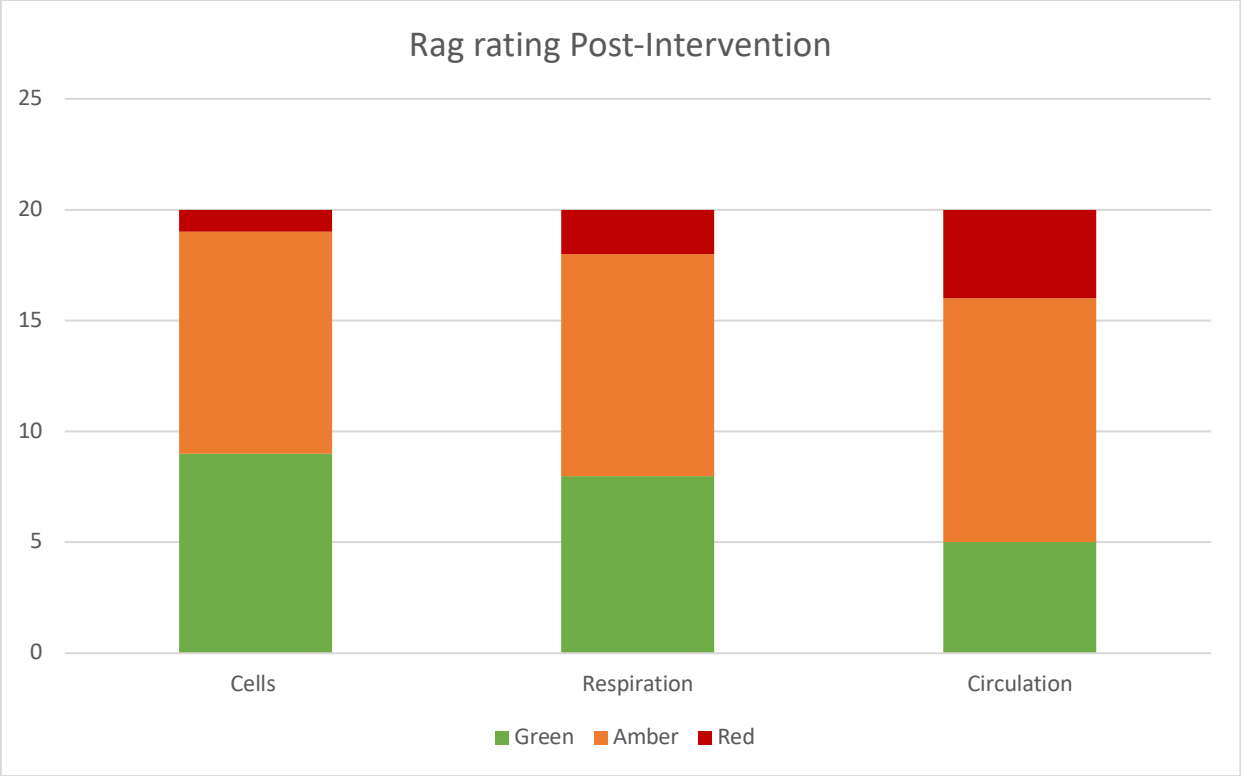


**Figure 2:** RAG ratings post-intervention (n=20). Pupils designate colours that represent their confidence with the material. Red represents unconfident, amber is fairly-confident, and green is confident.

The difference in sample size between the two RAG assessments makes it difficult to visualise side by side (n=22 versus n=20). To address this, I combined confidence ratings across topics covered and calculated the proportion of pupils rating themselves at each confidence level (figure 3 below). Pupils ranking themselves as unconfident went from 26% pre-intervention to 15% post-intervention. Furthermore, the percentage of pupils ranking themselves as confident went up from 23% pre-intervention to 30% post-intervention. Pupils ranking themselves as fairly-confident remained relatively the same with pre-intervention at 52% and post-intervention at 55%.

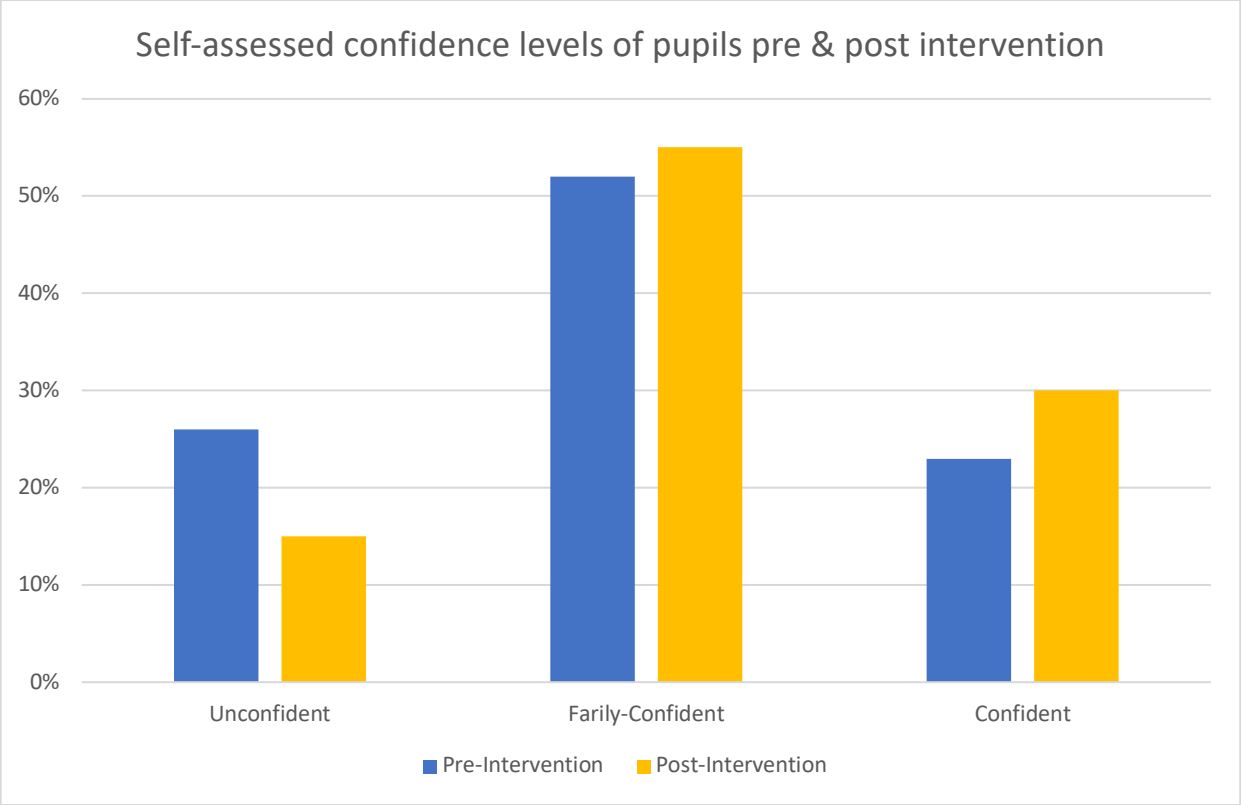


**Figure 3:** Bar graph depicting the proportion of pupil's confidence in relation to topics covered pre and post intervention.

To corroborate these results an anonymous survey was conducted (Lesson 4A). As seen from the RAG rating results the survey indicated that from the perspective of the class the revision materials made them more confident with both the material and approaching exam questions. In the survey pupils were asked to rank the difficulty of both the active revision maps and past papers question sections. As expected, the difficulty of the active retrieval map was scored lower than the difficulty of the past paper questions. This indicates that the scaffolding of difficulty inspired by the guidance fading effect did occur. Furthermore, pupils on average ranked the active retrieval maps difficulty at 3 out of 5 indicating that effortful practice was occurring, an important factor discussed surrounding the supply demand theory of neuroplasticity. Additionally, this effortful practice was in line with the ability of the pupils providing the most optimal conditions for plasticity to occur. Lastly, 77% of pupils agreed or strongly agreed that they felt more confident with both the material and approaching exam questions while 82% of pupils agreed or strongly agreed that the retrieval maps helped them in

answering the past paper questions. This serves as another indication that the resource diminished barriers for learning and fulfilled its intentions.

As a final end-point assessment a random selection of both the circulatory and respiratory system booklets of six pupils were selected. Random sampling was used to reduce bias and help ensure the sample was representative of the population. Cell booklets were not collected as the pilot run of the intervention did not allow enough time for pupils to complete an adequate amount of past paper questions. Due to workload considerations and variations in completion rates between samples a collection of 4 past paper questions were selected for analysis between the two booklets. The calculated average score in table 3 represents the mean of these four scores for each participant.

| Participant | Calculated average score | Predicted Score |
|---|---|---|
| **N1** | **88%** | **A*** |
| **N2** | **88%** | **A*** |
| **N3** | **88%** | **A** |
| **N4** | **77%** | **A** |
| **N5** | **77%** | **A** |
| **N6** | **96%** | **A*** |

**Table 3:** Averaged score compared to predicted GCSE score. Average scores were calculated from a selection of 4 past paper questions.

From this result we can see that the intervention had limited success in besting the sampled students' predicted scores. We can also see that the random sample ended up being skewed towards higher ability pupils. Being a high ability triple award class, this is still somewhat representative. It is also important to keep in mind that predicted scores are usually inflated from “true scores" as they are set as a high bar for student achievement. Furthermore, GCSE scores are also calculated on a relative scoring system rather than the absolute grades calculated here. To address this limitation, if I were to run this intervention again, I would implement a mock pre-test and post-test condition.

## Conclusion

Both successful futures and Wales' new curriculum emphasises the importance of teachers setting high expectations for learners. Expectations at key stage four and five are explicitly set by predicted exam scores. To meet these expectations pupils need effective revision tools that facilitate these ends. Based on the results above the active revision booklets were able to boost perceived confidence in pupils. The active revision booklets provided a scaffolded challenge for pupils that was both novel and effortful. This was intentional by design. The scaffolding of challenge represented efforts to take advantage of the guidance fading effect while the novelty of questions and effort was designed to maximise memory encoding based on both predictive coding theory and the supply-demand model of neuroplasticity. Perceived confidence may also have been boosted through the promotion of the growth mindset, a powerful positive psychology tool in increasing mental resilience and emotional intelligence amongst learners. While pupil scores remained largely unaffected relative to predicted GCSE scores the true effect may be masked by inflated predicted scores.

The primary limitation of this intervention is the time required for re-encoding and re-consolidation of information. This requires consistent spaced practice over time. This intervention could only be implemented and assessed once per week spanning three weeks. Another limitation is time constraints within the lessons. Even following the pilot run I still found it quite difficult to attain high completion rates of the active retrieval map and past paper questions while still having time for feedback. As all three are critical to effective retrieval practice, if I were to continue this intervention, I would chunk it down even further and potentially interleave the activity over multiple lessons. It would be interesting to consider setting up a micro-version of this intervention that still included the cycle of active retrieval, practice testing and feedback. It could then be established as a plenary or starter activity spaced across the school year. This spaced practice would allow for the consolidation periods required to facilitate stronger retrieval.

## Summary of Developing Pedological and Educational Philosophy

The process of carrying out and reflecting on this intervention has contributed in many ways to my developing educational and pedagogical philosophy. For background, I fundamentally do not believe that success on an exam represents a “good” science education. I do not believe that exams as endpoints in education are conducive to good pedagogy. However, I am also pragmatic in the sense that these exams are deterministic and therefore teaching to the test in this environment is an essential priority if pupils are to have further academic opportunities. I have seen this represented in practice ubiquitously by fantastic teachers with so much more to offer.

These statements are not intended to undermine my intervention and the principles that inform it. These criticisms are mainly targeted towards a system that places too much emphasis on exam grades and hence motivates the over usage of educational practices that ultimately promotes skills that do not transfer to the world at large. With that said, looking forward, the material and intervention outlined here will still serve a positive benefit for my own future practice. The intervention and principles discussed are great tools in priming students with the semantic knowledge required to address and develop higher order skills such as good scientific inquiry and critical thinking. To play the game of chess you need to first learn and memorise the movement of the pieces. Only once you pass this initial threshold a world of possibility for creative critical thinking and inquiry opens. In future practice I will use the tools developed here to move students beyond this initial hurdle. This will allow more time spent exploring and developing higher ordered and more transferable skills.

While most of this paper covers topics central to cognitivism. I’d like to also touch on the influence of the growth mindset within my developing philosophy. Although difficult to evidence, I have found this principle hugely beneficial in practice. The growth mindset is a great tool in developing mental resilience and emotional intelligence within students as well as myself. When thinking about the ideal education I am confronted with answering what needs to be taught for pupils’ future success. This is difficult because it

partly requires me to predict the future, something that not even the brightest and most funded hedge funds can do. Considering the unpredictability of the future, the only thing I can say for certain is that whatever future we try to prepare pupils for is not the future they will encounter. However, I am now more confident that the mental resilience and emotional intelligence that the growth mindset promotes creates well-adjusted individuals and lifelong learners that will be more capable in handling the challenges of the future as it unfolds.

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# An evaluation of retrieval-based learning through active organisational processing techniques

Mitchell Shiell

## APPENDIX (Evidence)



2000-Word Equivalency

# Lesson 1

*Cells, Movement Across Membranes & Enzymes*

| | |
|---|---|
| **Class** | Year 10 Triple |
| **Topic** | Series of weekly revision lessons covering various topics |
| **Purpose of the Unit / Topic** | Developing embedded knowledge schemas, expertise and confidence in approaching the GCSE examinations |
| **Core purpose** | ACL: 1, 2, 3 ECC: 5, 6, 7 HCI: 2, 7, 9 |

| What will you do? | What will the learners be learning / doing? | Resources |
|---|---|---|
| **Starter:** | | |
| Introductions<br>Hand out posted notes | Rank topic covered in terms of confidence<br>RAG rate each topic | Post it notes |
| Hand out Bingo sheets<br>Provide bingo clues through text and visuals | First to line up 5 in a row wins (carry on activity regardless) | Bingo Cards |
| **Main:** | | |
| Hand out Active Retrieval Booklets, explain to students the objective<br><br>Circulate the room, motivate students and promote growth mindset | Students complete the active revision map questions by using the revision guide notes | Active Revision notebook |
| **Plenary:** | | |
| Past paper questions and class feedback | Pupils complete past paper question, depending on time we can do a peer assessment or hand in for teacher assessment (allows for evidence of standard) | Past paper questions in active revision booklet |
| Exit ticket - WWW/EBI | Following this revision lesson students reflect and provide feedback on the active revision booklet resource. | Post it notes |

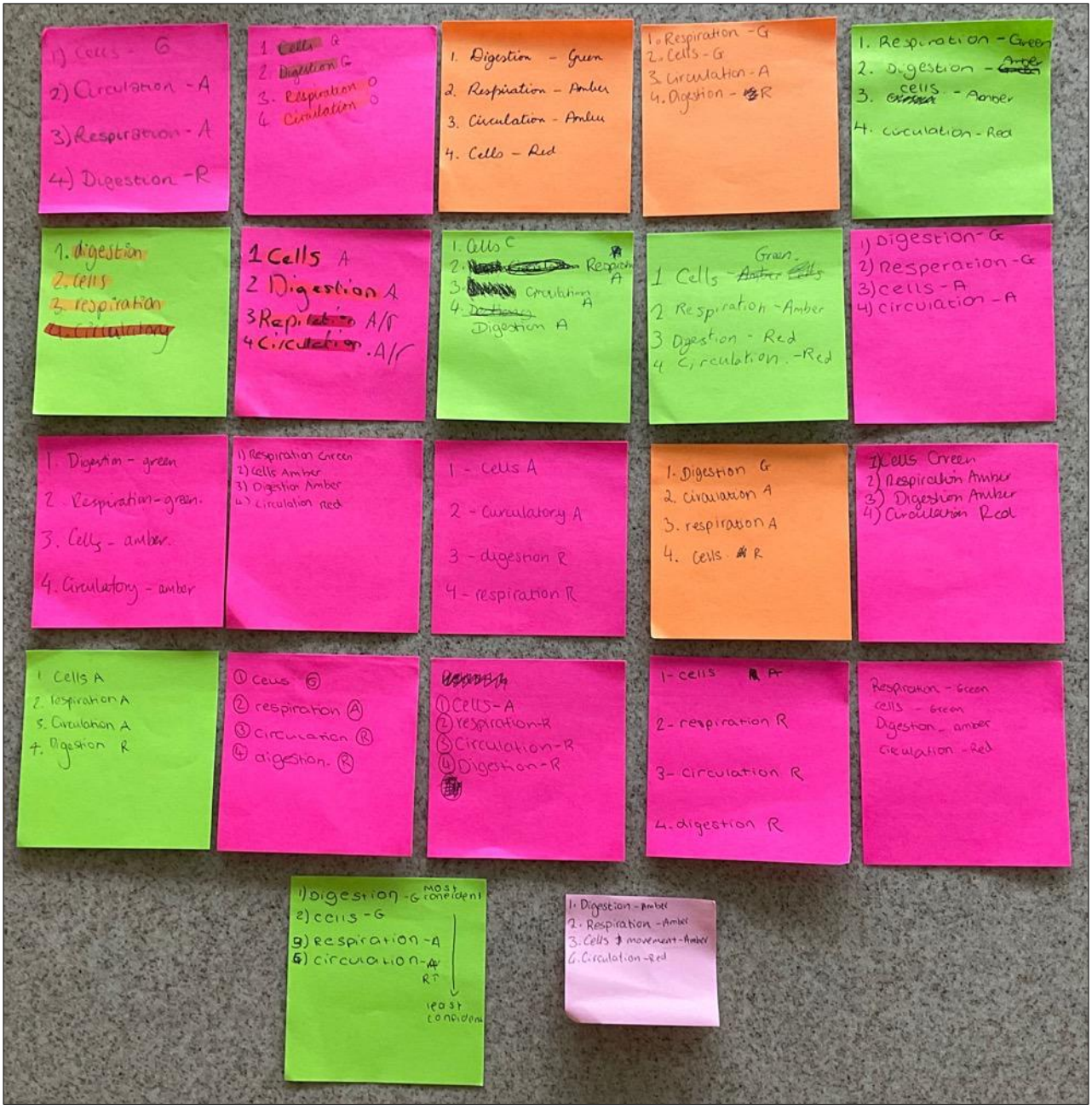
## Evaluation

For full guidance on this section, please click here

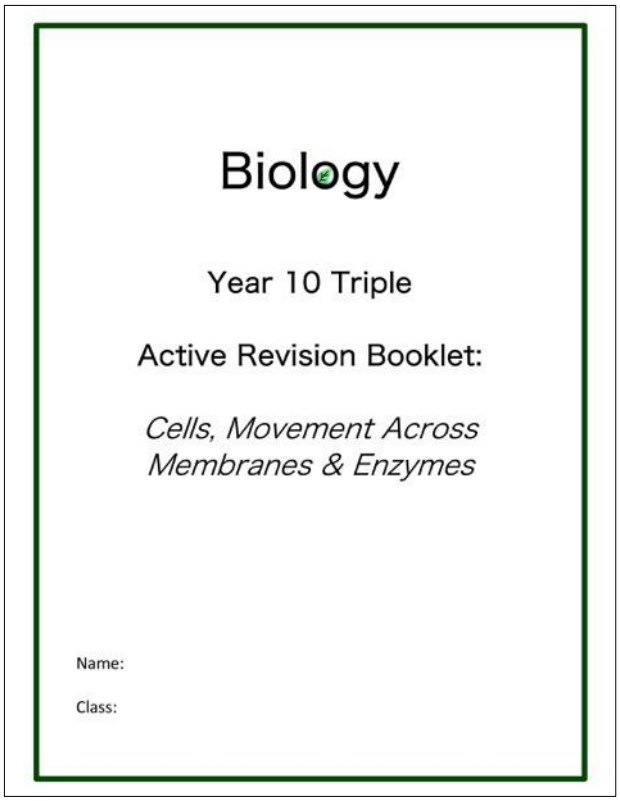
| Learning: progress against the learning intentions | Learning: how did you know? | Teaching: what was the impact of what you did? |
|---|---|---|
| Students enjoyed the bingo activity and were able to engage with the material enthusiastically<br><br>The revision maps were filled in and i was able to promote the growth mindset and mental resilience while addressing issues and misconceptions as i circulated the room | Revision guides are collected and briefly assessed following the lesson, during the lesson i actively circulate the room | The low stakes starter activity helped build relationships with the students that helped boost participation and students willingness to ask questions and reach out for help |

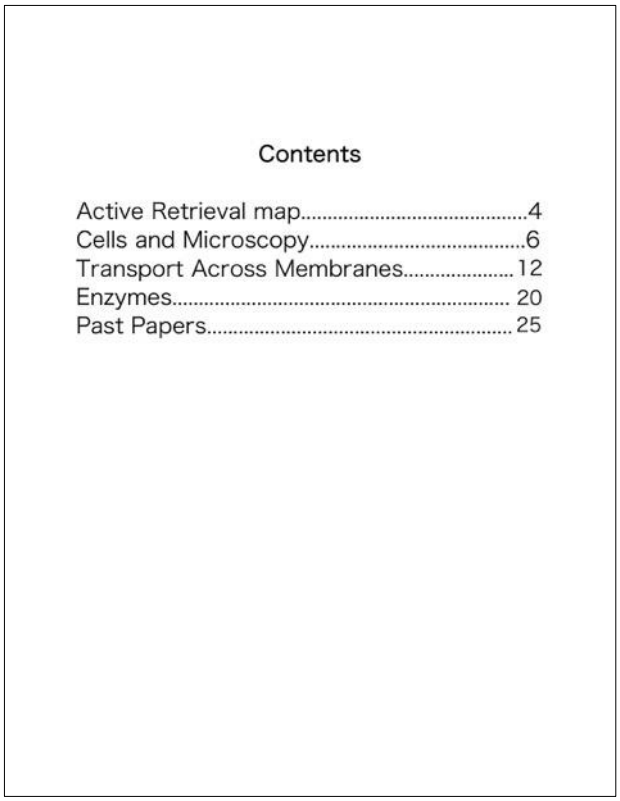
| Priorities for the next lesson (learning) | Priorities for the next lesson (teaching) |
|---|---|
| Did not have enough time for feedback on past paper questions, this was okay though as the class was engaged with the material, however it needs to become a priority as we move closer to their exams. | There are a few pupils who are currently discouraged especially since just finishing mocks and feeling as though they are "failing", I will try to ensure that i build confidence in these individuals as the revision lessons are an excellent opportunity for weaker pupils to develop confidence. |

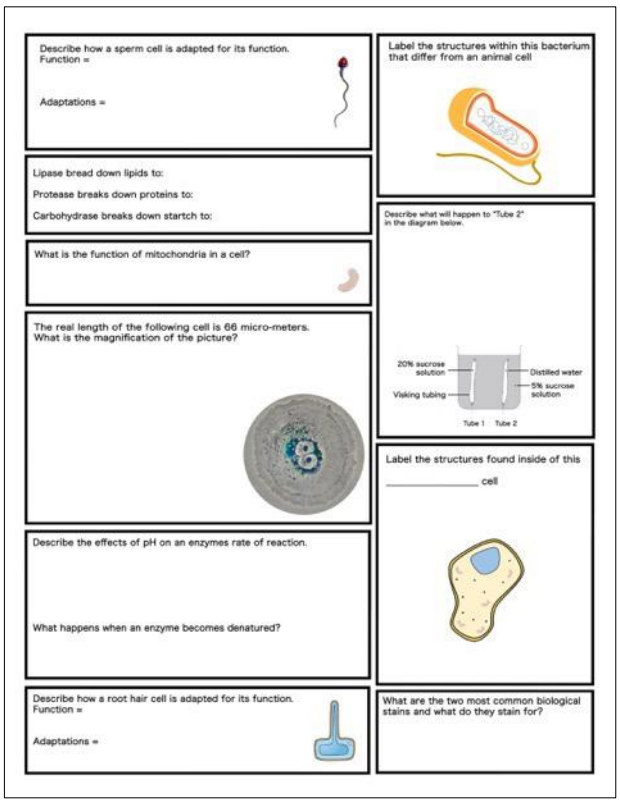
**Evidence Lesson 1A:** Lesson plan for pilot run of the active revision booklets. Learning intentions and success criteria are left out as the learning intentions reflect the specifications for the cells unit while the success criteria are all incorporated and achieved through completion of the active revision booklet.

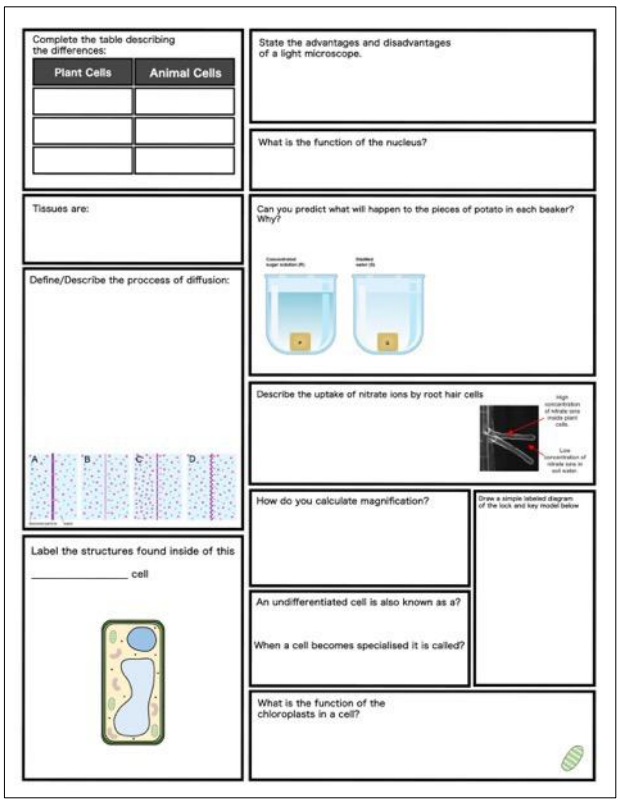



**Evidence Lesson 1B:** To gather feedback on students' current confidence with the material I had them anonymously rank the topics from most to least confident on sticky notes. Following this I had them RAG rate each topic individually. The RAG rating system designates red topics unconfident, amber as fairly-confident, and green as confident. Of the 22 responses, cells, digestion, and respiration had an average ranking of 2 while circulation had the lowest average ranking of 3 with 55% of correspondents ranking it as their least confident topic.

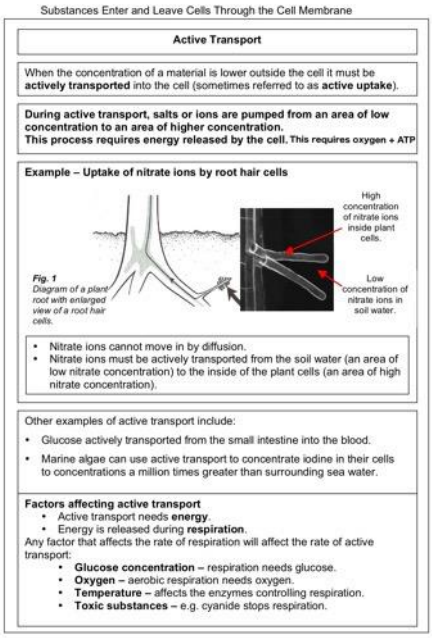



**Evidence Lesson 1C:** I produced the pilot active revision booklet on the cell's topic. Pictured above is the title page next to the table of contents and the active retrieval map. The active retrieval map spans two pages and covers all the content of the cell's topic. The answers to these questions can all be found from the revision notes found within the booklet. The information required to answer the retrieval map covers all the content for the past paper questions. This resource is an evidenced based design. For a more in-depth justification for its design refer to the literature review and subsequent justification of intervention found within the paper. Complete active revision booklets can be found on PLP.


Substances Enter and Leave Cells Through the Cell Membrane

**Active Transport**

When the concentration of a material is lower outside the cell it must be **actively transported** into the cell (sometimes referred to as **active uptake**).

**During active transport, salts or ions are pumped from an area of low concentration to an area of higher concentration.**
**This process requires energy released by the cell. This requires oxygen + ATP**

**Example – Uptake of nitrate ions by root hair cells**



*Fig. 1*
*Diagram of a plant root with enlarged view of a root hair cells.*

- Nitrate ions cannot move in by diffusion.
- Nitrate ions must be actively transported from the soil water (an area of low nitrate concentration) to the inside of the plant cells (an area of high nitrate concentration).

Other examples of active transport include:

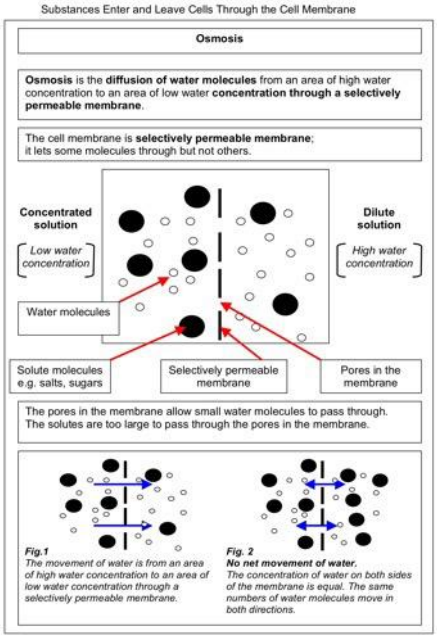
- Glucose actively transported from the small intestine into the blood.
- Marine algae can use active transport to concentrate iodine in their cells to concentrations a million times greater than surrounding sea water.

**Factors affecting active transport**

- Active transport needs **energy**.
- Energy is released during **respiration**.

Any factor that affects the rate of respiration will affect the rate of active transport:

- **Glucose concentration –** respiration needs glucose.
- **Oxygen –** aerobic respiration needs oxygen.
- **Temperature –** affects the enzymes controlling respiration.
- **Toxic substances –** e.g. cyanide stops respiration.


Substances Enter and Leave Cells Through the Cell Membrane

**Osmosis**

**Osmosis** is the **diffusion of water molecules** from an area of high water concentration to an area of low water **concentration through a selectively permeable membrane**.

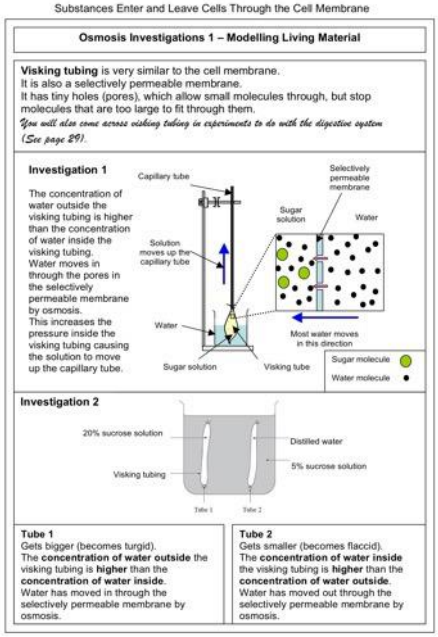
The cell membrane is **selectively permeable membrane**; it lets some molecules through but not others.



The pores in the membrane allow small water molecules to pass through. The solutes are too large to pass through the pores in the membrane.

*Fig.1*
*The movement of water is from an area of high water concentration to an area of low water concentration through a selectively permeable membrane.*

*Fig. 2*
***No net movement of water.***
*The concentration of water on both sides of the membrane is equal. The same numbers of water molecules move in both directions.*


Substances Enter and Leave Cells Through the Cell Membrane

**Osmosis Investigations 1 – Modelling Living Material**

**Visking tubing** is very similar to the cell membrane.
It is also a selectively permeable membrane.
It has tiny holes (pores), which allow small molecules through, but stop molecules that are too large to fit through them.
*You will also come across visking tubing in experiments to do with the digestive system (See page 29).*

**Investigation 1**

The concentration of water outside the visking tubing is higher than the concentration of water inside the visking tubing. Water moves in through the pores in the selectively permeable membrane by osmosis. This increases the pressure inside the visking tubing causing the solution to move up the capillary tube.

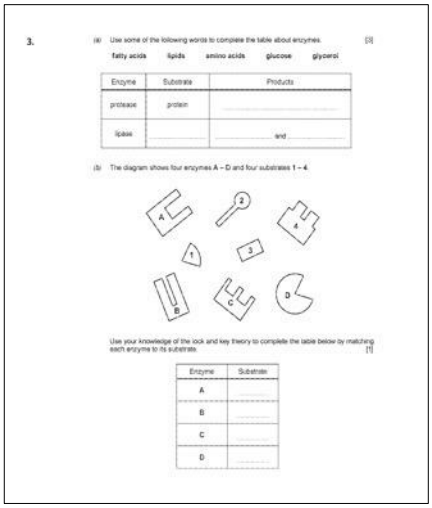


**Investigation 2**



**Tube 1**
Gets bigger (becomes turgid).
The **concentration of water outside** the visking tubing is **higher** than the **concentration of water inside**.
Water has moved in through the selectively permeable membrane by osmosis.

**Tube 2**
Gets smaller (becomes flaccid).
The **concentration of water inside** the visking tubing is **higher** than the **concentration of water outside**.
Water has moved out through the selectively permeable membrane by osmosis.


3. (a) Use some of the following words to complete the table about enzymes. [3]

fatty acids  lipids  amino acids  glucose  glycerol

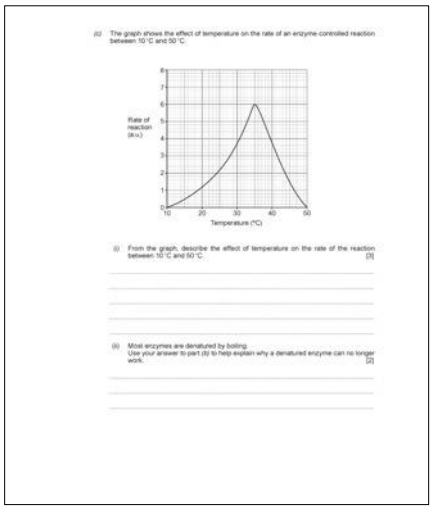
| Enzyme | Substrate | Products |
|---|---|---|
| protease | protein | ..... |
| lipase | ..... | ..... and ..... |

(b) The diagram shows four enzymes A – D and four substrates 1 – 4.



Use your knowledge of the lock and key theory to complete the table below by matching each enzyme to its substrate. [1]

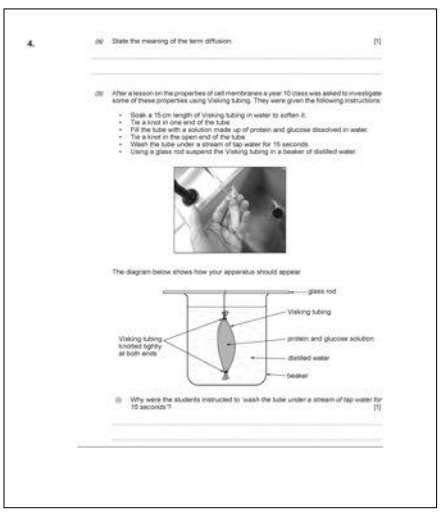
| Enzyme | Substrate |
|---|---|
| A | ..... |
| B | ..... |
| C | ..... |
| D | ..... |


(c) The graph shows the effect of temperature on the rate of an enzyme-controlled reaction between 10 °C and 50 °C.



(i) From the graph, describe the effect of temperature on the rate of the reaction between 10 °C and 50 °C. [3]

(ii) Most enzymes are denatured by boiling.
Use your answer to part (b) to help explain why a denatured enzyme can no longer work. [2]


4. (a) State the meaning of the term diffusion. [1]

(b) After a lesson on the properties of cell membranes a year 10 class was asked to investigate some of these properties using Visking tubing. They were given the following instructions:

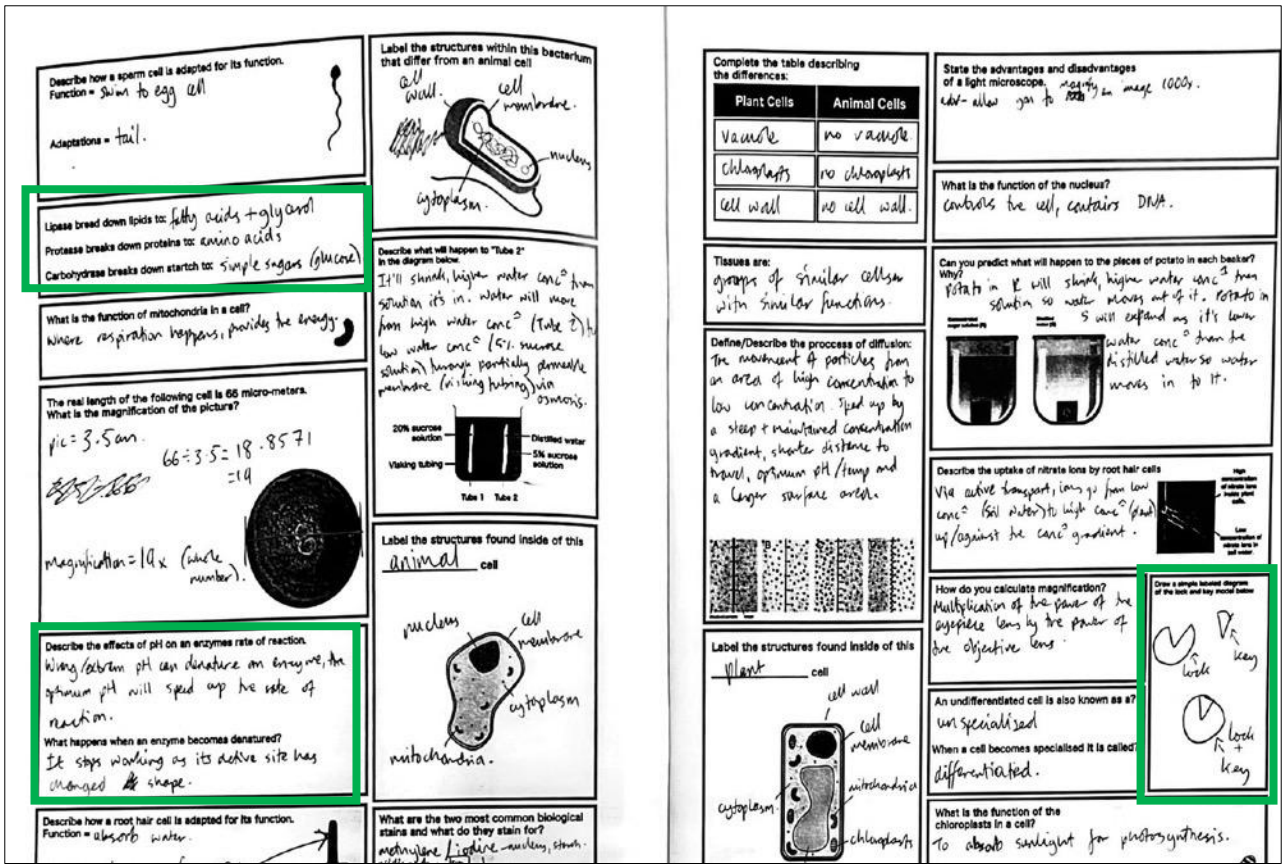
- Soak a 15-cm length of Visking tubing in water to soften it.
- Tie a knot in one end of the tube.
- Fill the tube with a solution made up of protein and glucose dissolved in water.
- Tie a knot in the open end of the tube.
- Wash the tube under a stream of tap water for 15 seconds.
- Using a glass rod suspend the Visking tubing in a beaker of distilled water.

The diagram below shows how your apparatus should appear.

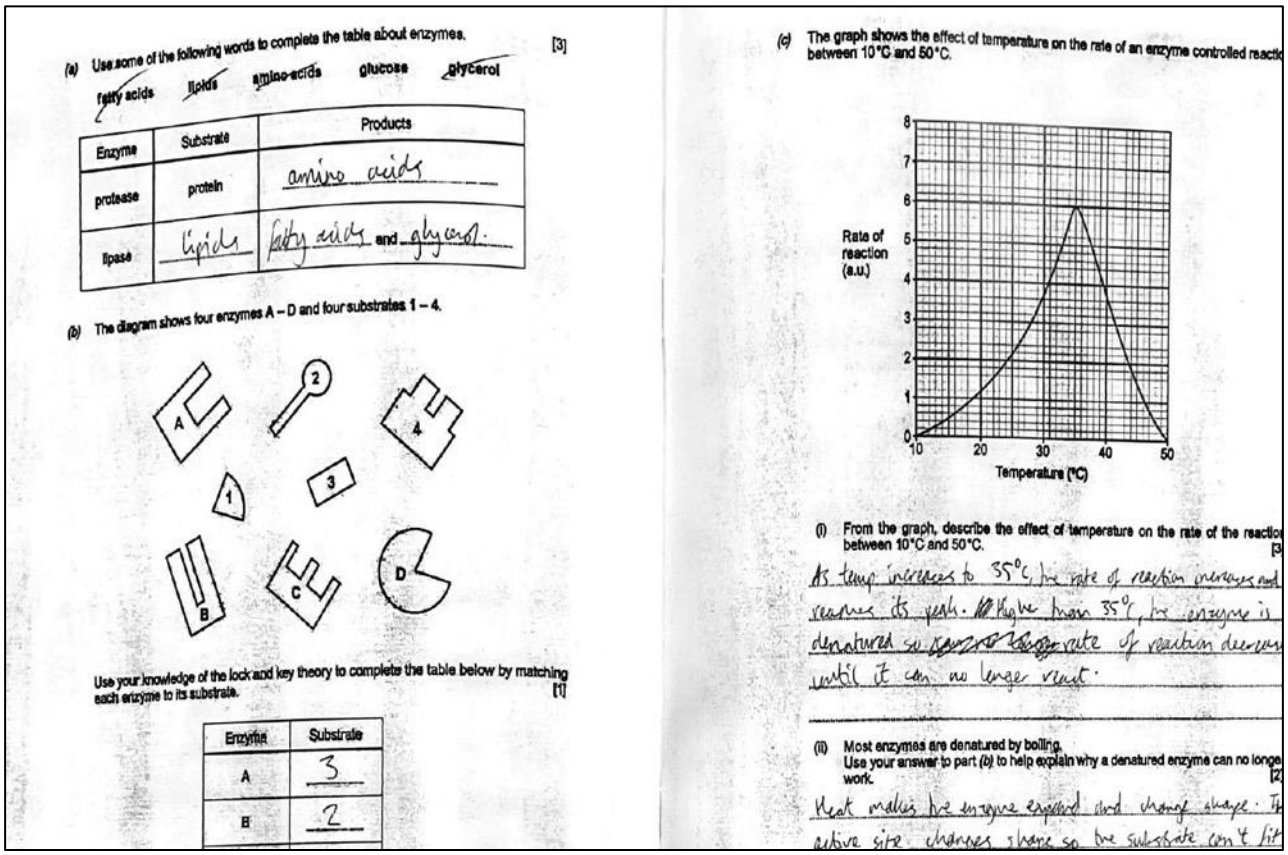


(i) Why were the students instructed to 'wash the tube under a stream of tap water for 15 seconds'? [1]

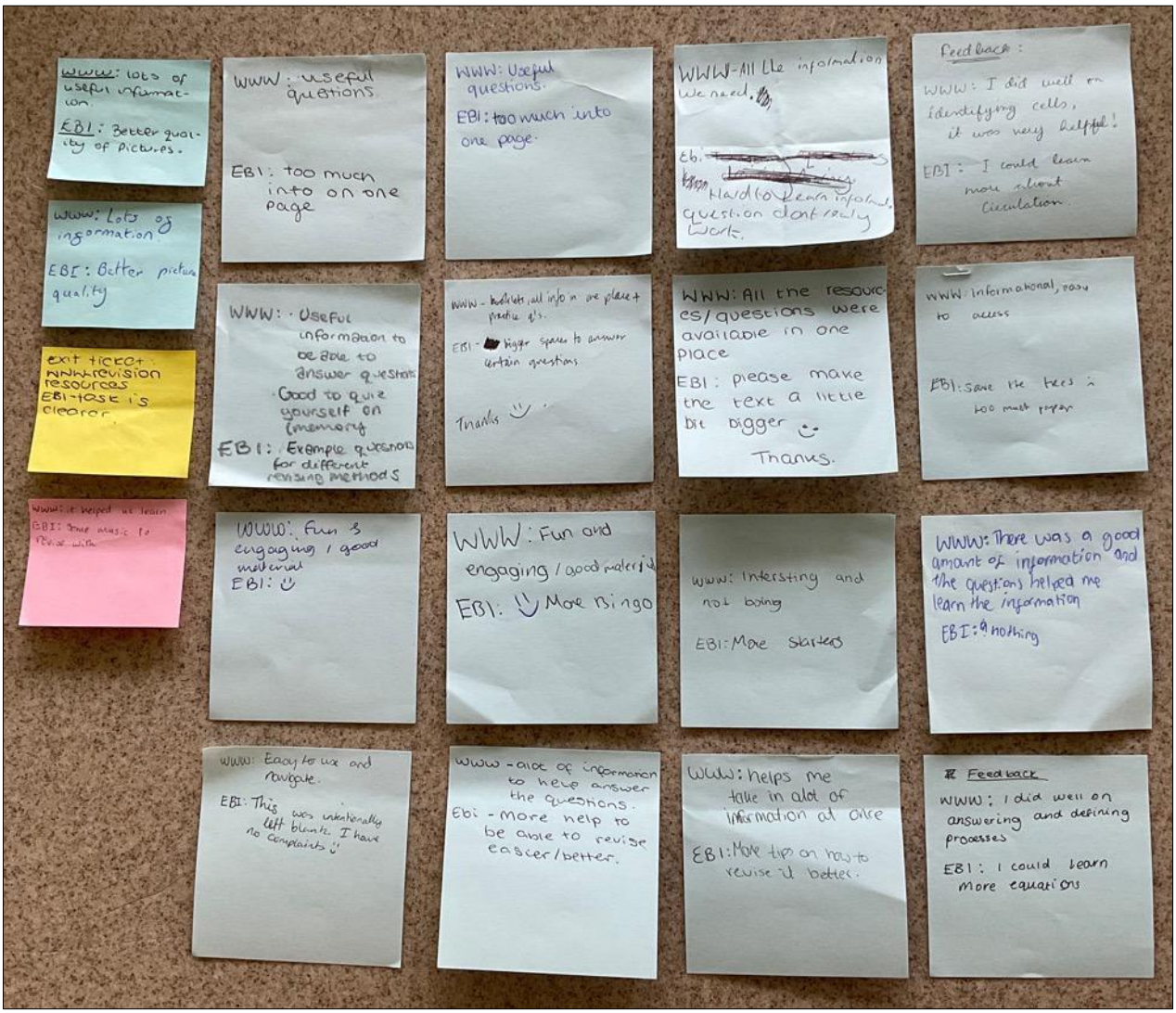
**Evidence Lesson 1D:** Each active revision booklet is constructed to holistically cover one unit. Here is an example of some Bangor revision sheets and some WJEC past paper questions covering the cells unit. The Bangor revision sheets serve as pre-made knowledge organisers for all the specification content within each unit. Past paper questions are selected to cover as much of the unit as possible and to address any misconceptions or areas of weakness relayed by my mentor. Using the marking schemes from the selected past paper questions I verify that the information is presented clearly within the revision sheets and adapt and edit the sheets where required. These sheets can be referenced by students if they are unable to retrieve the information on their own during the active retrieval map activity.




**Evidence Lesson 1E:** Example of a completed active retrieval map taken from the cell's active retrieval booklet. Boxes in green highlight retrieval map questions that match up with the past paper questions seen below. Relevancy to past paper questions was improved upon following the pilot run.




**Evidence Lesson 1F:** Example of a completed past paper questions taken from the cell's active retrieval booklet. On this pilot run we did not have time for feedback and marking using green pens.




**Evidence Lesson 1G:** I collected anonymous feedback from the students regarding the active revision booklet in the form of a WWW/EBI (what went well / even better if) exit ticket. Feedback was collated and summarised in table 2 of the paper. Based on this feedback action was taken which included: bigger text, less questions (retrieval map and past papers), improving picture quality (printing issue) and expanding on clarity in the explanation of the task.

# Lesson 2

*The*
*Circulatory System*

| What will you do? | What will the learners be learning / doing? | Resources |
|---|---|---|
| **Starter:**<br><br>Who wants to be a millionare | Using whiteboards students will answer 15 multiple choice questions in ascending difficulty<br><br>If incorrect the student will hand in there white board and be given a class pop<br><br>The student(s) who can hold on to their whiteboards the longest win | Who wants to be a millionaire ppt |
| **Main:**<br><br>Hand out circulatory active revision booklet<br><br>Explain the booklet (they should be familiar with it's design however it doesn't hurt to reiterate)<br><br>Provide a target time of 20 mins to complete, set timer on board and circulate room | Students will use the revision guide to complete the active revision map on pages 4 and 5 of the booklet, these questions are developed to provide practice for future retrieval during the past paper plenary activity. | Circulatory system active revision booklet |
| **Plenary:**<br><br>20 mins past paper questions, silent activity<br><br>Peer assessment will be completed at the start of the next revision lesson (spaced practice and delayed feedback) | Students will have 20 mins to complete the past paper questions at the back of the booklet | Circulatory system active revision booklet |

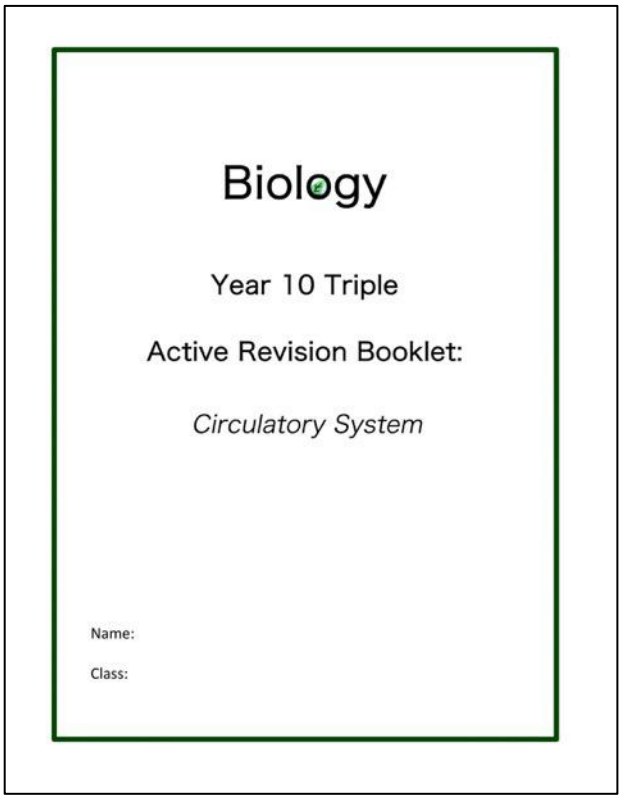
## Evaluation

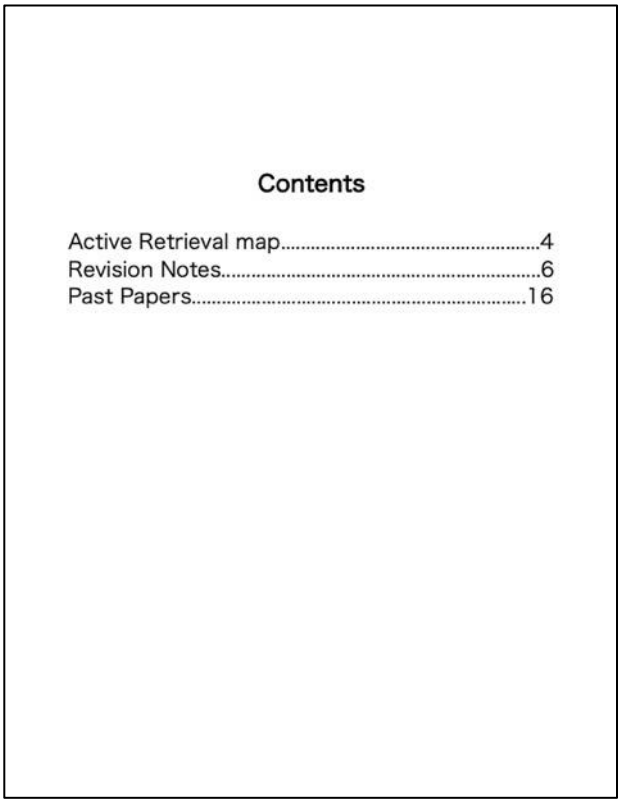
Click here for guidance on this section

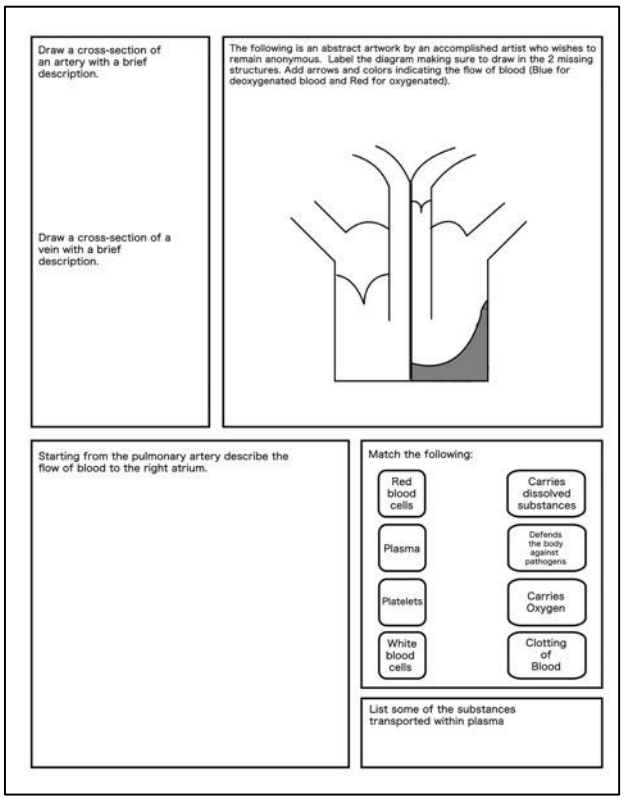
| Learning: progress against the learning intentions | Learning: how did you know? | Teaching: what was the impact of what you did? |
|---|---|---|
| Students were enthusiastic and engaged with the material, they were able to answer most questions on the active retrieval map and we able to get some feedback on the past paper questions within the plenary of the lesson. | Students were able to fill in the active revision map questions and make progress on the past paper questions. These booklets are collected following the lesson for assessment. | Most of the impact of this lesson was within the preparation of the revision guide. This iteration had less questions on the retrieval map which created time for feedback and self assessment using green pens following the lesson. |

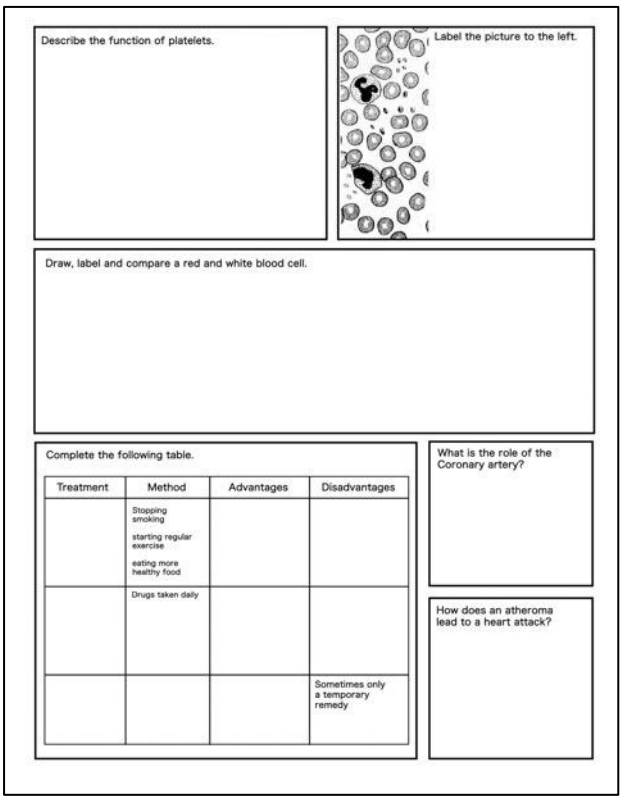
| Priorities for the next lesson (learning) | Priorities for the next lesson (teaching) |
|---|---|
| Next revision lesson we will focus on respiration and the respiratory system, I believe this was the second lowest in ranking when assessing the RAG rating activity from lesson 1. | Instead of doing a starter game I want to use direct instruction to emphasis the importance of a growth mindset when approaching the active revision booklet activity. |

**Evidence Lesson 2A:** Lesson plan for the circulatory active revision booklet. This lesson was more streamlined in order to provide more time to complete the active revision booklet and provide time for feedback on the past paper questions.

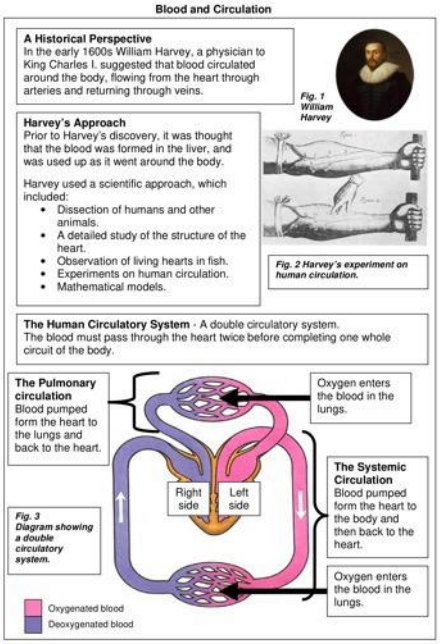


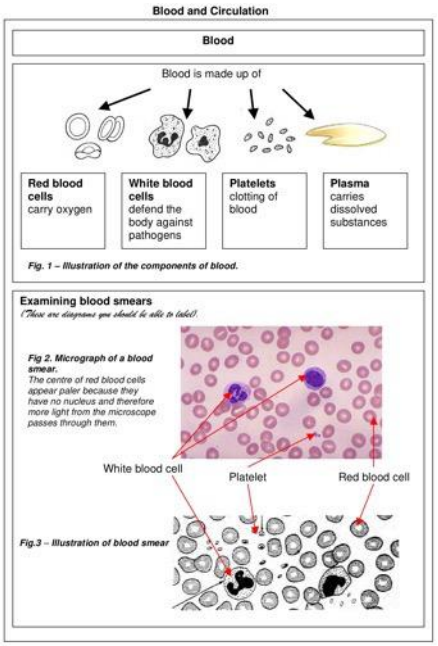



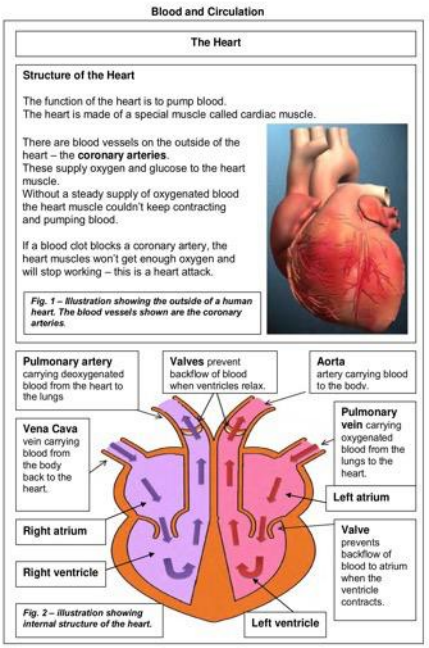



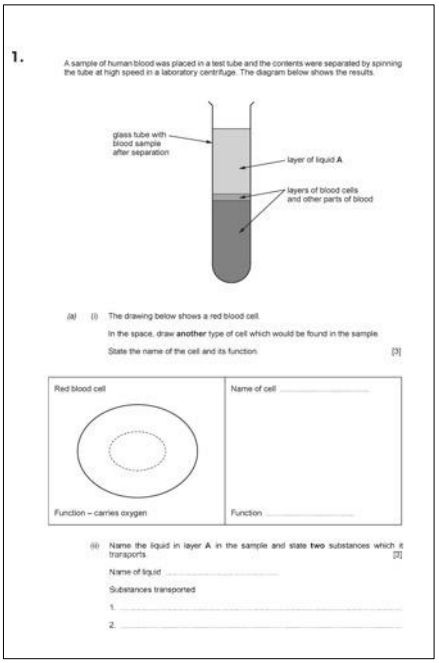



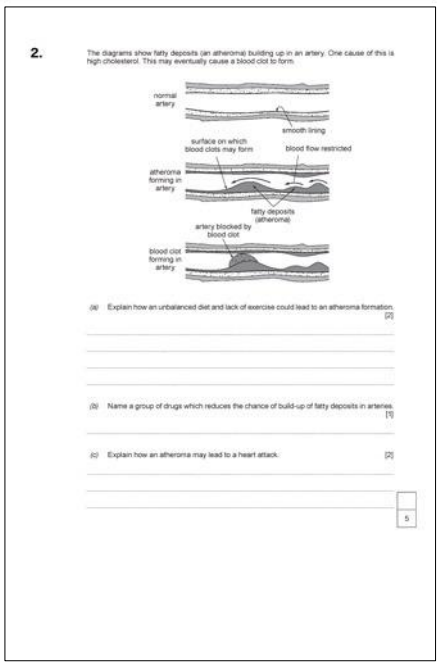

**Evidence Lesson 2B:** Based on the feedback from the pilot run I made several adjustments to the booklets. The next active revision booklet, the circulatory system seen here, was made with less questions on the active retrieval map (and therefore less past paper questions) and bigger text (scaled down to fit this page). A greater variety of question answer styles were used as well. For a more in-depth justification of its design refer to the literature review and subsequent justification of intervention found within the paper. Complete active revision booklets can be found on PLP.

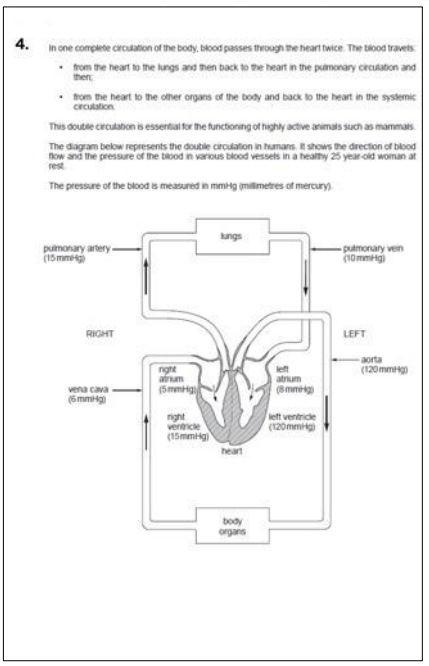


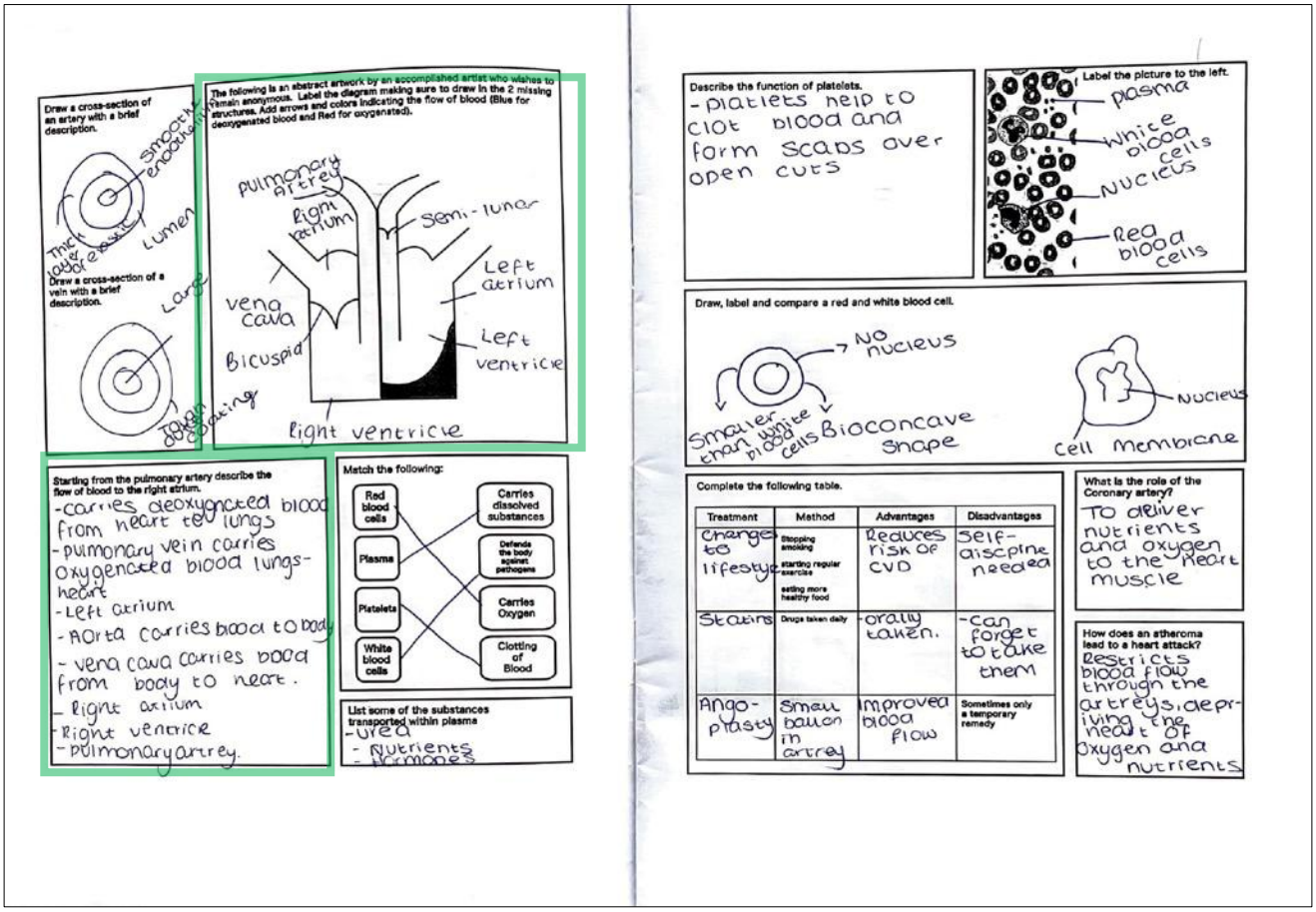



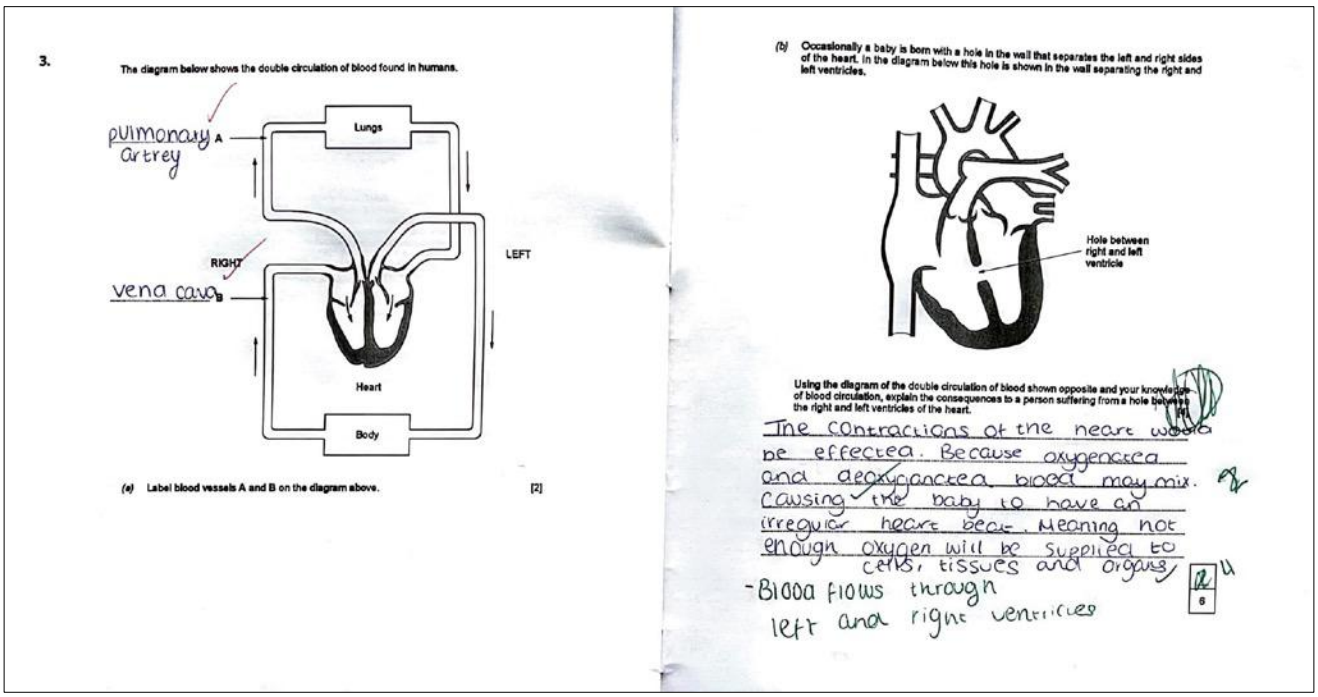




**Evidence Lesson 2C:** Here is an example of some Bangor revision sheets and some WJEC past paper questions covering the circulatory system unit. As with the previous active revision booklet, the Bangor revision sheets serve as pre-made knowledge organisers for all the specification content within each unit. Past paper questions are selected to cover as much of the unit as possible and to address any misconceptions or areas of weakness relayed by my mentor. Using the marking schemes from the selected past paper questions I verify that the information is presented clearly within the revision sheets and adapt and edit the sheets where required. These sheets can be referenced by students if they are unable to retrieve the information on their own during the active retrieval map activity.




**Evidence Lesson 2D:** Example of a completed active retrieval map taken from the circulatory system active retrieval booklet. Boxes in green highlight retrieval map questions that match up with the example past paper questions seen below. Relevancy to past paper questions was improved upon in this iteration.




**Evidence Lesson 2E:** Example of a completed past paper question taken from the circulatory system active retrieval booklet. Here you can see self assessed feedback in green pen. The improved timings of the lesson allowed adequate time for whole class feedback.

# Lesson 3

*Respiration &*
*The Respiratory System*

| What will you do? | What will the learners be learning / doing? | Resources |
|---|---|---|
| **Starter:**<br><br>Discuss importance of resilience and the growth mindset when approaching challenges and failures.<br><br>Hand out respiratory system active revision booklet | Get seated with equipment on desk ready to work | respiratory system active revision booklet |
| **Main:**<br><br>20 minutes to complete the active retrieval map | Students will use the revision guide to complete the active revision map on pages 4 and 5 of the booklet, these questions are developed to provide practice for future retrieval during the past paper plenary activity. | respiratory system active revision booklet |
| **Plenary:**<br><br>20 minutes Past paper questions<br><br>10 minutes feedback on past papers | Students will have 20 mins to complete as many of the past paper questions at the back of the booklet<br><br>Using green pens students will correct and assess their work compared to the marking scheme | respiratory system active revision booklet |
| | | |

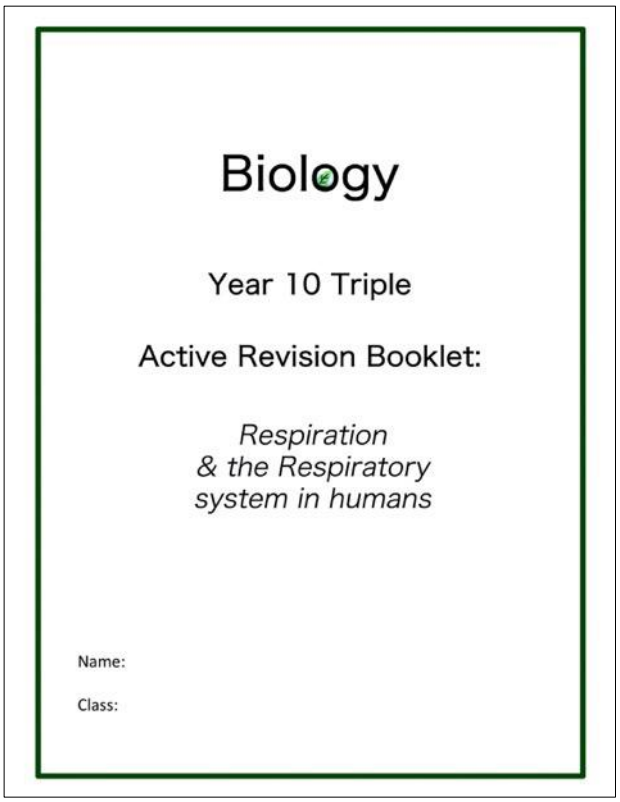
## Evaluation

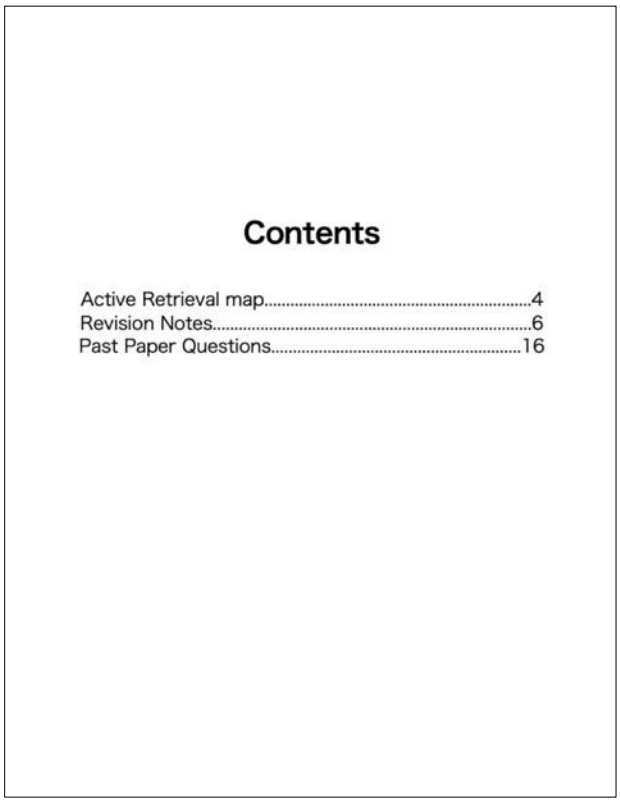
Click here for guidance on this section

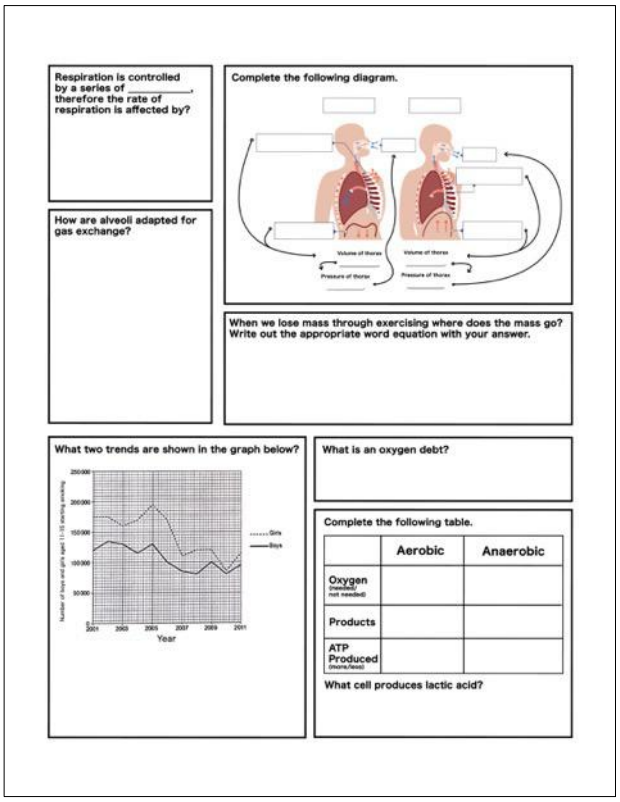
| Learning: progress against the learning intentions | Learning: how did you know? | Teaching: what was the impact of what you did? |
|---|---|---|
| Students were on task and working on the booklets for the larger majority of the lesson, they were able to answer more questions on both the retrieval map and past papers. | Books were collected, checked and scanned onto my ipad following the lesson. | Students generally displayed a greater degree of perseverance and were more relaxed and confident when writing answers. Highlighting the growth mindset at the start of the lesson framed the activity nicely as being a low stakes individually developmental activity. |

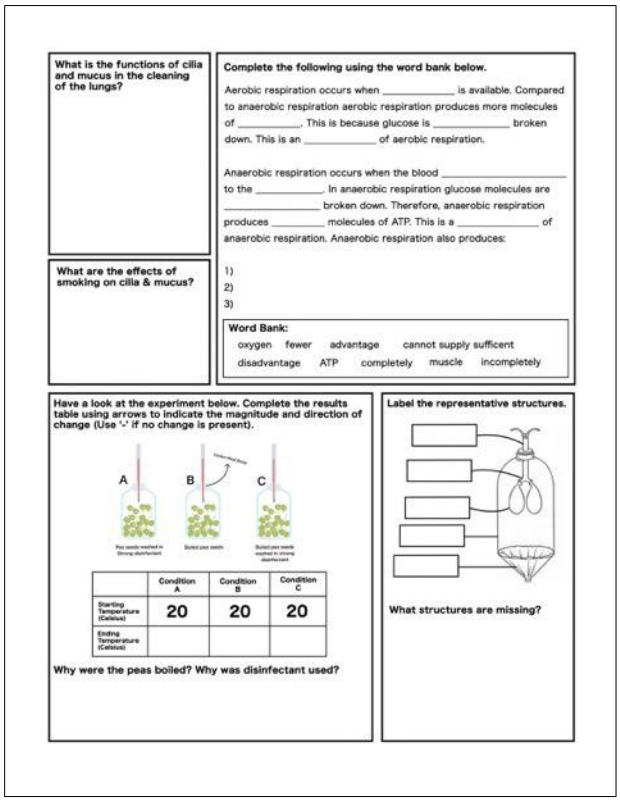
| Priorities for the next lesson (learning) | Priorities for the next lesson (teaching) |
|---|---|
| This was the last of the revision lesson, marking schemes will be posted onto the teams drive for pupils to reference when using the booklets for their revision | Within the next lesson I will conduct an anonymous post intervention survey to gather data and feedback on the intervention. |

**Evidence Lesson 3A:** Lesson plan for the respiratory system active revision booklet. This lesson further improved on the timing and pace of the lesson allowing adequate time for feedback on the past paper questions. It also incorporated the direct instruction of the growth mindset and how it can be used to benefit the students.

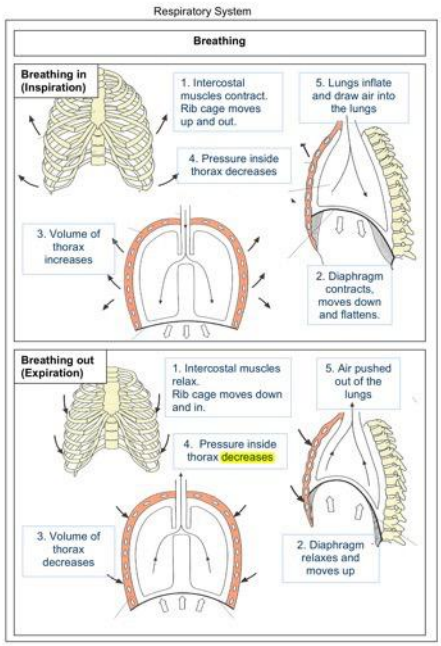


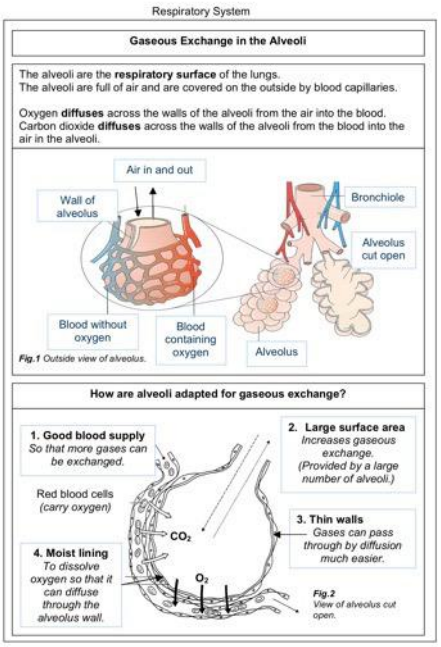



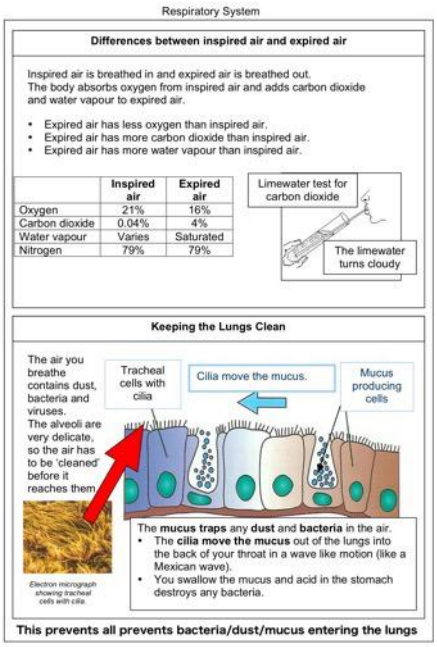



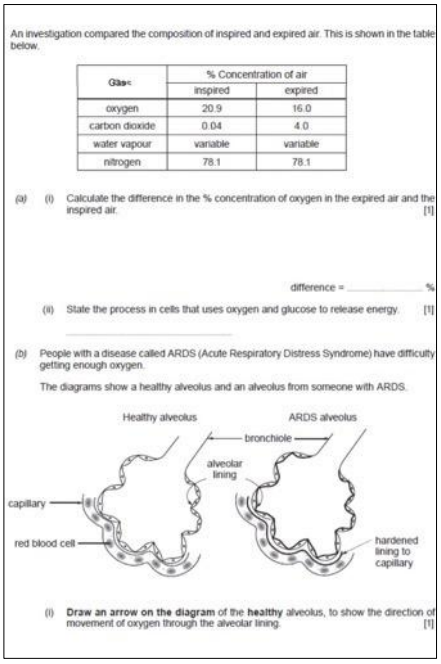



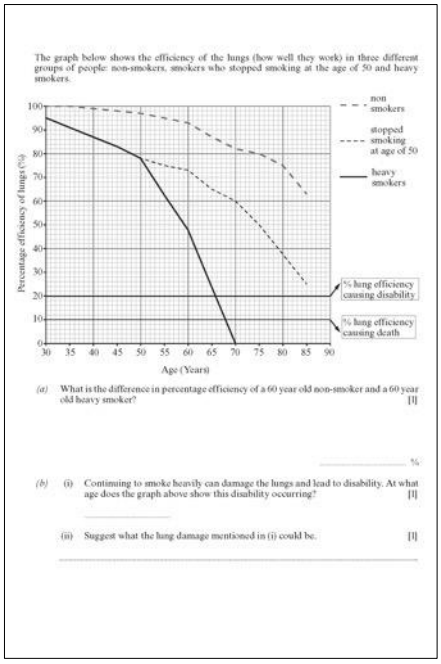

**Evidence Lesson 3B:** This iteration of the active retrieval booklet carried much of the same design elements as the prior booklet. In this booklet, I continued to ensure a variety question and answer formats were used to maximise the novelty factor. Again, for a more in-depth justification of its design refer to the literature review and subsequent justification of intervention found within the paper. Complete active revision booklets can be found on PLP.

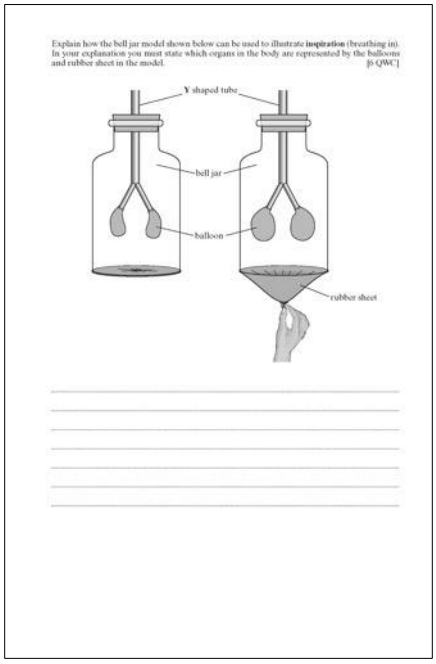


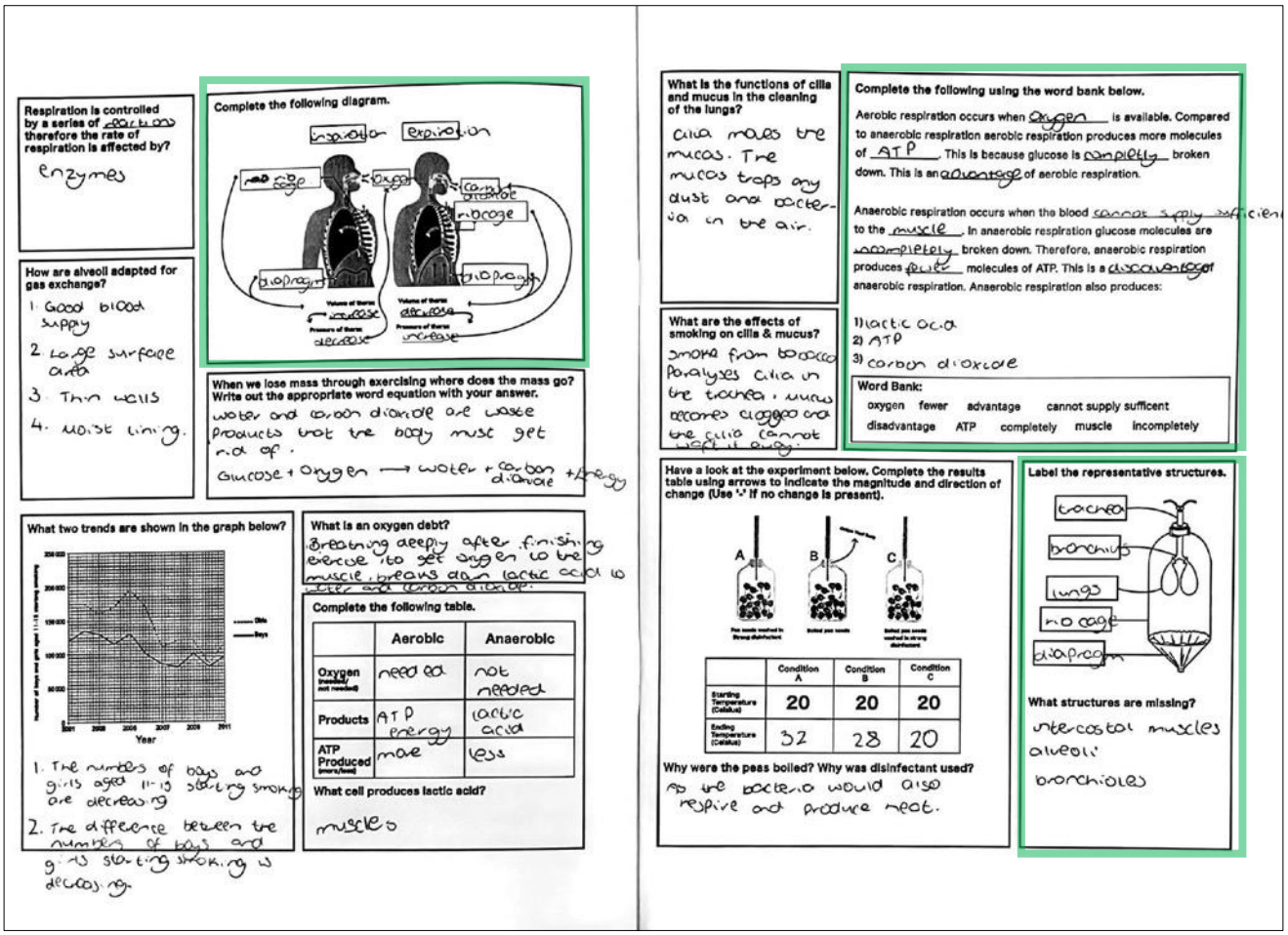



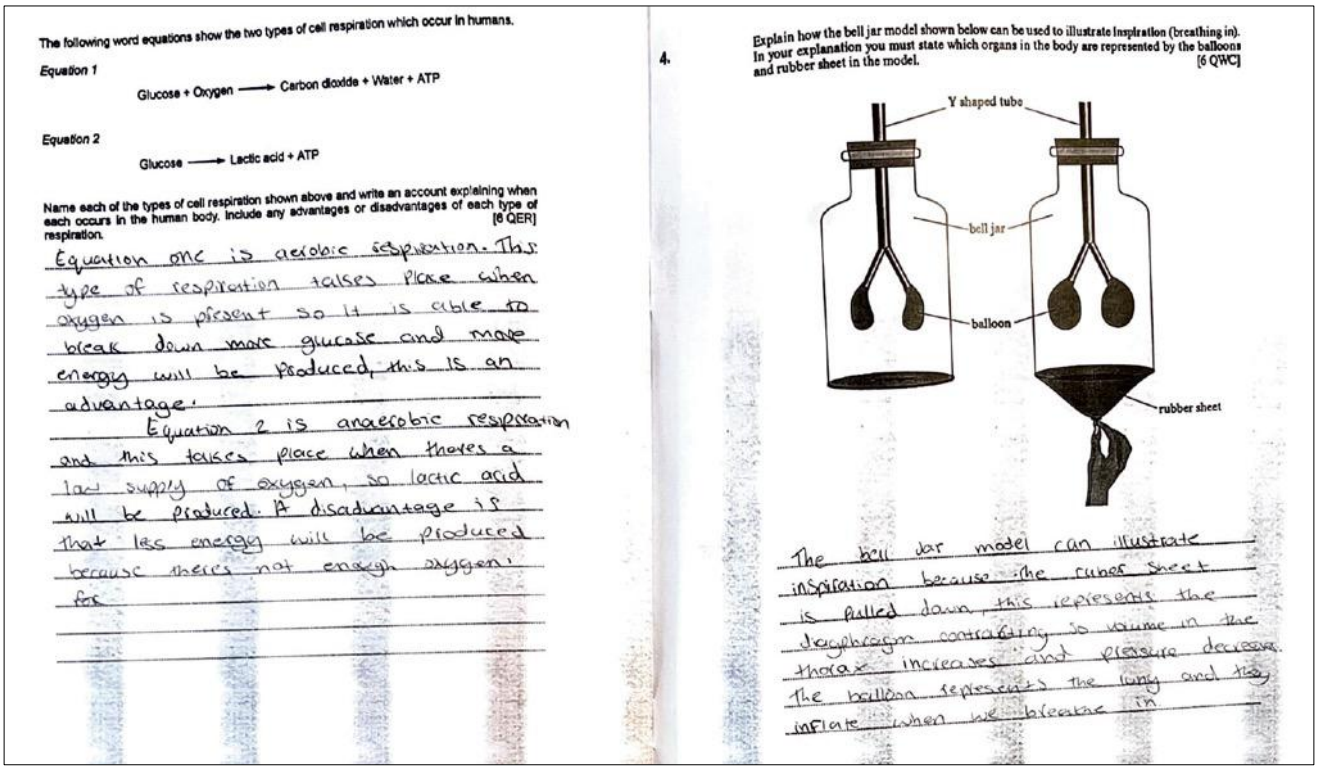




**Evidence Lesson 3C:** Here is an example of some Bangor revision sheets and some WJEC past paper questions covering respiration and the respiratory system. As with the previous active revision booklet, the Bangor revision sheets serve as pre-made knowledge organisers for all the specification content within each unit. Past paper questions are selected to cover as much of the unit as possible and to address any misconceptions or areas of weakness relayed by my mentor. Using the marking schemes from the selected past paper questions I verify that the information is presented clearly within the revision sheets and adapt and edit the sheets where required. These sheets can be referenced by students if they are unable to retrieve the information on their own during the active retrieval map activity.



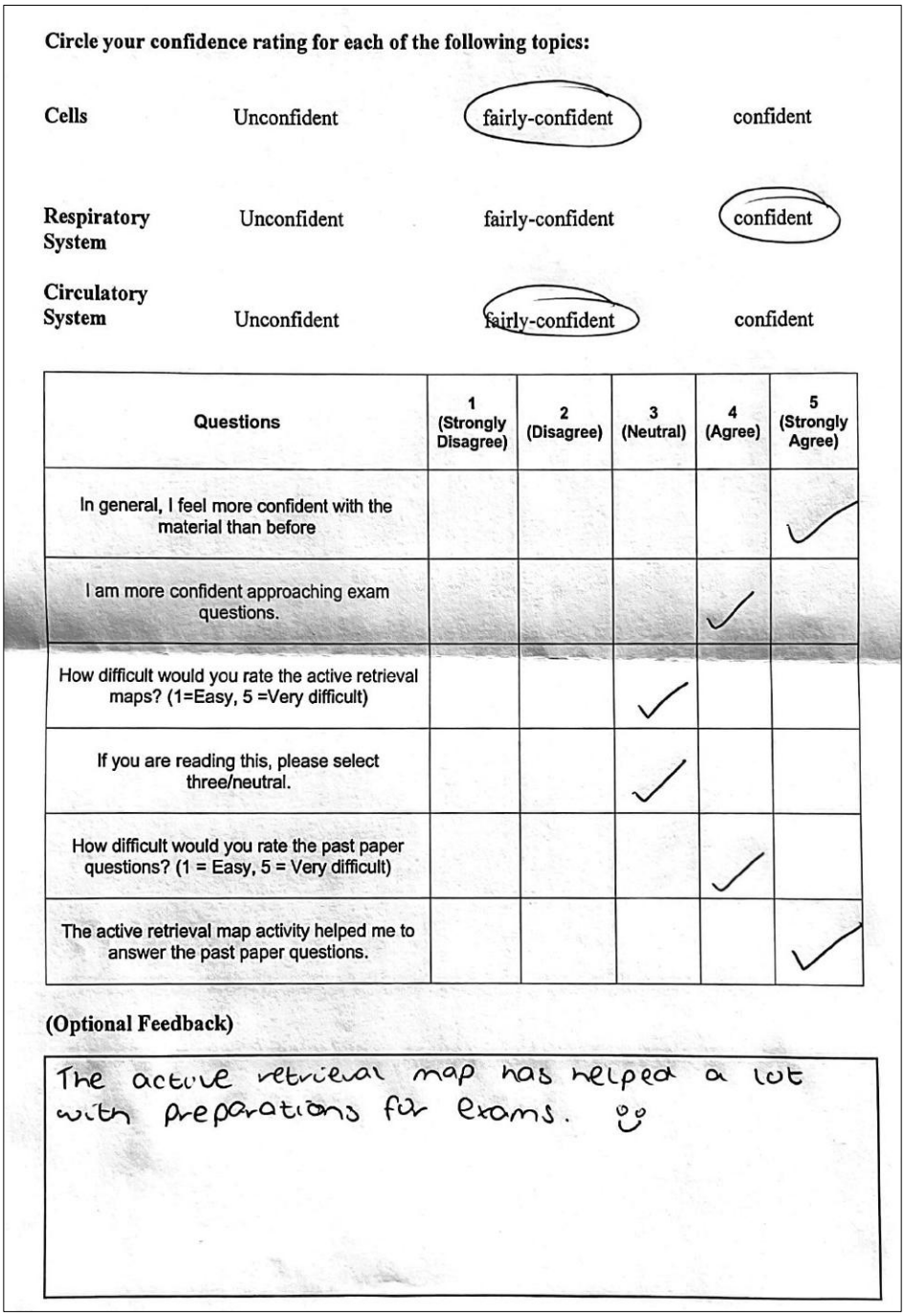

**Evidence Lesson 3D:** Example of a completed active retrieval map taken from the respiration and respiratory system active retrieval booklet. Boxes in green highlight retrieval map questions that match up with the example past paper questions seen below.




**Evidence Lesson 3E:** Example of a completed past paper question taken from the respiration and respiratory system active retrieval booklet.

# Lesson 4

*Follow-up Survey*



**Circle your confidence rating for each of the following topics:**

| | | | |
|---|---|---|---|
| **Cells** | Unconfident | fairly-confident | confident |
| **Respiratory System** | Unconfident | fairly-confident | confident |
| **Circulatory System** | Unconfident | fairly-confident | confident |

| Questions | 1 (Strongly Disagree) | 2 (Disagree) | 3 (Neutral) | 4 (Agree) | 5 (Strongly Agree) |
|---|---|---|---|---|---|
| In general, I feel more confident with the material than before | | | | | ✓ |
| I am more confident approaching exam questions. | | | | ✓ | |
| How difficult would you rate the active retrieval maps? (1=Easy, 5 =Very difficult) | | | ✓ | | |
| If you are reading this, please select three/neutral. | | | ✓ | | |
| How difficult would you rate the past paper questions? (1 = Easy, 5 = Very difficult) | | | | ✓ | |
| The active retrieval map activity helped me to answer the past paper questions. | | | | | ✓ |

**(Optional Feedback)**

The active retrieval map has helped a lot with preparations for exams. ☺

**Evidence Lesson 4A:** Example of completed anonymous survey. The survey indicated that from the perspective of the class the revision materials made them more confident with both the material and approaching exam questions. In the survey pupils were asked to rank the difficulty of both the active revision maps and past papers question sections. As expected, the difficulty of the active retrieval map was scored lower than the difficulty of the past paper questions. This indicates that the scaffolding of difficulty inspired by the guidance fading effect did occur. Furthermore, pupils on average ranked the active retrieval maps difficulty at 3/5 indicating that effortful practice was occurring, an important factor discussed surrounding the supply demand theory of neuroplasticity. Additionally, this effortful practice was in line with the ability of the pupils providing the most optimal conditions for plasticity to occur. Lastly, pupils generally agreed that the retrieval map questions presented a novel challenge and that the retrieval maps helped them in answering the past paper question. This evidence serves as another indication that the resource fulfilled its intentions.

# Supplemental Evidence

## Ethics Checklist

The Cardiff School of Education and Social Policy has adopted the British Educational Research Association's Ethical Guidelines for Educational Research, fourth edition (2018). The guidelines can be viewed by going to https://www.bera.ac.uk/researchers-resources/publications/ethical-guidelines-for-educational-research-2018.

| | |
|---|---|
| • I have familiarised myself with the BERA Ethical Guidelines. | ✓ |
| I undertake to:<br>• respect and protect the anonymity of the school, all participants and groups; | ✓ |
| • minimise any possible risk or disruption to the on-going life of the school, participants or groups; | ✓ |
| • explain the following to participants where relevant e.g. during data collection such as interviews, questionnaires, etc. | ✓ |
| • the purpose of the research; | ✓ |
| • the use to be made of the data; | ✓ |
| • that they have the opportunity to withdraw from the research at any time without prejudice; | ✓ |
| • provide evidence in my assignment that ethical considerations have been addressed. | ✓ |
| I have discussed the ethical implications of the research with my tutor, senior mentor and mentor. | ✓ |
| I have obtained consent to undertake this research from the Senior Mentor/Mentor at my Lead Partnership School. | ✓ |
| If photographs or videos have been included, the school has signed a "Written Permission to Use Photos or Videos" document. | ✓ |

*Please submit this form to your tutor*

*Make sure it has been signed and approved by your personal tutor and research champion.*

| | | |
|---|---|---|
| Signed: | (Student teacher) | Date: May 3, 2022 |
| Approved by: | | |
| | (Personal tutor) | Date: May 3, 2022 |
| | Senior Mentor/Mentor | Date: May 3, 2022 |

Cardiff Partnership for Initial Teacher Education | Partneriaeth Caerdydd ar Gyfer Addysg Gychwynnol i Athrawon

**Supplemental Evidence A:** Ethics form signed by my mentor, personal tutor and me.

## Partneriaeth Caerdydd ar gyfer Addysg Gychwynnol i Athrawon

### Written Permission to Use Photographs or Videos of a Child/Young Person for Academic and Professional Practice (to be issued by the Head Teacher)

Student teachers on ITE programmes at Cardiff Metropolitan University are required to undertake classroom-based research and enquiry and may, where appropriate, benefit from using media as evidence of learning. Student teachers are required to seek permission from their Head Teacher prior to this being undertaken and be fully aware of the pupils whose parents/guardians have not given permission to the school.

In line with the Cardiff Partnership Child Protection Policy and Student Teacher Code of Conduct, **written permission is required from schools for the use of photographs or videos** for academic and professional practice.

**Programme/Subject/Year:** PGCE Secondary Biology 2021/2022

**Student Teacher:** Mitchell Shiell

**School:** ~~Ead~~ Corpus Christi Catholic School

I agree to give permission for photographs or videos to be taken and used in support of student teachers' work whilst on their Initial Teacher Education programme.

**Signed (Head Teacher):** [signature] **Date:** 25/4/22

*An electronic copy of this form – with signatures - must be housed in the student teacher's Professional Learning Passport.*



**Supplemental Evidence B:** Written permission to use photographs or videos.