Designing an Evidence-Based Digital Study Platform Using Principles of Memory Science

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Abstract

Students often spend countless hours studying without knowing whether the strategies they use help them retain information. The purpose of this project was to identify the study strategies that are most strongly supported by research in cognitive neuroscience, cognitive psychology, and educational psychology and develop them into an educational technology prototype. Peer-reviewed studies, systematic reviews, and meta-analyses were examined using PubMed, PubMed Central, and Google Scholar to identify common elements of effective learning methods. Five principles were consistently identified: attention and encoding into memory, retrieval practice, spaced learning, corrective feedback, and metacognitive monitoring. These results led to the development of the NeuroLearn prototype, an interactive browser application with preset science questions, confidence ratings, corrective feedback, review recommendations, and progress tracking. NeuroLearn has not been tested with human participants and it therefore cannot be determined if the platform improves learning outcomes. Rather, it shows how memory research findings can be applied in everyday study software and provides a foundation for future evaluation with delayed retention results.

Keywords: retrieval practice; spaced learning; metacognition; educational technology; long-term retention; memory encoding

1. Introduction

1.1 Motivation

Every day, students spend hours studying, yet many still struggle to retain what they learn. Effective learning requires more than repeated exposure to information. Before a memory can be formed, information must first receive attention, be encoded, and later be strengthened through retrieval and continued review.

Despite the extensive scientific research on memory, many learners continue to rely on techniques such as rereading and highlighting because they feel productive. However, familiarity with information does not necessarily mean that it can be recalled later. Research in cognitive neuroscience, cognitive psychology, and educational psychology has consistently supported strategies such as retrieval practice, spaced learning, corrective feedback, and metacognitive monitoring as more effective approaches for long-term learning. However, these strategies are often presented individually rather than as components of a complete system for students to use.

This gap between memory research and everyday study habits is what motivated the development of NeuroLearn. NeuroLearn was designed not to promise better grades or learning outcomes, but instead as a proof of concept. It aims to combine several ways of improving memory into one educational resource.

Existing study platforms, including Quizlet and Anki, incorporate some evidence-based learning strategies. NeuroLearn was designed to integrate multiple complementary principles identified in the literature within a single study workflow rather than presenting them as separate study techniques.

1.2 Research Question

Which study strategies are most strongly supported by cognitive psychology and cognitive neuroscience research for improving attention, memory formation, and long-term retention in students?

This project explores how discoveries in cognitive psychology and memory research can be used to create new learning technologies for students. The research focuses on understanding the neural mechanisms and cognitive processes involved in information encoding, storage, and retrieval. The analysis guides the design of an interactive prototype, NeuroLearn, which combines the studied strategies to support learning.

2. Scientific Foundation and Literature Review

The concept of NeuroLearn is based on the findings of cognitive neuroscience, cognitive psychology and educational psychology. Rather than trying to develop novel ways of learning, the prototype adopts science-based strategies which affect attention, memory and retention. The following literature review summarizes the evidence directly relevant to the development of NeuroLearn.

2.1 Attention and Memory

In order for the information to be retained, it needs to gain enough attention to get encoded. Neuroimaging research has shown that successful encoding occurs through interactions between the hippocampus and the prefrontal cortex rather than a single "memory centre." In a review of 275 PET and fMRI studies, Cabeza and Nyberg found consistent involvement of these brain regions during attention, working memory, and episodic memory formation.[1] Similarly, Aly and Turk-Browne highlighted that information receiving focused attention was more likely to be successfully encoded into memory.[2] Research has also demonstrated that attention and memory interact closely during learning, helping determine which information is successfully encoded.[3] These results indicate that minimizing unnecessary distractions could help enhance the process of encoding. Consequently, NeuroLearn takes this knowledge into account and presents one question at a time, minimizing unnecessary distractions through visual information.

2.2 Retrieval Practice

In retrieval practice, learners are required to remember information from their memory before seeing the answer. Roediger and Karpicke's study on the testing effect demonstrated the advantages of retrieval practice over repeated studying.[4] While repeated study produced better performance outcomes immediately after learning, students who engaged in distributed retrieval had shown stronger retention one week later. Specifically, students who reread the material retained approximately 40% of the content, whereas those who practiced retrieval retained approximately 61%.[4] These findings demonstrate that strategies producing the strongest short-term performance are not always the most effective for long-term retention. For this reason, NeuroLearn requires learners to answer each question before feedback is given. Questions will keep appearing even after successful retrieval since learning information once does not end the reviewing process.

2.3 Spaced Learning

Learning is also influenced by when material is reviewed. Instead of focusing all studying in one session the day prior to the test, spaced practice involves reviewing in several different sessions. A large meta-analysis by Cepeda and colleagues examined 317 experiments and 839 comparisons and found that distributed practice consistently produced better long-term retention than massed practice.[5] More recently, a 2025 meta-analysis involving more than 3,000 learners reported a moderate improvement in learning through spaced review, further supporting the benefits of spacing.[6] NeuroLearn has adopted this technique by scheduling weaker/unknown content for earlier review sessions and postponing stronger content to later review sessions based on these results.

2.4 Feedback and Metacognitive Monitoring

Successful learning depends not only on retrieving information, but also on recognizing what is and is not understood. Corrective feedback prevents errors from being reinforced, while metacognitive monitoring helps learners judge the accuracy of their own knowledge. Butler, Karpicke, and Roediger found that providing corrective feedback substantially improved later retention, particularly for answers that were originally given with low confidence.[7] It means that mere accuracy cannot be used as a measure of true learning, since an accurate response could be either due to real learning or luck. Confidence judgments are widely used as measures of metacognitive monitoring and help distinguish genuine understanding from uncertainty.[8] Research has also shown that learners frequently stop retrieval practice too early when directing their own studying, even though continued retrieval would improve long-term retention.[9] To address this, NeuroLearn asks learners to rate their confidence before receiving feedback. Confidence, along with accuracy, will then be used to determine what areas need further review.

Table 1. Accuracy and confidence rules used by NeuroLearn

Accuracy	Confidence	Prototype interpretation	Review priority
Correct	High	Relatively secure response	Low
Correct	Low	Possible uncertainty or guessing	Medium-high
Incorrect	Low	Recognized uncertainty or knowledge gap	High
Incorrect	High	Possible misconception or uncertainty	Highest

The priority which is chosen by the algorithm determines how frequently and soon the concepts return for review. Concepts identified as weaker or uncertain will be again for review, other concepts which demonstrate stronger memory are reviewed after longer times. This rule-based scheduling represents a simplified implementation of the evidence reviewed in this paper rather than a validated adaptive learning algorithm.

3. Methods

3.1 Research Design

This project used a structured rapid-review and evidence-translation design. Instead of testing the effectiveness of a particular learning intervention on human participants, this project attempted to operationalize the conclusions of previous research studies in the design of the prototype. As such, the scope of the project was limited to determining the study strategies that have been shown to be most effective for improving memory, not original evidence that NeuroLearn improves learning.

3.2 Literature Review

Peer-reviewed literature was collected from PubMed, PubMed Central (PMC), and Google Scholar between July 13 and July 15, 2026. Search combinations included: (retrieval practice OR testing effect) AND (learning OR retention); (distributed practice OR spaced learning) AND retention; corrective feedback AND learning; (metacognition OR confidence judgment) AND learning; and attention AND encoding AND memory. Additional search terms included *working memory, cognitive load, educational neuroscience,* and *long-term retention*.

Studies were included if they met the following criteria:

- published in English in a peer-reviewed source
- involved human learners
- used an experimental design, systematic review, or meta-analysis
- are related to learning, recall, retention, feedback or even metacognitive monitoring
- are published between 2000 and 2025, except for foundational work
- contained findings that could be translated into a prototype feature

Studies that were excluded included articles presenting opinions or non-peer reviewed reports, focused primarily on clinical rehabilitation or non-human models, reported outcomes irrelevant to learning or memory, or provided insufficient information about at least one software feature. Initially, titles and abstracts were screened for eligibility. Following that, the most relevant publications were selected for full-text screening. A total of 35–45 items were screened, and 10 top publications were chosen to build the evidence map.

3.3 Study Quality and Evidence-Confidence Grading

Each learning principle was assigned an evidence-confidence grade based on four criteria:

1. study design and level of evidence;
2. consistency of findings across studies;
3. directness of the evidence to the proposed feature;
4. relevance to student learning and delayed retention.

Table 2. Evidence-confidence rubric

Grade	Criteria used in this report
High	Meta-analysis or systematic synthesis as well as consistent controlled evidence which is a direct link to delayed learning or retention.
Moderate	Multiple peer-reviewed experiments or a strong review, but with limits in directness, population, setting, or implementation.

Indirect	Design inference, isolated evidence, or a feature not directly evaluated by the included learning studies.

Evidence-confidence grading criteria were used for all key articles referenced in this review. Both retrieval practice and spaced learning have been graded highly due to the presence of experimental and meta-analysis evidence. The attention principle, corrective feedback, and metacognitive monitoring have been rated moderately due to strong but indirect evidence on their effectiveness in implementing educational software. This evidence reflects the confidence in the underlying theory not in the validation of NeuroLearn itself.

3.4 Prototype Development

The findings from the literature review were organized into five research-supported principles: attention and memory encoding, retrieval practice, spaced learning, corrective feedback, and metacognition. Retrieval practice was implemented by requiring learners to answer each question before viewing the correct response. Metacognition was incorporated through confidence ratings completed before corrective feedback was displayed. Review recommendations were determined using the learner's answer accuracy together with confidence ratings, allowing weaker concepts to return sooner than stronger ones. The progress statistics and review priorities were updated after every completed question to promote self-regulated learning.

Answer accuracy and confidence ratings jointly determine review priority. Concepts answered incorrectly or with low confidence are scheduled for earlier review, while concepts answered correctly with high confidence are reviewed after longer intervals.

The prototype was implemented as a browser-based application using a preset bank of science-related questions, and no personal information was necessary to participate in the current prototype. The application only stores learning data such as answers, confidence levels, review priorities, and progress within the browser. The prototype also incorporates various accessibility features such as consistent navigation across different sections, readable font sizes, descriptive alt text for images, keyboard shortcuts, and a clean and simple layout that minimizes distractions and cognitive load. However, note that while these accessibility considerations were designed into the prototype, it was not actually tested for compliance with established accessibility standards.

4. Prototype Design and Technical Output

4.1 Prototype Output

The final prototype of NeuroLearn is an online study platform featuring preset questions on a science-related topic, which allows students to answer the questions, assess their confidence in their answers, and receive both immediate corrective feedback as well as suggestions for when to review the material. A review queue and progress dashboard track the students' performance, confidence level, material review suggestions, and progress through the material. Demonstration data are built into the final prototype, and the progress dashboard is dynamic, updating as more questions are completed. A publicly accessible version of the prototype was developed to demonstrate the features of a complete study platform (Appendix A).

4.2 Applications of Research into NeuroLearn's Features

Each major feature of NeuroLearn was developed from evidence identified in the literature review. The relationship between the supporting evidence and the corresponding prototype features is summarized in Table 3.

Table 3. Application of Memory Research in NeuroLearn

Evidence Based Principle	**Supporting Evidence**	**NeuroLearn Implementation**
Focused attention supports effective encoding.	Attention and memory research shows that reducing distractions improves encoding.[1-3]	One question is displayed at a time using a simplified interface with minimal distractions.
Retrieval practice strengthens long-term retention.	Retrieval practice consistently outperforms repeated study on delayed retention tests.[4]	Learners answer each question before viewing the correct response and explanation.
Spaced review improves long-term retention.	Distributed practice consistently outperforms massed practice across multiple meta-analyses.[5,6]	Review recommendations prioritize weaker concepts for earlier review while delaying stronger concepts.
Corrective feedback improves learning.	Immediate feedback reduces misconceptions and improves later retention.[7]	Corrective feedback and explanations are displayed immediately after every response.
Metacognitive monitoring supports self-regulated learning.	Confidence judgments help distinguish genuine understanding from uncertainty.[8,9]	Learners rate their confidence before feedback, and confidence contributes to review priority.

Note. This table summarizes the evidence supporting each learning principle. It does not validate the effectiveness of NeuroLearn itself.

4.3 Project Outcome

This project demonstrates one possible application of current research on human memory within educational technology. Rather than demonstrating improved learning outcomes, NeuroLearn illustrates how evidence-supported principles from cognitive neuroscience, cognitive psychology, and educational psychology can be translated into a functional educational tool. The prototype provides a foundation for future controlled evaluation using measures of immediate recall, delayed retention, and long-term learning.

5. Discussion

The literature reviewed for this project indicated that the five learning principles are attention, encoding, retrieval practice, spaced learning, and corrective feedback. These principles and other studies' results support the idea that learning is most effective when combined with additional related strategies, as opposed to passive studying. The project addressed the research question by indicating which study methods have the most evidence supporting them in cognitive neuroscience and psychology and how to combine them. Instead of postulating a unified learning theory, it suggests a list of methods that have been proven to be effective and can be combined into a single educational software program.

One of the project's strengths is that the software was designed based on peer-review studies and meta-analyses. However, since the target population was not tested, the only conclusion that can be made is that the design reflects the existing research. The software implementation can be seen as a concept showing how the results of memory studies can be applied in the real world.

The current version of the NeuroLearn software is also limited as it uses a built-in question bank and test data instead of real-time user input. It also assumes that learners answer honestly and that confidence ratings accurately reflect their understanding. Correct answers produced through guessing, inaccurate confidence ratings, or differences in individual learning patterns may reduce the accuracy of review recommendations. Additionally, it should be noted that this review only included articles published in English, and there may be relevant research in other languages that was not analyzed. The suggestions for future research include conducting the control experiment with the target population and implementing the changes mentioned above while adding more functionality. The essential measurements will be the performance of the target population after a single session, retention after seven and 28 days, and the long-term retention of information.

6. Conclusion

This project identified five learning principles consistently supported by research in cognitive psychology: attention and memory encoding, retrieval practice, spaced learning, corrective feedback, and metacognition. Based on the results, a prototype of an interactive browser-based study platform called NeuroLearn was created. The platform was designed to illustrate how findings from memory research could be applied in a real-time educational setting.

It is important to note that the prototype was not tested with human subjects since it was only built to demonstrate how elements discovered in research could support learners. Additionally, the platform included a set of predesigned material for study and did not offer personalization. Therefore, further research on the effectiveness of the prototype on human subjects should be conducted. Future studies should explore the development of the software to allow users to personalize their learning and include automated question banks.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics Statement

Ethics approval was not required because the data were publicly available.

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Appendix A. NeuroLearn Prototype

Prototype Link – NeuroLearn (Interactive Prototype): https://neurolearn-ten.vercel.app/

The prototype shows the studying techniques proposed in this paper using a preset bank of science-related questions. Users can answer questions, rate confidence, receive immediate feedback, view recommended review intervals, and monitor their progress through the dashboard. The current prototype only serves as a proof of concept and does not support the user's own study material and question generation just yet, however that is a future plan.

Figure A1. NeuroLearn Question Interface

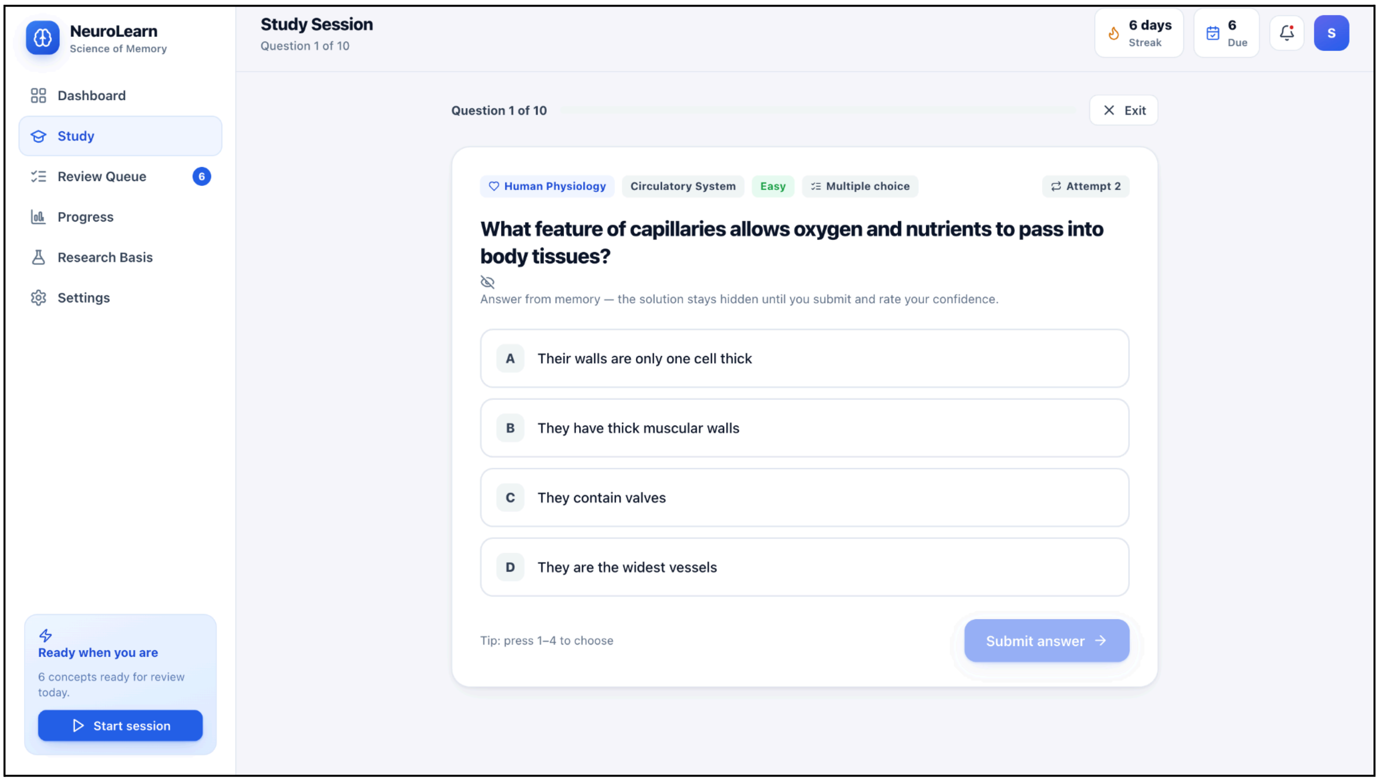

Figure A1. *Learners answer a preset science-related question before viewing the correct response, applying retrieval practice.*

Figure A2. Confidence Rating and Feedback

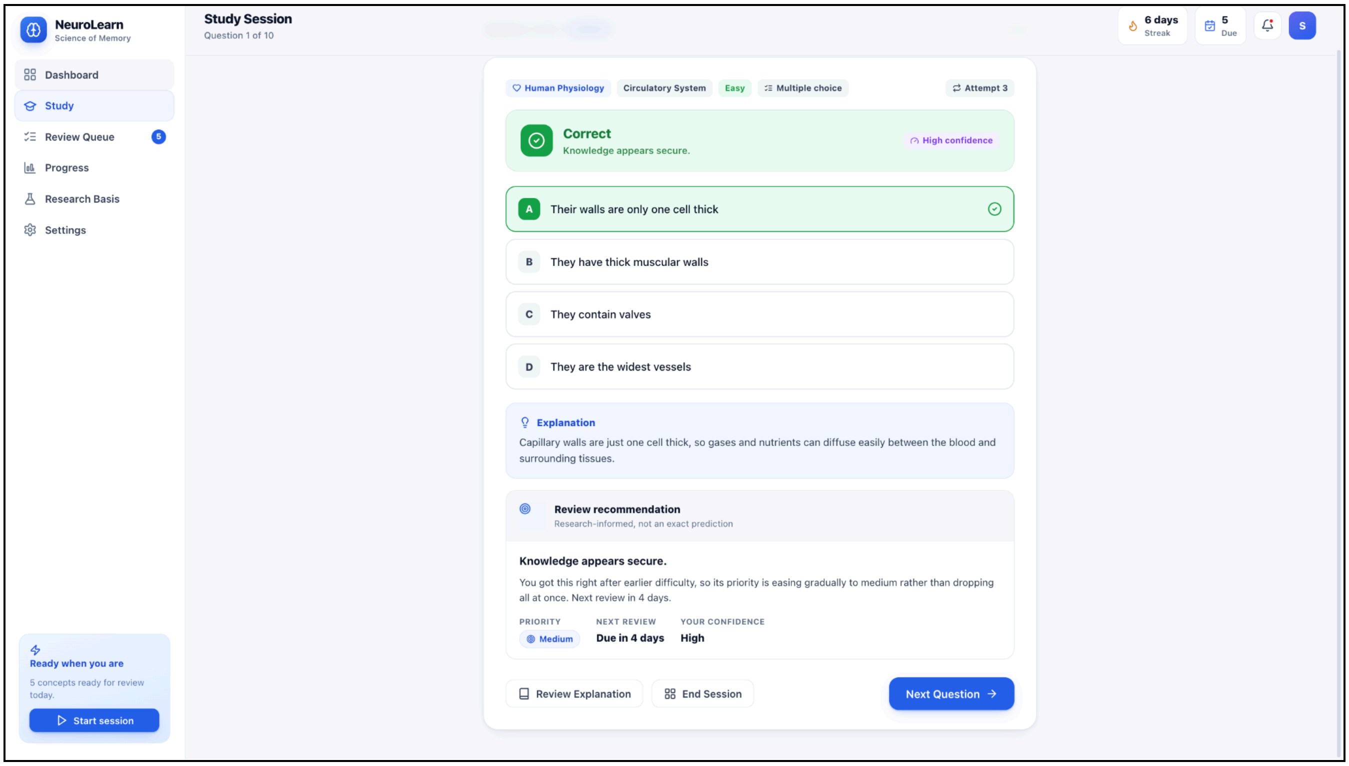

Figure A2. *After submitting, learners assess their confidence before receiving immediate corrective feedback and a brief explanation.*

Figure A3. Review Dashboard

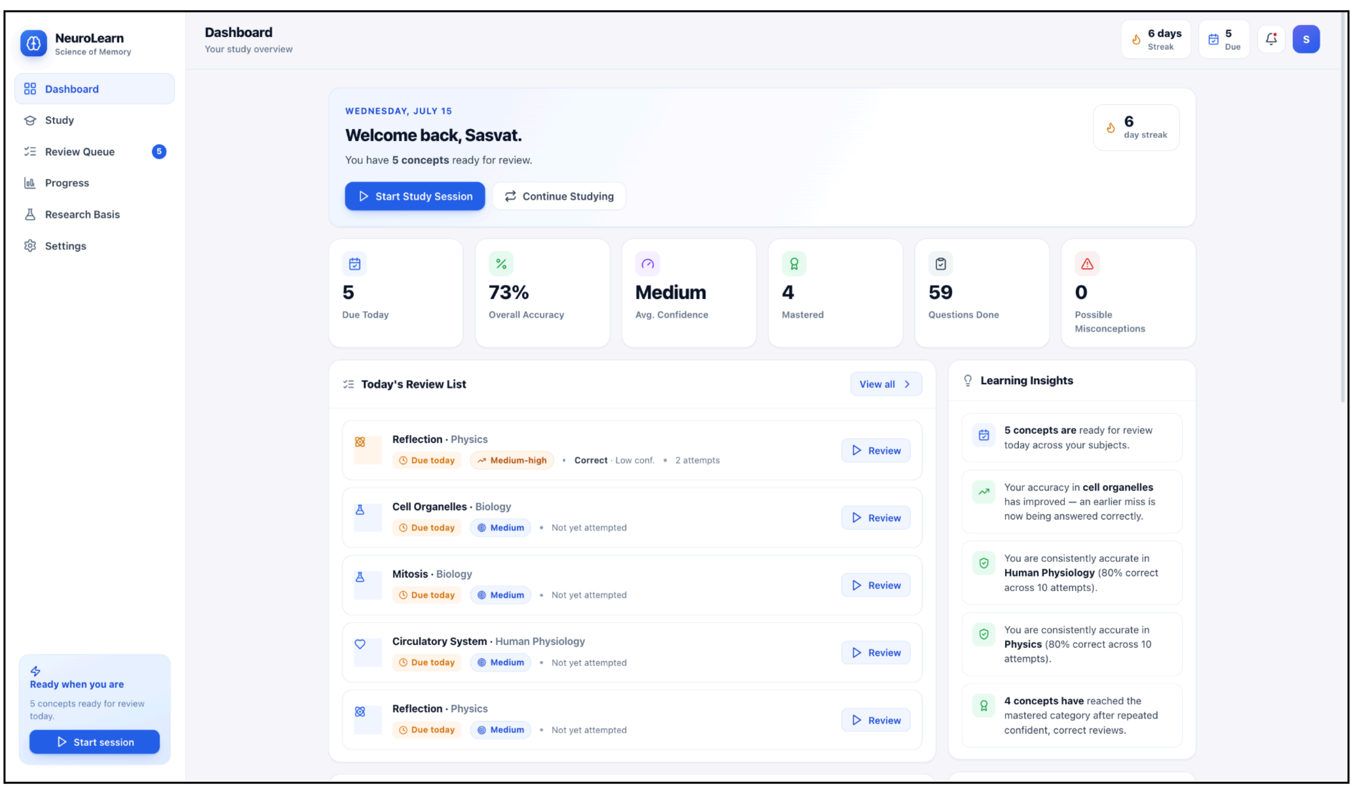

Figure A3. *The review dashboard is the page that users see to have a simplified view over all their tasks and studying materials.*

Figure A4. Progress Page

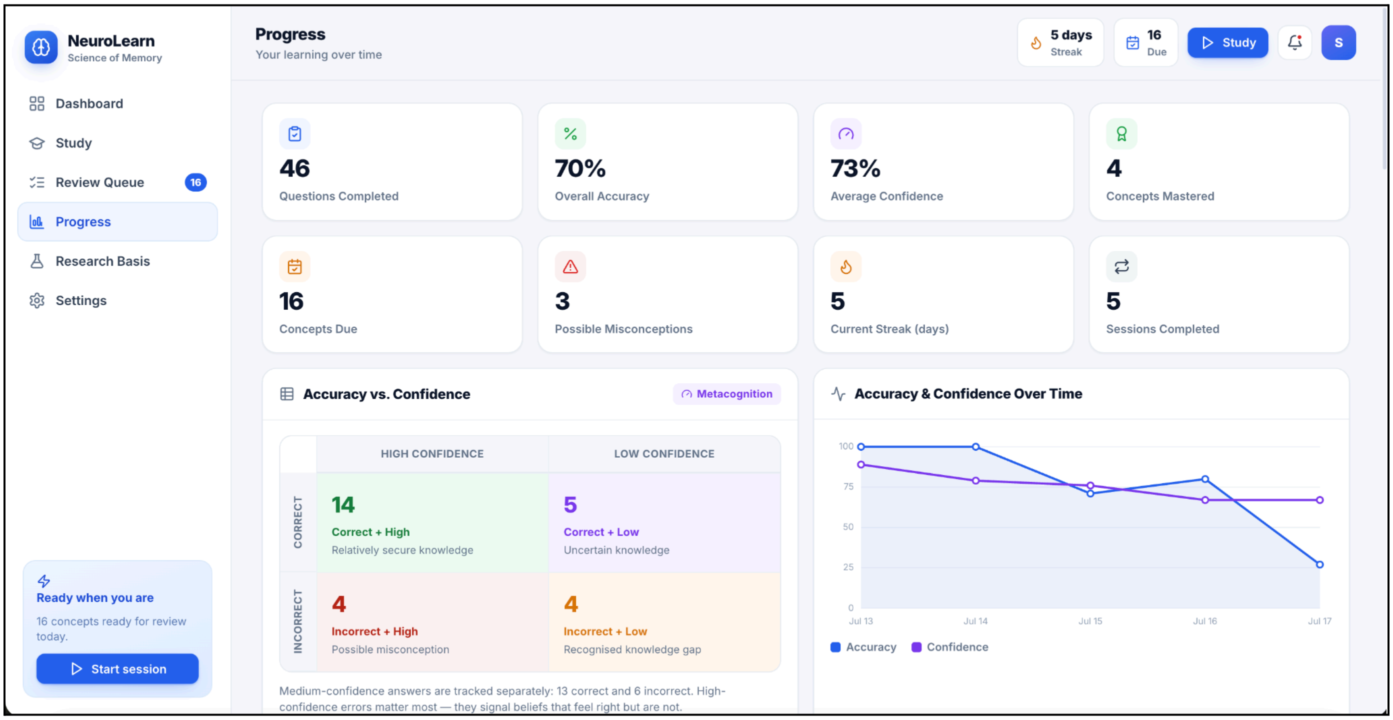

Figure A4. *The progress page summarizes learner performance, review priorities, and overall study progress.*