

IMPACT OF AI-ASSISTED SECONDARY SCIENCE LEARNING AND METACOGNITIVE
STRATEGIES ON STUDENT PERFORMANCE

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

June 2026

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DEDICATION

This work is dedicated to my students, whose curiosity, resilience, and honesty about their learning continue to inspire me every day.

To my family, thank you for your unwavering love, patience, and support throughout this journey.

I also dedicate this project to the mentors and colleagues in the MSSE program who challenged my thinking and encouraged me to grow as both a teacher and a researcher.

ACKNOWLEDGEMENTS

I would like to acknowledge the students in my 9th-grade biology classes, whose openness, curiosity, and willingness to experiment with new study tools made this project possible and meaningful.

I am deeply grateful to the faculty and staff of the Montana State University Master of Science in Science Education program, especially Professor Walter Woolbaugh, Ms. Robyn Klein, Holly Thompson Reed, and my committee members, for their guidance, feedback, and steady encouragement throughout this work. Ms. Robyn Klein served as my science reader, and I am grateful for her thoughtful feedback and support. Professor Woolbaugh's mentorship in action research and Holly Thompson Reed's pivotal support and guidance is invaluable throughout the capstone process.

Special thanks are due to my colleagues and administrators at my school for supporting classroom data collection, technology integration, and schedule flexibility while this action research was implemented. Their insights and collaboration helped strengthen both the study design and my understanding of student learning.

I also wish to thank my family, especially my mom and dad, whose deep belief in the value of education and steady encouragement to keep learning have guided me for many years. Their example and the time, love, and effort they invested in me and my brother continue to shape the way I approach my work and my teaching. I am equally grateful to my friends for their patience, understanding, and unwavering support during the long evenings, weekends, and summers devoted to coursework, teaching, and writing.

This project was supported in part by professional development resources provided through my school district and the Montana State University MSSE program.

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GLOSSARY

AI – Artificial Intelligence; software systems that perform tasks typically requiring human intelligence, such as language processing, pattern recognition, or decision support, including tools like chatbots and recommendation systems.

AI-assisted studying – The use of AI tools (e.g., LLMs, adaptive quiz generators) to support planning, practice, feedback, and review during independent study.

AR – Action Research; a cyclical process in which educators systematically plan, act, observe, and reflect to improve practice and student outcomes in their own contexts.

Cognitive debt – The accumulated cost of repeatedly outsourcing thinking and production to AI tools, which can weaken independent reasoning, memory, and sense of ownership over work over time.

Cognitive offloading – The practice of using external tools or resources to reduce the mental load of storing information or performing routine operations so that attention can focus on higher-order thinking.

Comparative cohort – The group of students in this study who receive explicit instruction in traditional, non-AI study strategies and use those methods as their primary study supports.

CEQ (Classroom Experience Questionnaire) - A teacher-designed composite scale that aggregates students' Likert-style responses about their in-class experience during a unit, including items on perceived preparedness, effectiveness of study methods, and the extent to which class tools or materials helped them see what they did and did not understand.

ELL – English Language Learner; a student who is developing proficiency in English in addition to proficiency in one or more other languages.

Exploration (in studying) – Trying new strategies, representations, or question types—often with AI support—to broaden understanding, test ideas, or discover more effective ways of learning.

Exploitation (in studying) – Repeatedly relying on familiar strategies or AI outputs that feel efficient or comfortable, sometimes at the expense of deeper processing or skill development.

ICR – In-Class Resource; a co-taught classroom model in which a general education teacher and a special educator share responsibility for instruction, differentiation, and support within the same section.

IEP – Individualized Education Program; a legally mandated plan that outlines special education services, goals, and accommodations for an eligible student with a disability.

LASSI – Learning and Study Strategies Inventory; a standardized instrument that measures students' use of strategies related to time management, self-testing, motivation, and other aspects of self-regulated learning.

LLM – Large Language Model; a type of AI trained on large text datasets to generate and interpret human-like language, used here for explaining concepts, generating questions, and supporting study planning.

Metacognitive strategies – Deliberate approaches for planning, monitoring, and evaluating one's learning, such as setting goals, checking understanding, and reflecting on the effectiveness of study methods.

MSSE – Master of Science in Science Education; the graduate program under which this capstone action research project is conducted.

SNAP – Supplemental Nutrition Assistance Program; a U.S. federal program that provides food-purchasing assistance for eligible low-income individuals and families.

Self-regulated learning (SRL) – A cyclical process in which learners set goals, select and apply strategies, monitor progress, and adjust their approaches based on feedback and reflection.

ABSTRACT

This action research project compared 9th-grade students who rely on traditional study methods such as note-taking, retrieval practice, and concept mapping, with students who were taught how to use LLM-based tools to set study goals, self-monitoring and self-regulating habits. Artificial intelligence (AI) software can be valuable adjunct in science classrooms to promote personalized learning and to support metacognitive skill development. Large language models (LLM) can assist students in grasping concepts, generating questions, and optimizing study planning. Over a twelve-week treatment, the AI cohort was given three LLM models to choose from and then shown how to train these programs to help the student study the unit materials. The traditional cohort was given explicit training and structure on non-ai study methods. Most of the existing research in the literature has been conducted on university students, with few examples of high school science students. This project bridges this gap by implementing AI tools in the classroom and showing how LLM models can support self-regulation learning, time management and self-testing for early high school students. The results showed that AI-assisted helped a lower-starting AI cohort nearly match the final performance of a higher-starting traditional cohort. AI-based self-testing showed more rapid increases in confidence, perceived preparedness, and active recall routines. AI-assisted studying helped a lower starting cohort narrow the achievement gap in optimizing study techniques. These findings can inform effective strategies for implementing study skills for 9th grade students.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Research Topic and Significance

My action research (AR) project examines how high school biology students use artificial intelligence (AI), specifically large language models (LLMs), to personalize study materials and how this affects their study habits, summative assessment performance, and overall learning effectiveness. LLM-powered tools can provide adaptive feedback, on-demand quizzes, and personalized study pathways, but their impact depends on how well students use metacognitive strategies such as self-monitoring, goal setting, and self-regulation (Benson, 2022; Zimmerman, 2002) alongside exploration.

This AR project compares students who use LLM-based tools with those who rely on “traditional” study methods (such as note-taking, retrieval practice, and concept mapping) and investigates how explicitly teaching metacognitive strategies: goal setting, self-monitoring, and self-regulation, can help both groups study more productively rather than passively, ultimately deepening their understanding and improving biology outcomes.

In this AR project, I use the terms LLM and AI interchangeably when referring to AI-driven conversational tools. Existing research on AI in education focuses on university students, with growing but still limited work in secondary contexts, especially around AI-based study techniques in high school science (Joseph et al., 2024; Jantaraweragul et al., 2021; Ward et al., 2024). My study addresses this gap by asking whether explicit instruction in metacognitive strategies helps students engage meaningfully with AI tools so that they retain content more

effectively and improve their biology assessment performance (Benson, 2022; Griffin et al., 2012; Zimmerman, 2002).

This AR work matters for my teaching practice, my students, and broader educational communities. For my own practice, the project refines how I integrate technology in my classroom to foster self-regulated learning, to scaffold time management, self-testing, and strategic review rather than replace thinking (Benson, 2022; Zimmerman, 2002). I am particularly interested in whether AI can support healthy cognitive offloading—using tools to reduce unnecessary cognitive load—without tipping into cognitive overload or over-reliance, where students allow the system to do too much of the planning, explaining, or sense-making for them (Chirayath et al, 2025; Kosmyna et al., 2025). Liljedahl (2020) argues that meaningful learning depends on preserving student agency and autonomy; if students are given the intellectual freedom to make choices, explore paths, and own their confusion, they develop deeper understanding than when answers are simply handed to them (Liljedahl, 2020).

For my students, the intervention is designed to increase independence, motivation, and achievement by giving them tailored study support that adapt to individual strengths and needs. AI-based studying can deliver immediate feedback on practice questions and explanations, addressing learning gaps more quickly than traditional feedback cycles where comments may arrive days after confusion first appears (Ward et al., 2024). In past units, many students admitted waiting until the night before tests to review—one shared, “I always just try to memorize the study guide the night before, but I forget most of it after the test” a pattern that contributes to inconsistent performance and weak long-term retention. Breaking this cram-and-forget cycle

through structured AI-supported self-testing and planning is a central motivation for the AR project (Griffin et al., 2012; Hefferon & Levina, 2024).

At a broader level, this AR study can inform colleagues who are navigating how to bring AI and LLMs into science or text heavy classrooms in ways that promote personalized learning and support metacognitive skill development rather than widen existing inequities (Joseph et al., 2024; Ward et al., 2024). Recent work on cognitive offloading shows that AI tools can either scaffold resilience and critical thinking or create cognitive overload and dependency, depending on how they are designed and used (Chirayath et al., 2025). Likewise, studies of “cognitive debt” during LLM-supported writing suggest that heavy over-exploitation of AI—repeatedly delegating complex thinking to the model—can weaken independent problem solving and sense of ownership over work (Kosmyna et al., 2025). By explicitly teaching students when and how to use AI for exploration (trying new question types, explanations, and representations) and when to pull back from over-exploitation, this AR project seeks to model classroom practices that harness AI’s benefits while guarding against these risks (Chirayath et al., 2025; Kosmyna et al., 2025).

Statement of Purpose and Research Questions

The purpose of this action research (AR) project is to evaluate how high school biology students’ use of AI, specifically large language models (LLMs), to personalize studying, following explicit instruction on AI-based study techniques, affects their summative assessment performance and self-regulated study habits. This AR project is grounded in the belief that integrating AI tools can scaffold essential learning strategies such as time management, self-testing, and goal-setting, which prior work has linked to academic success and equity in diverse classrooms (Griffin et al., 2012; Hefferon & Levina, 2024; Zimmerman, 2002).

Main Research Question

How does the use of AI-assisted studying, after targeted instruction on AI-based study techniques, affect high school biology students' summative assessment performance and self-regulated study habits?

Sub-Questions

1. How does AI-assisted learning influence students' knowledge retention and comprehension in science education?
2. How does students' use of AI impact their study habits and self-regulation, including their balance between exploration (trying new strategies) and exploitation (reusing familiar approaches)?
3. To what extent do metacognitive interventions improve AI-assisted learning outcomes in terms of both process (e.g., strategy use, confidence) and performance?
4. How do AI tools influence students' time management and self-testing behaviors, using LASSI subscales and related constructs as a framework for measuring change?
5. How do students' perceptions of AI utility—including perceived cognitive offloading benefits and concerns about over-reliance—correlate with their summative assessment performance?

Settings and Demographics

Biology, with a total of eighty-five students aged 14–15. The student population is 78% White, 8% Asian, 8% two or more races, 8% Hispanic or Latino, 6% Black or African American,

and 4% other races. Approximately 2.3% of families are below the poverty line, and 2.9% receive food stamps/SNAP benefits.

Treatment and comparative groups were assigned randomly across these four sections. In total, thirty-seven students receive special education services through Individualized Education Programs (IEPs) or Section 504 accommodation plans, and three students are classified as English Language Learners (one Japanese, one Indian, and one Ecuadorian). These supports and language needs are distributed across both treatment and comparative cohorts.

Three sections in in-class support (ICR) are co-taught, and one section is taught by a single teacher, allowing comparisons across instructional models while maintaining consistent course expectations. Both comparative and treatment groups receive equivalent instructional time, pacing, and unit content; the primary difference is that comparative groups receive explicit instruction and structured use of AI-supported studying, whereas the treatment group receives explicit instruction focused on traditional study methods. Co-teaching supports, accommodations, and classroom routines are kept as parallel as possible, and any meaningful variations are documented and considered during analysis.

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Introduction

The reviewed studies provide a strong foundation for understanding AI-assisted learning, metacognitive strategies, and active learning approaches. Researchers consistently emphasize self-regulated learning, digital literacy, and the thoughtful integration of AI tools as key drivers of effective learning with technology (Griffin et al., 2012; Hefferon & Levina, 2024; Joseph et al., 2024; Zimmerman, 2002). At the same time, most existing work has been conducted with university students, which leaves important questions about how AI-supported and metacognitive interventions should be designed, scaffolded, and assessed in high school science classrooms (Benson, 2022; Jantaraweragul et al., 2021; Joseph et al., 2024).

Literature Review Summary

Three peer-reviewed sources provide key insights into AI-driven personalized learning, digital literacy, and metacognitive interventions. Hefferon and Levina (2024) showed that metacognitive interventions in college science courses significantly improved student performance, with students who used six or more study strategies outperforming peers who relied on fewer techniques (Hefferon & Levina, 2024). Their work underscores self-monitoring, active planning, and self-evaluation as critical elements of effective study, aligning closely with the self-regulated learning focus of this action research project (Zimmerman, 2002).

Joseph et al. (2024) examined digital literacy and AI tool use among 409 university students in India, reporting a strong correlation between digital literacy and effective use of AI tools for learning ($r = 0.628$). They also found that peers-supported collaborative learning mediated this relationship, suggesting that students benefit most from AI when they can discuss and co-construct understanding with others while using these tools (Joseph et al., 2024). This highlights the importance of coupling AI-assisted study with explicit instruction and collaborative structures rather than assuming that access to tools alone is sufficient.

Jantaraweragul et al. (2021) investigated AI-supported project-based learning in STEM contexts and found that AI scaffolds increased student engagement, problem-solving skills, and self-regulation over time. Their interdisciplinary design showed how AI can support task management, iterative feedback, and adaptive strategy use when embedded in rich, inquiry-driven learning environments (Jantaraweragul et al., 2021). Collectively, these studies suggest that AI-assisted learning is most powerful when paired with metacognitive supports, strong digital literacy, and collaborative or project-based structures, conditions this high school AR project seeks to adapt for a 9th-grade biology setting.

In addition to these benefits, recent work on cognitive offloading and cognitive debt complicates how educators should think about AI-assisted learning. Cognitive offloading describes using tools to externalize memory or routine processing so that learners can focus on higher-order thinking, while overreliance can slide into “cognitive debt,” where repeated delegation of core tasks to AI weakens independent reasoning and retention over time (Chirayath et al., 2025; Kosmyrna et al., 2025). These studies also highlight an exploration–exploitation tension: students can use AI to explore new explanations, representations, and problem types, but

they may also be tempted to repeatedly exploit convenient outputs instead of engaging in effortful sense-making. This literature suggests that effective classroom use of LLMs requires explicit guidance on when to lean on AI for exploration and when to withhold it so that students practice core skills without accumulating cognitive debt (Chirayath et al., 2025; Kosmyna et al., 2025). Liljedahl (2020) reinforces this concern: his research on thinking classrooms argues that student independence and autonomy are non-negotiable conditions for deep learning, not optional add-ons—a principle that applies equally to traditional study environments and AI-integrated ones, where outsourcing cognition is always one click away (Liljedahl, 2020).

Theoretical Frameworks

Self-regulated learning (SRL) provides the primary theoretical lens for this action research project. Zimmerman’s model conceptualizes learning as a cyclical process in which students set goals, monitor their progress, and reflect on outcomes to adjust future strategies (Zimmerman, 2002). In this project, large language models (LLMs) are positioned as scaffolds for each SRL phase: students use AI to articulate concrete learning goals, generate practice questions and explanations that support real-time monitoring, and then analyze post-assessment results to evaluate which strategies were most effective. The goal is not for AI to replace SRL, but to make goal-setting, self-monitoring, and reflection more visible and accessible for 9th-grade learners.

The Learning and Study Strategies Inventory (LASSI) framework further shapes the design of the intervention. Griffin et al. (2012) found that subscales such as time management, self-testing, use of study aids, and motivation correlate strongly with academic performance, suggesting that targeted support for these skills can improve outcomes. In this study, AI tools are

aligned intentionally with these dimensions: students use LLMs to create structured study schedules, generate on-demand quizzes for self-testing, and build customized study guides, while reflections and check-ins prompt them to consider how these strategies affect their motivation and confidence. Taken together, the SRL cycle and LASSI framework provide a theoretical backbone for using AI to strengthen and not shortcut students' learning and study skills.

Synthesis and Application

Despite the university-level focus of much existing research, these studies offer strategies that can be adapted for younger learners, such as explicitly teaching metacognitive routines, structuring collaborative use of AI tools, and embedding reflection prompts into content learning (Benson, 2022; Hefferon & Levina, 2024; Joseph et al., 2024). This project bridges that gap by implementing metacognitive interventions with AI tools in a 9th-grade biology setting, extending the AI-and-metacognition framework to secondary education and examining how large language models can support self-regulated learning, time management, and self-testing for early high school students.

CHAPTER THREE

METHODOLOGY

Description of Treatment

This intervention evaluates how explicit instruction in AI-based study techniques, paired with multiple AI tools, influences students' study effectiveness and summative assessment performance across two to three biology units. Grounded in the LASSI framework, the treatment targets time management, self-testing, information processing, and the strategic use of study aids as core levers for improving self-regulated learning and achievement.

Both cohorts receive equivalent unit content, pacing, and formative assessment opportunities to keep instructional exposure as parallel as possible. The primary difference lies in the study supports emphasized: the treatment cohort receives explicit training and structured expectations for AI-assisted studying, while the comparative cohort receives explicit training and structure around traditional, non-AI study methods. In earlier units, students are encouraged to use their assigned methods primarily outside of class; in the focal unit, each cohort also receives protected in-class study time before the unit test dedicated to practicing its designated methods.

AI tool integration centers on using large language models and related platforms as study partners rather than answer engines. Students in the AI cohort primarily work with Perplexity and NotebookLM to generate adaptive quizzes, create targeted concept summaries, and build personalized study schedules that respond to their formative assessment performance, with many also choosing to supplement their studying with Quizlet; a smaller number of students reported using Gemini during check-ins, but it played a secondary role compared with Perplexity,

NotebookLM, and Quizlet, which together formed the core AI-supported study toolkit for this intervention.

Instructional scaffolding for the treatment group includes two 45-minute sessions that introduce both AI tool use and foundational self-regulated learning (SRL) strategies. In these sessions, students practice entering specific study topics and question types into AI tools, interpreting and verifying AI outputs against trusted sources, and adjusting their study plans in response to performance data and perceived understanding. Reflection prompts and class discussions emphasize healthy cognitive offloading, meaning using AI to reduce friction and organize practice, while guarding against over-reliance, such as copying explanations without attempting independent reasoning.

Across the 12-week intervention period, both cohorts begin with two 45-minute onboarding lessons that mark the start of treatment: a shared initial session on core SRL routines, followed by a second, cohort-specific session in which the AI cohort is introduced to AI-assisted study routines and the comparative cohort receives parallel instruction in traditional, non-AI study methods. In the AI-specific session, students practice using platforms such as Perplexity and NotebookLM to upload or link their biology notes, teacher-provided study guides, and practice problems, generate targeted practice quizzes, and structure self-testing cycles that emphasize quizzing themselves, checking explanations, and revising prompts to better match their individual gaps. In the traditional-specific session, students rehearse applying active recall without AI by turning notes and study guide summaries into student-generated quizzes, creating and rotating through flashcards, and using peer quizzing and study guides to plan timed self-testing blocks and track which strategies feel most effective. Over the subsequent three biology

units, students in both cohorts consistently reinforce and refine their assigned study approaches during protected in-class study blocks and assigned out-of-class practice.

For teachers who want to replicate this comparative cohort (AI) treatment, the classroom routine can be framed as a simple sequence: first, teach core study and self-regulation skills such as planning, self-testing, checking for understanding, and revising weak areas; second, provide all students with a study guide and practice problems; third, model how to use common AI platforms to give feedback at a 9th-grade level rather than simply provide answers. Useful prompts already used in this study include: *“Create 10 multiple choice questions on [topic] for 9th grade biology with an answer key,” “Turn these notes into flashcards,” “Explain [topic] in simple terms with an example,”* and *“Give me feedback on this biology answer. Is it accurate and complete for 9th grade?”* To move students toward gap detection, teachers can also model prompts such as *“Using this study guide and these practice problems, quiz me one question at a time and do not give the answer until I respond,” “Tell me which topics I keep missing and what I should study first,” “Make me practice questions only on the parts I am weakest on,”* and *“Test me on this until I get 5 questions right in a row, and increase the intensity for every one I get right.”* From there, students can use AI to support time management, active recall, peer games, and more individualized feedback, while the teacher continually reminds them to verify answers against class notes, the study guide, and trusted course materials.

Research Methods and Data Collection

Multiple data sources are used to examine how explicit instruction in AI-supported study guides affects student performance and self-regulated learning habits. Core quantitative measures include pre- and post-unit tests for each biology unit and LASSI-aligned survey items that track

changes in time management, self-testing, use of study aids, and related SRL constructs over the intervention period (Griffin et al., 2012). For the AI cohort, basic AI usage analytics (e.g., frequency and type of AI-generated quizzes or summaries) complement these measures by documenting how often and in what ways students engage with tools such as Perplexity, NotebookLM, and Quizlet.

Qualitative data deepen this picture by capturing students' perceptions, strategies, and decision-making around studying with and without AI. Reflection journals and embedded check-in prompts invite students to describe when they turn to AI or traditional methods, how they handle distractions and procrastination, and how confident they feel about their understanding before assessments. Semi-structured interviews and small-group discussions provide opportunities to probe themes such as exploration versus exploitation of AI outputs, perceived cognitive offloading, and shifts in metacognitive awareness, allowing the study to connect observed performance patterns with students lived experiences of the intervention (Benson, 2022; Zimmerman, 2002).

Instrumentation and Validity

Core instruments include summative unit assessments, LASSI-aligned surveys with both Likert and open-ended items, AI usage analytics for the treatment cohort, embedded reflection prompts delivered via Google Forms, and semi-structured interviews. To strengthen validity, the study employs methodological triangulation (combining test scores, survey data, usage logs, and qualitative reflections), multiple regression analyses to explore relationships among SRL constructs and performance, and iterative qualitative coding of open-ended responses. Member checking with student focus groups is used to confirm emerging interpretations, and all data are

stored securely under anonymized IDs to protect confidentiality and reduce social desirability pressure in student responses.

Data Collection Schedule and Matrix

Data collection spans approximately 12 weeks and three instructional units in 9th-grade biology. Each unit includes a pre-test and post-test, along with LASSI-aligned survey items and either AI usage analytics (for the AI cohort) or study-method tracking (for the comparative cohort) to document how students are actually studying between assessments. Check-ins occur roughly two weeks before, one week before, and the school day prior to each unit test, using brief reflection prompts to capture real-time metacognitive awareness and strategy use, followed by post-intervention surveys and interviews near the end of the third unit. Table 1 maps each research question to specific instruments, constructs (e.g., time management, self-testing, perceived cognitive offloading), and timepoints, ensuring systematic coverage of both process and outcome variables across the study. All procedures were reviewed as no-more-than-minimal-risk classroom research, and the researcher completed Montana State University's CITI IRB Students and Class Projects training prior to data collection (Record ID 68182919; completion 23 February 2025; see APPENDIX C: CITI IRB).

CHAPTER FOUR

DATA ANALYSIS: CLAIMS AND EVIDENCE

Results

This section presents findings from the initial intervention week and a twelve-week treatment Units 3–5, combining quantitative (Likert-scale surveys, Classroom Experience Questionnaire composites, pre/post assessments) and qualitative (coded open-ended responses) data for both cohorts. Throughout this chapter, the comparative cohort refers to students using AI-assisted study tools (e.g., NotebookLM, Perplexity), and the traditional cohort refers to students relying on conventional study methods (notes, study guides, flash cards, peer quizzing) without AI.

Quantitative Data Analysis

Day 1 – Foundations of Self-Regulated Learning

On the baseline SRL survey, both cohorts reported using a mix of active and passive strategies and named similar barriers. Most students endorsed goal setting, varied tools, and self-testing as important, but they also described distractions, procrastination, and inconsistent scheduling as routine problems; one student summarized the initiation challenge by explaining, “*While I can study once I get started, I find it difficult to actually get started.*” These patterns reflect what Liljedahl (2016) describes as a pervasive norm of answer-seeking over thinking: students have been conditioned to expect fast solutions, and when those are not immediately available, whether from a teacher, a peer, or an AI tool, they default to avoidance rather than

sustained effort (Liljedahl, 2016). Table 1 shows that the traditional cohort began with slightly higher confidence in planning and managing study time ($M = 3.84$ vs. 3.55), while metacognitive awareness of “*checking if methods are working*” was essentially identical across groups (3.76 vs. 3.77).

Table 1. Confidence Progression by Cohort and Timepoint (N=83)

Prompt	Comparative Cohort Mean	Comparative Cohort Median	Traditional Mean	Traditional Median	Difference
Confident in Planning & Managing Study Time	3.55	4.0	3.84	4.0	-0.29 (Comparative higher)
Can Explain SRL Concepts	3.58	3.0	3.70	4.0	-0.12 (Comparative higher)
Likely to Use New Study Strategies	3.76	4.0	3.93	4.0	-0.17 (Comparative higher)
Know How to Check if Study Methods Are Working	3.76	4.0	3.77	4.0	-0.01 (Essentially equal)

Day 2 – AI Training vs. Traditional Review

Both cohorts first received a 45-minute review of self-regulated learning skills, followed by a single 45-minute study-methods session: the AI cohort was introduced to AI-assisted study routines, and the traditional cohort received parallel instruction in non-AI, traditional study strategies. AI tool confidence rose from 3.94 to 4.43 (median 5.0), a 0.88 -point gain in one lesson. Verification literacy climbed from 3.70 to 4.20 with no students rating below 3, yet “*writing good AI prompts*” remained the lowest-rated skill (3.83), signaling that students were eager to use AI but not yet fluent in directing it. Adoption told the same story: prior to instruction

only 21.2% of AI-cohort students planned to use AI for studying, but by the end of the lesson that figure was 96.7% (Table 2), and students echoed this shift in comments such as AI “made it easier to find information so I could cut down on excessive study time” and NotebookLM “*generated a practice test with varying levels of difficulty*” that previously would have required Quizlet alone.

Table 2. AI Adoption Timeline (Comparative Group) N=35

Timepoint	Percentage Reported Using/Planning to Use AI (%)
Pre-instruction	21.2
Day 2 Do Now	54.5
Day 2 Exit Ticket	96.7

As shown in Table 3, the traditional cohort entered with slightly higher confidence on most baseline items, but both cohorts reported nearly identical metacognitive awareness of “checking if methods are working” (3.76 vs. 3.77). By Day 2, traditional students showed modest growth in study-planning confidence from 3.84 to 4.00, as shown in Figure 1, and active strategy use 3.77 to 4.12, Table 2, while metacognitive monitoring barely moved (+0.04), whereas AI-cohort students posted a sharper confidence surge without closing their prompt-writing gap. Table 3 summarizes these parallel skill gaps: AI students struggled most with writing effective prompts (3.83), while traditional students struggled equally to judge whether their methods were working (3.70), a pattern that persisted across the remainder of the study. The sustained impact of Day 2 instruction appeared two weeks later, when the AI cohort held a 0.73-point self-efficacy advantage over the traditional cohort on an unannounced assessment (Table 3).

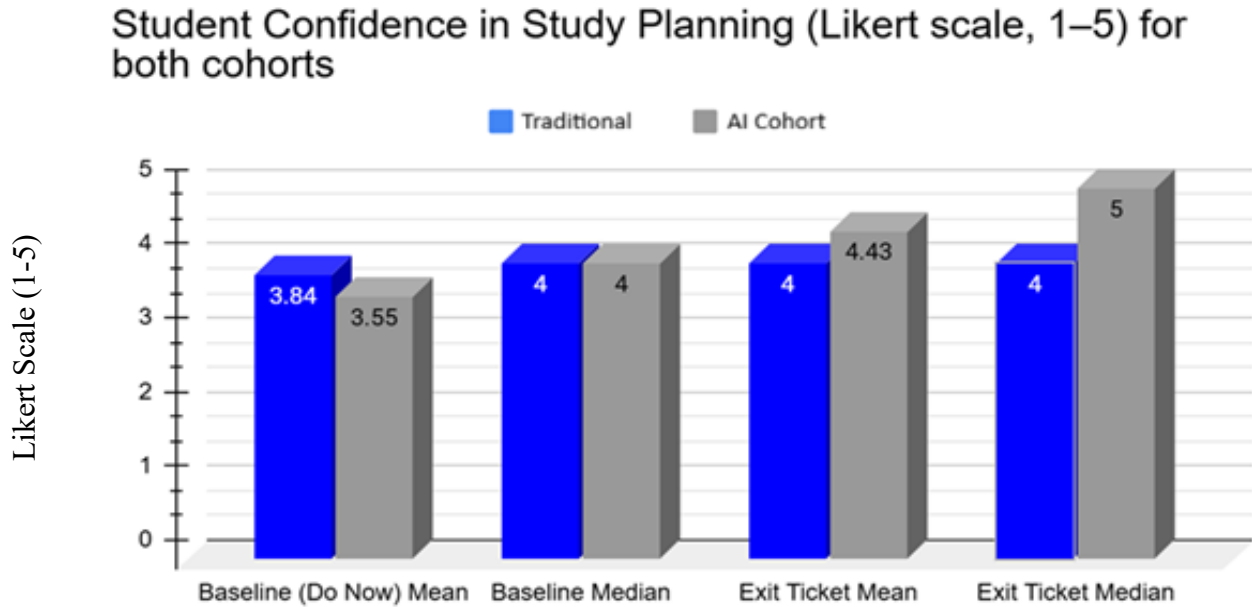


Figure 1. Study-planning confidence rose from 3.55 to 4.43 (median 5.0) for the AI cohort after Day 2, compared with a smaller increase from 3.84 to 4.00 for the traditional cohort (N = 83).

Table 3. Pre- and Post-Assessment Performance Across Units 3–5 by Cohort (N=240)

Unit	Cohort	MEAN PRE	MEAN POST	Mean gain	Median Gain	SD of Gain	count	MEDIAN PRE	MEDIAN POST
3,4,5	AI	36.88	70.99	37.08	46.48	24.52108	104	40	75
3,4,5	Traditional	42.29	76.86	29.88	31.76	16.94645	136	45	82.35

Unit Level Achievement Patterns (Units 3–5)

In Unit 3, pre-unit scores were equivalent (AI M = 5.00 vs. traditional M = 5.50, $d = 0.24$), but by post-test the AI-supported cohort showed a small-to-medium advantage (AI M = 17.03 vs. 14.61, $d = 0.45$; 58.7% vs. 50.4%) (Figure 2). Across Units 3–5 combined, AI students improved from 36.88% to 70.99% (mean gain 33.20 points), while traditional students rose from 42.29% to 76.86% (mean gain 28.64 points); in both cohorts, pre–post gains were statistically very large (AI $t \approx 14.0$, $d \approx 1.35$; traditional $t \approx 20.0$, $d \approx 1.69$), indicating robust learning across the intervention period (Table 3).

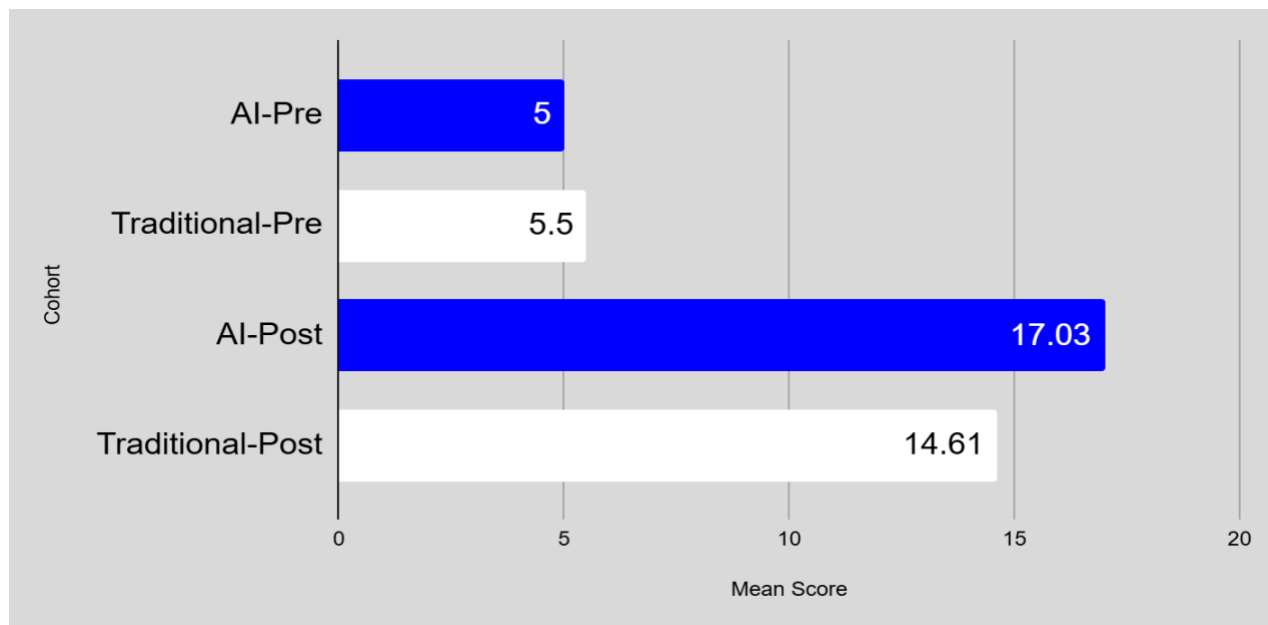


Figure 2. In Unit 3, both cohorts started with similar pre test means (5.00 vs. 5.50), but the AI cohort's post test mean (17.03) exceeded the traditional cohort's (14.61) by about 2.4 points (N = 81).

Unit-specific patterns nuance this story. In Unit 3, the AI cohort posted clearly larger mean and median gains than the traditional cohort (45.28 vs. 32.91 points; 46.48 vs. 32.58), with the entire score distribution shifted upward in the AI boxplot (Figure 3). In Unit 4, both cohorts again

improved substantially, but results were mixed: the AI cohort showed a larger raw gain on embedded items (≈ 28.9 vs. 25.1 percentage points), while the traditional cohort achieved a higher post-test mean (89.33% vs. 81.47%) and slightly higher normalized gain (0.75 vs. 0.70), so no method was clearly superior (Figure 3). In Unit 5, post-test means and gains converged (75.07% vs. 75.30%; mean gains 22.94 vs. 24.87), with somewhat tighter clustering in the AI cohort and wider spread in the traditional cohort (Figure 3). Across Units 3–5, AI-assisted studying therefore allowed a lower-starting AI cohort to nearly match the final performance of a higher-starting traditional cohort, with a clear AI advantage only in Unit 3 and comparable outcomes in Units 4 and 5.

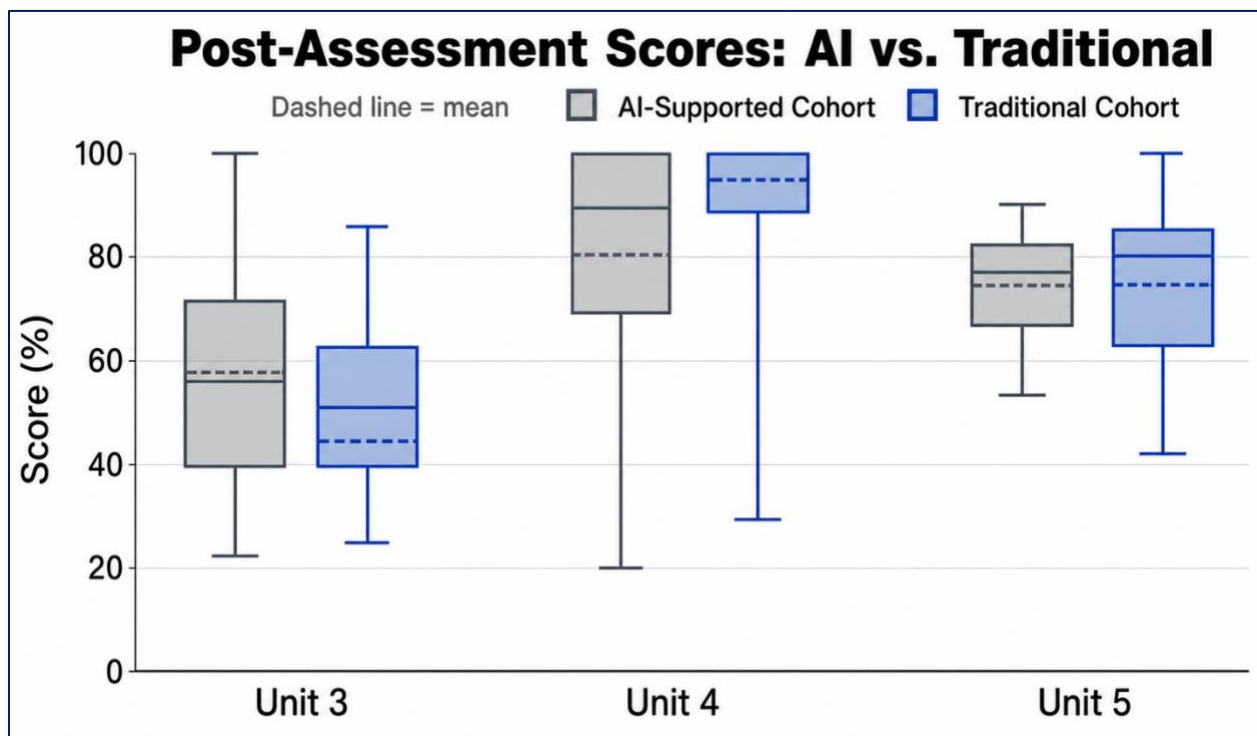


Figure 3. Unit 3–5 Post-Assessment Score Distributions by Cohort (N= 226). Across Units 3–5, then, AI-assisted studying allowed a lower-starting Comparative cohort to nearly match the final performance of a higher-starting traditional cohort, with a clear AI advantage only in Unit 3 and comparable outcomes in Units 4 and 5.

End of Treatment Classroom Experience Questionnaire

Unit 5 CEQ and SRL data show that, by the end of the treatment, both AI and traditional cohorts felt more prepared for assessments, but AI students reported stronger self-regulation, slightly better gap detection, and fewer perceived barriers overall.

The Unit 5 CEQ composites indicate that both cohorts entered the unit with low confidence, by the end of Unit 5, CEQ “Preparedness & Perceived Effectiveness” means rose from roughly 2.4–2.6 to about 3.4–3.6 in both cohorts, suggesting that students in each pathway shifted from below neutral toward agreement that they were prepared and that their study methods helped them perform well (Figure 4)

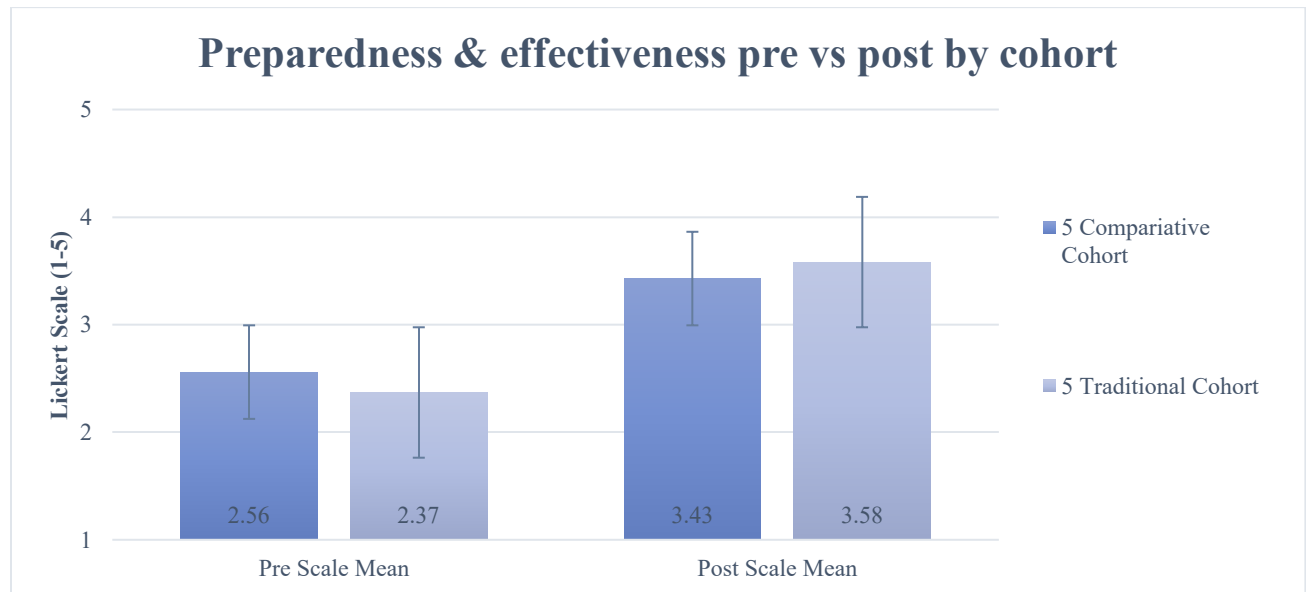


Figure 4. Preparedness and perceived effectiveness pre- and post-intervention for Unit 5 by cohort. Bars show mean scale scores (1–5) with standard deviation error bars for the AI-assisted comparative cohort and the traditional cohort (N = 160).

This quantitative pattern aligns with students’ reflections: one AI student wrote, “*I have studied more this year than any year before so I feel like this helped,*” while a traditional student

similarly noted that *“this time was better because I actually studied,”* explicitly connecting increased effort with a stronger sense of readiness.

For self-regulated learning constructs, Unit 5 post data show a clearer advantage for the AI cohort. On the combined SRL planning, time, and self-testing scale, the AI group reported a higher mean ($M = 3.41$, $SD = 0.98$, $n = 80$) than the traditional cohort ($M = 2.95$, $SD = 0.90$, $n = 80$), indicating stronger overall planning and self-testing behaviors by the end of the unit. Agreement patterns reveal the same story: 52.9% of AI students versus 20.5% of traditional students agreed they had a clear plan, 66.7% versus 25.6% agreed they used self-testing, and 54.8% versus 31.3% agreed they used their time effectively to study (Figure 5). Qualitative comments illustrate these differences. An AI student described giving *“AI a full list of the Mitosis and Meiosis study guide and [asking] it to give me a quiz based off that information,”* using the tool to structure practice and target key concepts, whereas a traditional student described a more informal routine of making *“a plan in the car with my mom to help me study later—I studied 3 days before the test,”* capturing the same intention but with less built-in structure.

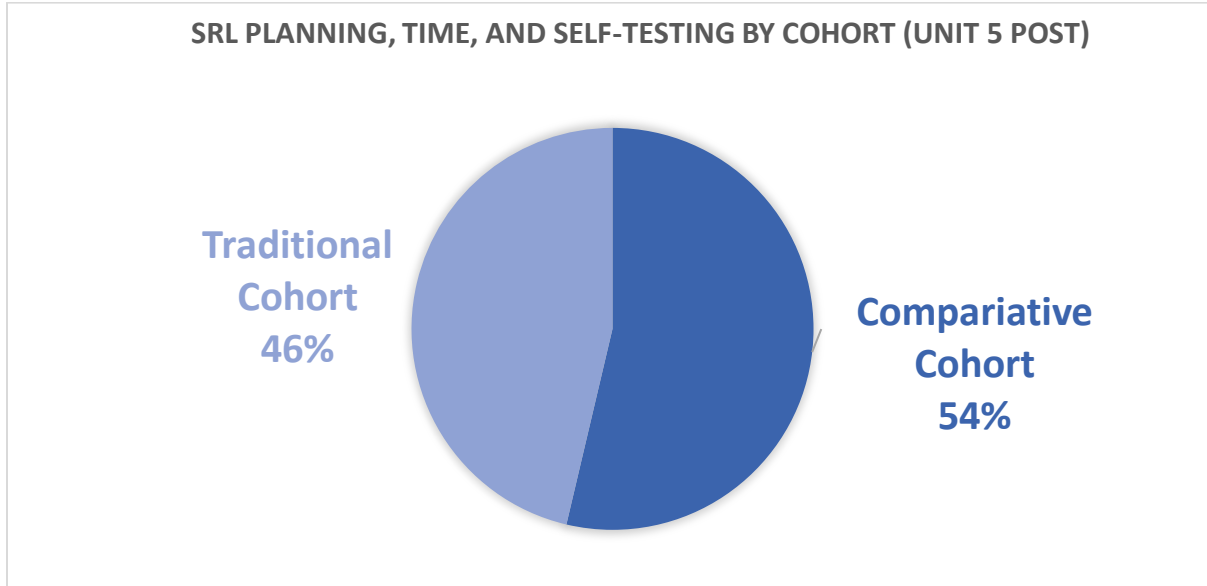


Figure 5. SRL Planning, Time, and Self Testing Scale Scores by Cohort (Unit 5 Post), visualizes these differences in a simple pie-style proportion: 54% of the combined SRL score belongs to the AI cohort and 46% to the traditional cohort, reflecting the 3.41 versus 2.95 mean difference. In practical terms, this figure highlights that AI-supported studying was associated with more frequent reports of having a plan, using self-testing, and managing time effectively, even though both groups had been exposed to self-regulation instruction (N=160).

Understanding and gap detection improved in both groups. Figure 6, Understanding and Gap Detection Scale Scores by Cohort, Unit 5 Pre–Post, shows that both cohorts moved from mid-range agreement at pre (AI M = 2.75, SD = 1.14; traditional M = 2.52, SD = 1.07) to higher agreement at post (AI M = 3.55, SD = 1.07; traditional M = 3.49, SD = 0.82), indicating that students in both pathways felt better able to use assessments and study materials to see what they did and did not understand by the end of the unit. The AI cohort supported a small post-survey advantage (3.55 vs. 3.49), consistent with their frequent use of AI-generated quizzes and explanations for checking understanding. A chi-square test on the key gap-detection item (“*my tools/materials helped me see what I did and did not understand*” (Appendix B. Table A9)) showed significant shifts ($p=0.000742$) from disagreement toward agreement in both

cohorts, with the AI group showing a larger drop in neutral responses and a slightly higher proportion of agreement at post, suggesting that AI-supported studying increasingly functioned as a tool for diagnosing strengths and weaknesses rather than just supplying information.

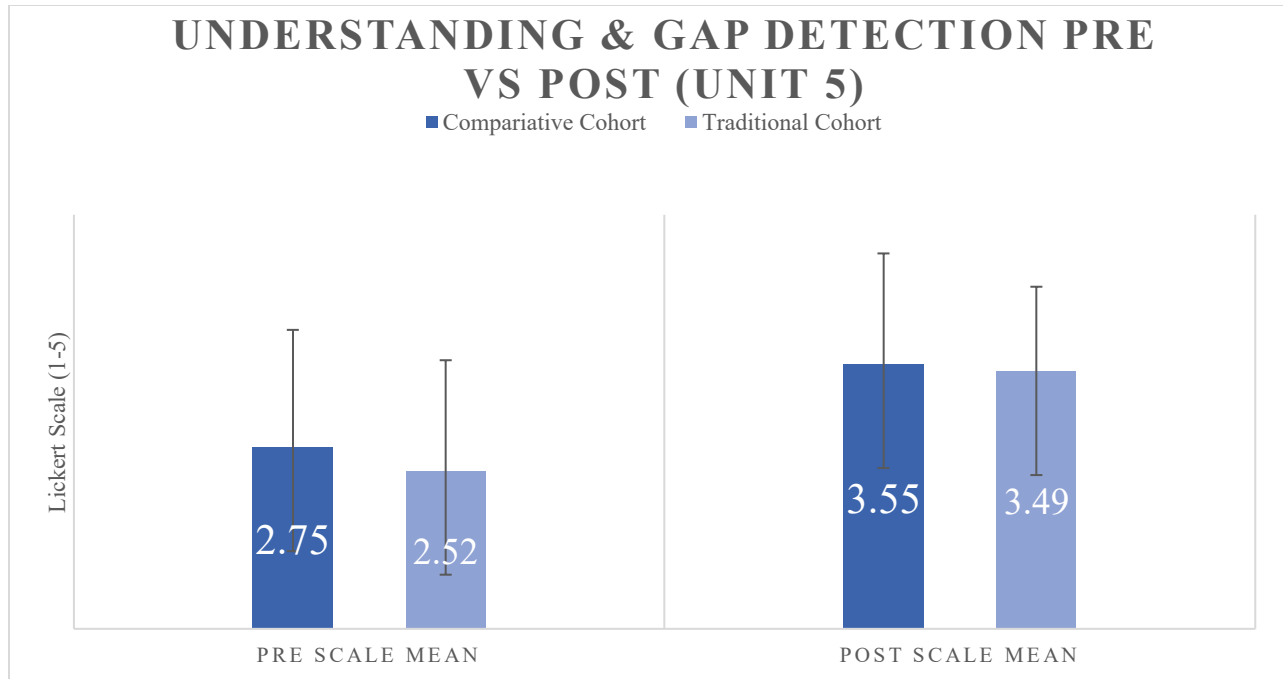


Figure 6. Understanding and Gap Detection Before and After Unit 5 by Cohort (N=160)

Engagement patterns also favored the AI cohort. On the engagement scale, AI students reported a higher mean ($M = 3.31$) than their traditional peers ($M = 2.94$), and 51.5% of AI students versus 31.3% of traditional students selected agree or strongly agree that their study methods were interesting (Figure 7).

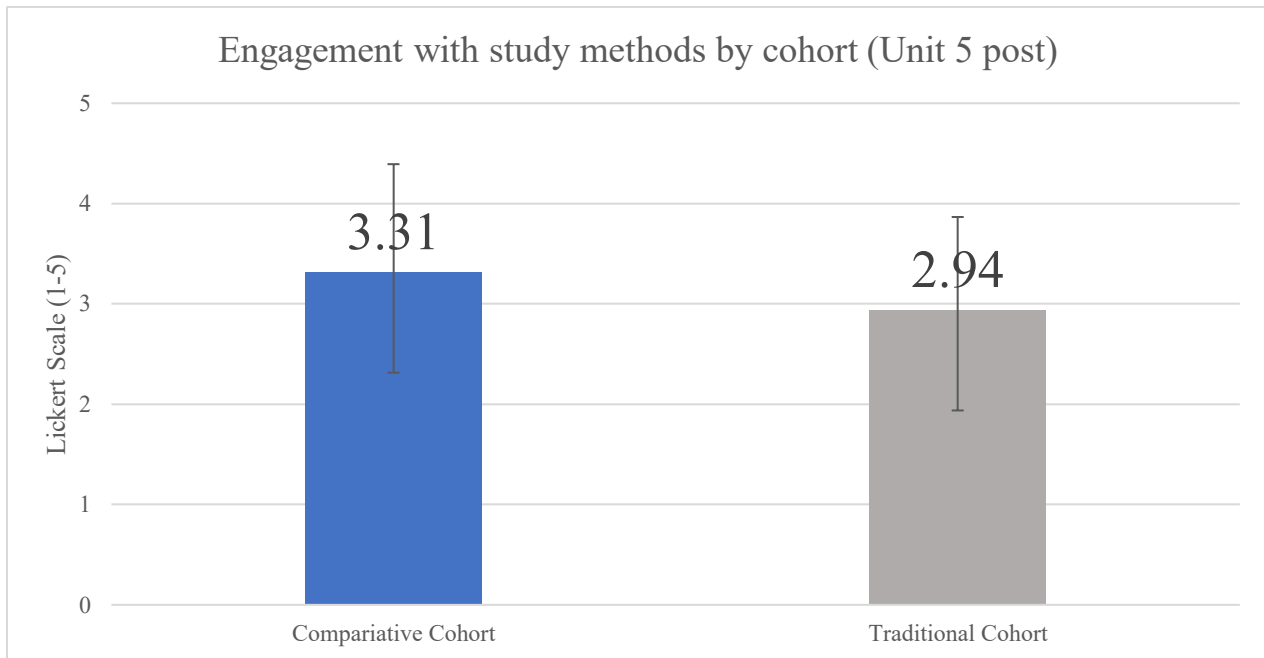


Figure 7: Engagement with study methods by cohort for Unit 5 posttest. Bars display mean engagement ratings (1–5) with standard deviation error bars for the AI-assisted comparative cohort and the traditional cohort (N = 160). The comparative cohort reported higher engagement with its designated study methods than the traditional cohort.

Students' comments help explain this gap. One AI student described *“making a personal study guide using games [Quizlet AI]”* and emphasized that this approach was *“both fun and educational at the same time and it’s not like just studying and testing myself which makes it less boring,”* highlighting how AI-mediated games and customized practice made studying feel more engaging. In contrast, a traditional student contrasted her experience *“going on Blooket or Kahoot,”* where *“questions are repeated and all I had to do was memorize which was right,”* and concluded that she wanted games that actually *“build on knowledge, not just memorize which button is right,”* suggesting that non-AI review and non AI-games sometimes felt shallow or repetitive.

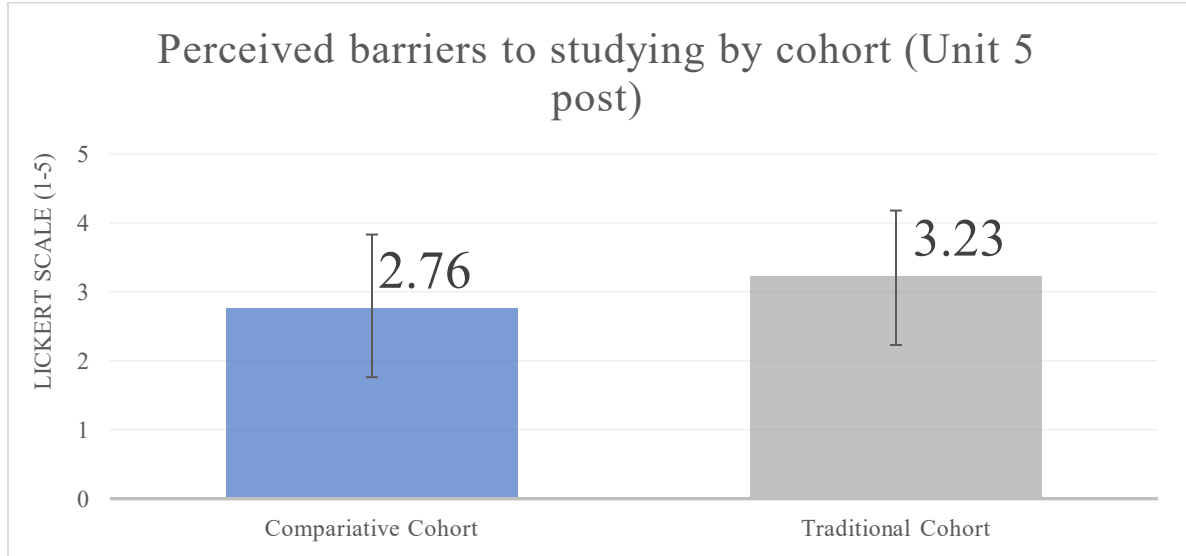


Figure 8: Perceived Barriers to Studying After Unit 5 by Cohort (N=160)

Finally, the barriers data suggest that AI-supported studying was associated with somewhat fewer perceived obstacles, though not with the elimination of challenges. Figure 8 Perceived Barriers, shows that AI students reported a lower mean on the combined barriers scale ($M = 2.76$, $SD = 1.07$, $n = 80$) than traditional students ($M = 3.23$, $SD = 0.95$, $n = 80$), a pattern that places the AI cohort below the midpoint of the 1–5 scale and the traditional cohort slightly above it. This suggests that, on average, AI students experienced somewhat fewer problems with distractions, confusion, time, and access when studying, even though both groups still reported meaningful obstacles. Open-ended responses point to different barrier profiles rather than a simple “with vs. without barriers” divide. Traditional students more often described difficulty accessing or organizing materials and staying focused with non-AI routines; one student captured this by admitting that “*sometimes I would get bored and feel the need to check my phone [which] delayed study time.*” AI students, by contrast, more frequently referenced technical glitches and the temptation of other tabs or apps while using AI, for example, one student wrote that “*AI*

made it harder to study as it was easier for me to click another tab and get distracted,” a reminder that lower barrier scores in the AI group represent a group-level trend rather than a universal experience.

Together, these CEQ and SRL findings suggest that explicit AI-supported study routines did not merely raise students’ perceived preparedness in parallel with the traditional pathway; they were also associated with stronger reported planning and self-testing habits, slightly better perceived gap detection, higher engagement, and somewhat lower perceived barriers, even as both cohorts continued to grapple with distractions, time pressure, and the challenge of turning intentions into consistent, strategic studying.

Qualitative Data Analysis

Day 1 Themes (Both Cohorts)

Day 1 reflections from both cohorts painted a consistent picture of what students believed “*studying effectively*” should look like and where they felt they were falling short. When asked to define effective study, students overwhelmingly described active recall strategies such as self-quizzing, using teacher-provided study guides, “*learning from mistakes*” on past assignments, and reducing distractions so they could focus. Several students emphasized that testing themselves or having someone quiz them helped them remember key ideas, and a few already used language like “*active recall*” or “*going over things multiple times*” to explain why these methods worked.

At the same time, the same Day 1 responses revealed that students saw their biggest problems not in knowing what works, but in actually doing it. Many wrote about distractions, procrastination, forgetting to study, or “*waiting until the last minute*” as their main barriers, often

pairing this with vague intentions to “*study more*” without specifying when or how. One traditional-cohort student admitted, “*I only studied today and last night, and felt stressed beforehand,*” while another simply wrote that they “*didn’t study much,*” capturing the mix of last-minute effort and non-preparation underlying their baseline habits. These themes mirror the quantitative SRL Planning and barriers patterns from the same week, where students in both cohorts reported mid-range scores on planning items and frequently endorsed time, distraction, and procrastination as persistent obstacles, even before any AI-specific instruction had begun.

Early Intervention – Comparative & Traditional Cohort

By Day 2 of the intervention, AI cohort students had clearly repositioned AI as a self-testing engine rather than an answer key. A narrow majority 52.8–53.3% named AI-generated quizzes or flashcards as their single most helpful strategy, emphasizing that these tools removed setup friction “*don’t have to make a test yourself,*” let them aim for mastery by repeating questions until all were correct, and transformed static study guides into active recall routines. Students described having AI “*create a practice test with varying levels of difficulty*” and “*quiz me and tell me what I need to keep studying and what I already know,*” using AI both to practice and to detect gaps in understanding. Over the same 45-minute lesson, academic integrity anxiety dropped from about one-third of students reporting concern to 73.3% expressing confidence in appropriate use, and AI adoption jumped from 21.2% planning to use AI for studying at baseline to 96.7% by the Day 2 exit ticket.

This process pattern extended across Units 3–5: AI cohort reflections repeatedly cast AI as a gateway to active recall—pasting notes or study guides into chatbots to generate quizzes, using AI explanations and feedback to locate weaknesses, and asking for simpler explanations

when stuck, yet students still narrated familiar time-management problems. Many reported cramming (“*studied the night before*”), vague intentions to “*study more,*” or difficulty sticking to schedules, mirroring quantitative SRL Planning scores that hovered in the mid-3s and confirming that tool gains did not, by themselves, resolve chronic planning and procrastination gaps.

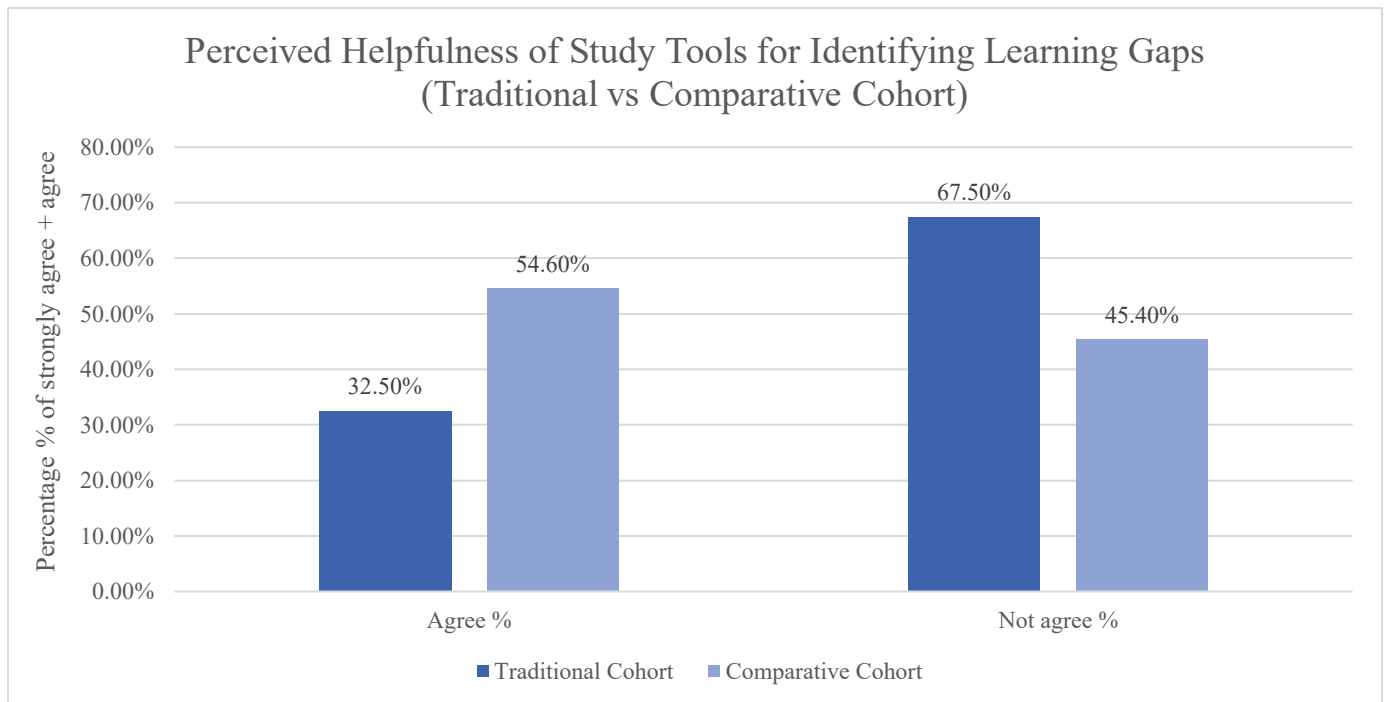


Figure 9. Agreement That Study Tools Help Reveal Strengths and Gaps: the percentage of students in each cohort who agreed or strongly agreed that their study tools helped them see what they did and did not understand. AI cohort students were substantially more likely to endorse this statement (54.6% vs. 32.5%), aligning with qualitative comments about AI quizzes “*telling me what I need to keep studying what I already know,*” while traditional students more often described using past assignments and study guides to “*highlight information I don’t know or should know more about.*” (N=180)

Traditional cohort students also converged on active recall as their perceived best strategy but reached it through more social and analog routes. Their dominant methods included, handwritten or digital flashcards, peer and family quizzing, and teacher-provided study guides

review reading, with reflections highlighting peer interaction (“*having my friends/family quiz me on the content*”) and environmental restructuring (moving away from distractions, putting phones in another room, or turning the phone off and “*lock[ing] in for 30 minutes at a time*”) as key self-regulation repairs. In coded qualitative themes, traditional students more often foregrounded content prioritization and assessment alignment—phrases like “*focus on what I don’t know*,” “*study what’s on the study guide*,” or “*what I studied wasn’t on the test*” aligned with richer gap-detection and content-selection language than in the AI cohort. At the same time, a small but important subset of traditional students admitted doing little or no studying for some assessments (“*I didn’t study, I just took it*”), reinforcing survey results that showed higher barriers scores and persistent time-management failures despite their stronger language around what to study.

Later Units – Cross-Cohort Themes

Across later units, both cohorts treated active recall as the engine of learning but relied on different delivery systems. In the Comparative cohort, dominant themes included AI-generated quizzes and flashcards, cognitive offloading as AI cut setup time, and AI-driven habit change as students shifted from rereading notes to AI quizzes; several remarked that AI let them “*study for*

20 or so minutes instead of using that time to make a quiz” and made it easier to study vocabulary and understand notes even when they still crammed.

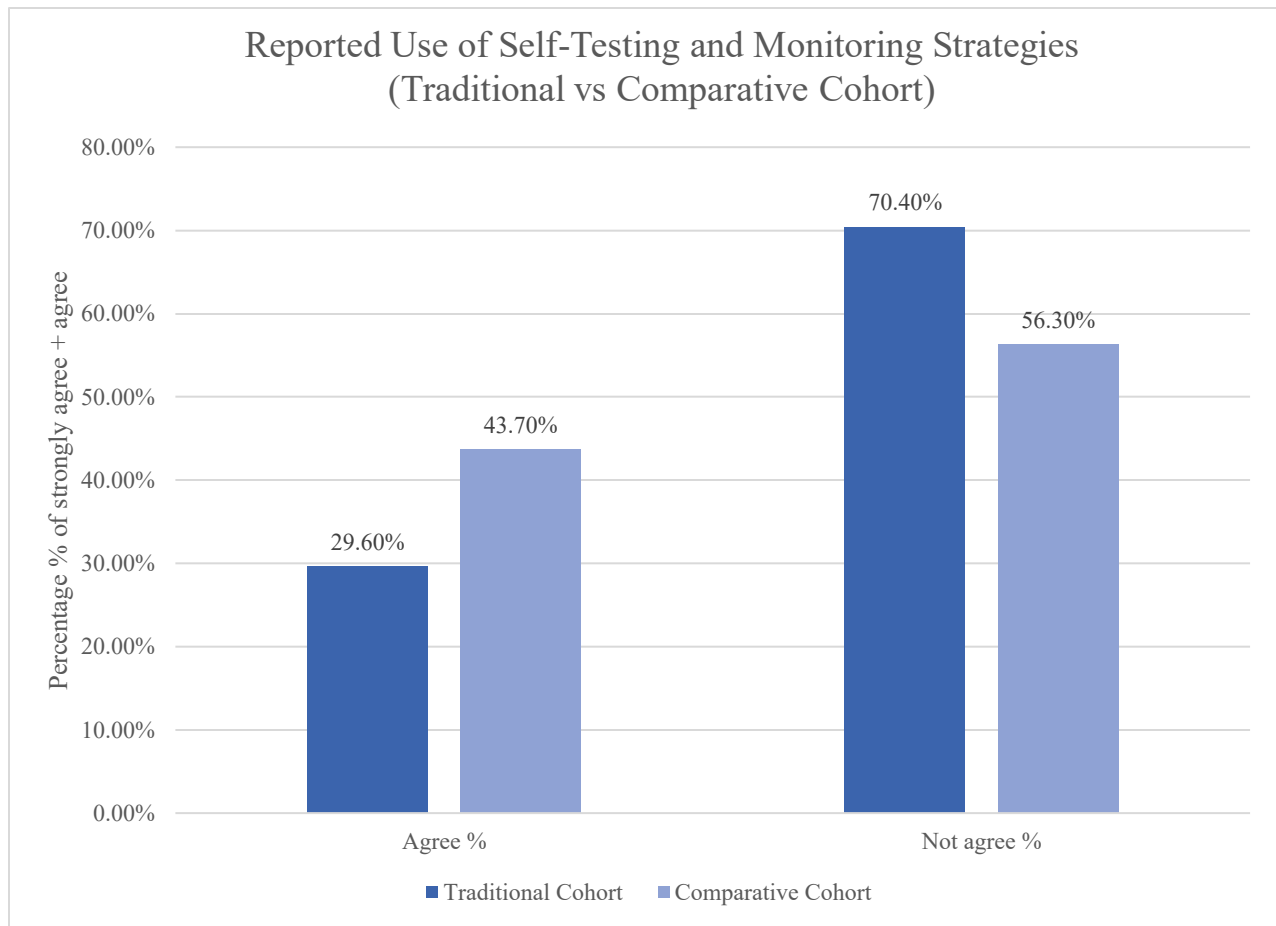


Figure 10. Self-Testing and Metacognitive Monitoring by Cohort: This figure compares the proportion of students in each cohort who agreed or strongly agreed that they regularly used self-testing and monitoring strategies when studying. A larger share of AI cohort students endorsed these behaviors (43.7% vs. 29.6%), supporting qualitative descriptions of AI as a gateway to active recall—students reported using AI to generate quizzes, practice tests, and explanations—while traditional peers more often relied on Quizlet, peer quizzing, and teacher guides for self-testing. (N=180)

The traditional cohort’s coded themes instead foregrounded peer and family quizzing, Quizlet as a central tool, and environmental restructuring—moving away from distractions, removing phones, or “*locking in*” for 30-minute blocks—to manage attention. Their reflections showed somewhat stronger content prioritization and gap-detection language, with students

urging themselves to “*isolate and focus on more important topics—don’t overload the brain, focus on what I don’t know*” and describing the use of past assignments to highlight information they “don’t know or should know more about.”

Across both cohorts, metacognitive vocabulary expanded but remained uneven: students increasingly named “*active recall*,” “*finding weaknesses*,” “*studying earlier*,” and “*visualizing a plan*” as explicit goals, and some narrated shifts from memorizing notes to concept understanding or from copying definitions to self-testing (for instance, realizing that “*memorizing notes was a pretty bad idea*” and deciding they “*should’ve made flashcards*”). However, many responses still defaulted to vague resolutions signaling that sophisticated planning and monitoring skills continued to lag behind rising confidence and tool adoption in both AI and traditional pathways.

Triangulation and Synthesis

Confidence, Preparedness, and Achievement

Explicit AI instruction produced faster, larger gains in how confident and prepared students felt than in their actual test performance. Across Units 3–5, effect sizes for engagement and CEQ preparedness/performance hovered around $d \approx 0.56$ and 0.53 , modestly outpacing the achievement effect of roughly $d \approx 0.45$ and signaling a process–outcome gap where motivation and self-belief improved more than scores.

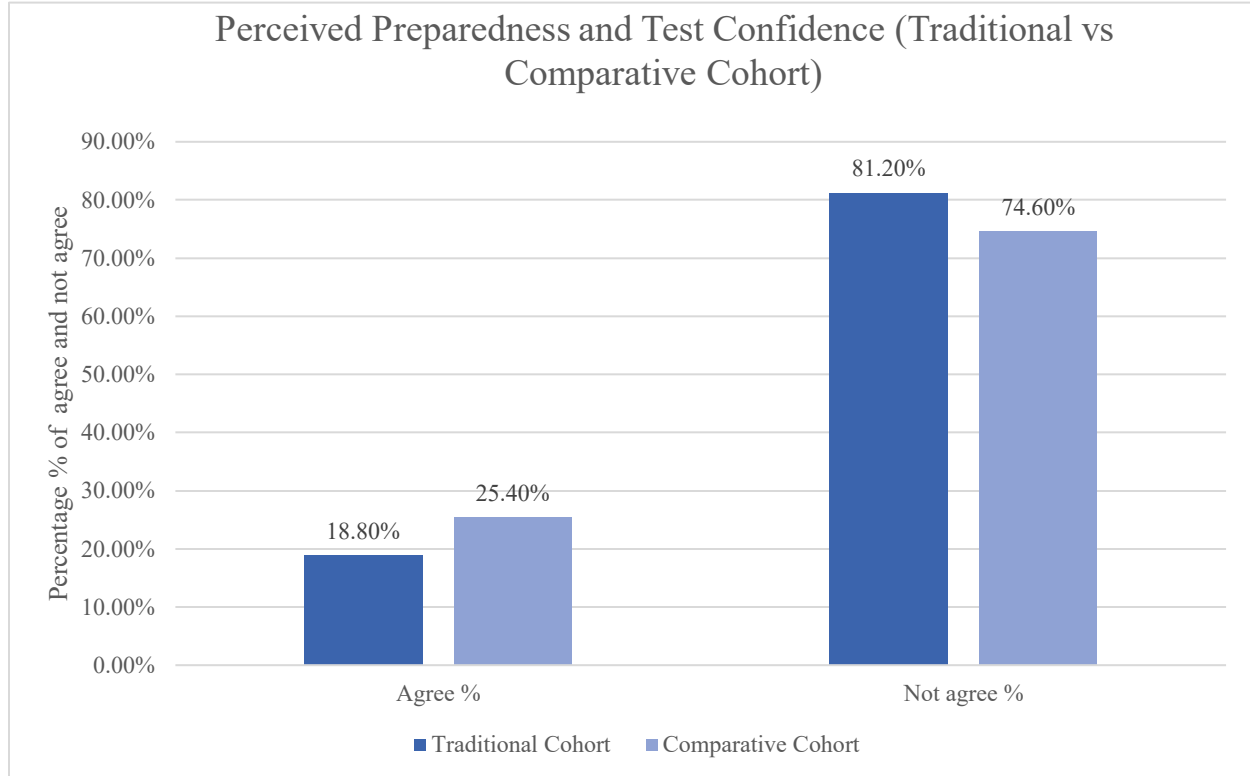


Figure 11. Preparedness and Performance Beliefs by Cohort: This figure compares the proportion of students in each cohort who agree (agreed or strongly agreed) that they felt prepared and performed well on biology assessments (CEQ preparedness/performance factor) to the proportion of students who did not agree (disagree + strongly agree). AI cohort students were more likely than traditional peers to endorse high preparedness and performance (25.4% vs. 18.8% agreeing), consistent with qualitative reflections describing feeling “*more prepared*,” “*more organized*,” and less anxious once AI tools were integrated into their study routines. (N=180)

Quantitatively, AI cohort students were more likely than traditional peers to agree that they felt prepared and performed well on biology assessments; about 25.4% vs. 18.8% endorsing high preparedness and performance on the CEQ composite, with the majority in both groups still selecting not-agree options. These ratings align with qualitative narratives in which AI students repeatedly described feeling “*more prepared*,” “*more organized*,” and less anxious once AI-generated quizzes, flashcards, and summaries became part of their routines, even when grade

gains were described as only “*slight*” or “*a little better*.” One student captured the perceived shift by explaining that having “*an extra tool to help manage my time, especially as someone with anxiety, helps me out so much*,” underscoring that AI’s strongest short-term impact was on confidence and emotional regulation around assessments rather than on dramatic jumps in achievement.

Strategy Use and Metacognitive Gaps

Both cohorts converge on active recall as “*what works*,” but they diverge sharply on how they get there and still share a common bottleneck: they can execute strategies but rarely monitor and optimize them in a sophisticated way.

Across Units 3–5, AI students overwhelmingly route active recall through AI-generated quizzes, flashcards, and game-like practice sets built from their notes or study guides, while traditional students reach the same mechanism through Quizlet, peer/family quizzing, and teacher materials. Unit 5 SRL Planning and Self Testing scales show clear gains in planning awareness and self-testing in both groups—with higher agreement in the AI cohort that they had a plan and used self-testing—but the means still sit in the mid–3s, and detailed, consistently enacted plans remain the exception rather than the norm. The most stubborn quantitative gaps cluster right around that same band: AI students rate “*writing good AI prompts*” at 3.83, while traditional students place “*knowing if my methods are working*” near 3.70, signaling that both cohorts feel competent *doing* their strategies but far less confident steering or revising them. Liljedahl (2016) would recognize this as the gap between executing a routine and genuinely wrestling with ideas—a form of productive struggle that requires students to tolerate uncertainty and normalize getting stuck as a necessary part of learning, not a signal to stop (Liljedahl, 2016).

Qualitative responses reinforce this pattern. When asked what they would change, students in both pathways default to “*study more*,” “*start earlier*,” or “*use my time better*,” with only a minority describing concrete repairs like time-blocking, targeting just the hardest concepts, or upgrading question difficulty. A few AI students model more advanced metacognitive moves—asking AI to “*re explain in a memorable way or at my grade level vocab*” or pasting in past assignments to identify gaps just as a few traditional students describe using past quizzes to find weak spots or isolating “*more important topics*” to avoid overload. These parallel weaknesses and isolated exemplars support the claim that, whether they are using AI or traditional tools, students learn to execute study routines faster than they learn to evaluate when those routines are working and how to optimize them over time.

Barriers and Supports

Barriers remained visible yet distinct in the two cohorts, with traditional students reporting higher overall obstacles in Unit 5 (barriers mean 3.23 vs. 2.76). Their open-ended responses centered on time pressure, competing coursework, and distraction, and they most often responded by restructuring their environment: removing phones, changing study locations, or studying near parents to avoid devices (e.g., “*no electronics and testing myself*,” “*not having my phone around me while studying*”). The Comparative cohort, while reporting fewer total barriers, more often pointed to AI-specific friction such as over-detailed explanations, uncertainty about what to paste or ask, and persistent procrastination (“*I think I could’ve spent more time studying with AI; I want to have more timing*”), even as they used AI to reduce the setup cost of self-testing.

The Unit 5 gap-detection composites and bar charts indicate that both cohorts increasingly saw their tools as helping them “*see what they know and don’t know*,” with the AI cohort slightly more likely to agree that AI revealed gaps and the traditional cohort describing feedback from quizzes, study guides, and past assignments in richer language. One AI student captured this double edge by writing that AI practice “*made me nervous when I didn’t know something but confident when I did*,” while a traditional peer described using past assignments “*to highlight information I don’t know or should know more about*,” illustrating parallel movement toward monitoring through different supports. Together, these patterns suggest that while AI lowers friction for generating practice and surfacing errors, traditional structures: peer supports, paper tools, and environmental design still play a central role in how students manage distraction and translate feedback into concrete changes.

Major Patterns and Findings

Confidence surged fastest in the Comparative cohort: AI-tool confidence rose by 0.88 points to 4.43 (median 5.0) within a single 45-minute session, and a 0.73-point self-efficacy advantage persisted on an unannounced later assessment, even though achievement advantages were small and unit-specific. Strategy use converged on active recall but diverged in delivery, with AI students leaning on AI-generated quizzes, flashcards, and games, and traditional students relying on Quizlet, peer/family quizzing, and teacher-created materials to drive the same underlying mechanism.

Across Units 3–5, SRL Planning and evaluation items stayed in the mid-3s (roughly 3.4–3.8), and open-ended responses in both cohorts were dominated by “*study more*,” “*start earlier*,” and vague time-management goals rather than detailed, sustained plans, even though a minority

named upgrades such as time-blocking, distributed practice, or visualizing a plan beforehand. In this context, AI's main value was lowering friction for evidence-based study: students described AI as making it "*easier*" to self-test, generate practice materials, condense notes, and repair confusion, aligning with higher SRL Self-Testing rates, fewer reported barriers, and qualitative themes of cognitive offloading and gamified engagement. Traditional supports, by contrast, appeared to foster stronger peer interaction, more explicit content-prioritization language, and richer gap-detection and environmental-restructuring strategies, suggesting that these students may also have engaged in more productive struggle as they worked through confusion with fewer automated supports. This pattern implies that, although AI reduced friction around self-testing and review, the traditional pathway may have required more sustained sensemaking and effortful processing from students. Traditional students also reported more global time and distraction barriers and more variable self-efficacy.

Neither pathway, on its own, "fixed" time management or consistency. Across surveys and reflections, both cohorts repeatedly identified time, procrastination, and follow-through as their weakest SRL areas, reinforcing the rationale for Units 4 and 5 scaffolds that targeted planning, monitoring, and explicit strategy adjustment routines rather than tool use alone. Together, these findings support a central claim of this action research cycle: explicitly taught AI routines can rapidly change how students study and how confident they feel, while parallel SRL conversations in both cohorts shift language and habits around self-testing and gap detection; yet in both conditions, deep planning and optimization skills lag behind, pointing to the need for longer, competence-focused SRL scaffolds that cut across tools and units.

CHAPTER FIVE

VALUE: REASONING AND REFLECTION

Claims from the Study

Across three biology units, AI assisted studying helped a lower starting AI cohort nearly match the final performance of a higher starting traditional cohort, with only a modest test score advantage in Unit 3. The strongest and most consistent effects of AI appeared in students' self-reported processes: confidence, preparedness, and self-testing habits, with a single 45-minute AI training session producing sharp jumps in tool confidence and adoption. One AI cohort student captured the perceived shift by reflecting that *“study time shortened, routines got easier and less hard to manage, and check ins boosted grades,”* while another noted that AI *“increased efficiency”* by cutting down on time *“just trying to find material”* so they could *“get straight to the point.”* A third student described chaining tools together—*“I input the study guide to make flashcards on Quizlet as well as a question by question practice quiz on ChatGPT that explained my wrong answers right away”*—illustrating how AI supports more continuous self-testing and error correction.

Taken together, these patterns answer the main research question and sub-questions: AI assisted studying, after explicit instruction, yielded summative assessment gains that were comparable to or slightly stronger than traditional methods while more dramatically improving students' confidence and self-regulated study habits; it boosted retention and comprehension through frequent, targeted practice; it nudged students toward more exploratory, active strategies even as some continued to exploit familiar routines; metacognitive coaching around AI use enhanced strategy use and confidence more than raw scores, and effects on time management,

self-testing, and perceptions of AI utility were generally positive but still dependent on sustained scaffolding and peer and teacher collaboration.

Value of the Study and Consideration for Future Research

This study adds value by extending university focused AI research into a secondary context, foregrounding self-regulated learning rather than only test scores and comparing AI supported and traditional pathways under matched content and pacing conditions. For practitioners, a key contribution is that relatively brief, targeted instruction in AI based self-testing, especially quiz generation, can produce rapid increases in confidence, perceived preparedness, and active recall routines without sacrificing summative performance, pointing to the need for future work that tests how sustained, multi-unit coaching might translate these short-term process gains into larger, long-term achievement effects.

At the same time, the study raises important cautions for future work. Several AI cohort students described using AI primarily to polish or compress existing work, for example *“refine the raw information... define vocab words, make flashcards, and summarize chunks of info”* or *“clean up”* messy notes, rather than to push into new, harder questions, aligning with mid-range ratings on prompting and gap targeted practice. Both cohorts showed persistent SRL bottlenecks around planning, monitoring, and optimization, with many students defaulting to “study more” as their main change and a smaller subset beginning to articulate more sophisticated goals such as *“isolate and focus on more important topics, don’t overload the brain, focus on what I don’t know.”*

Student comments also underscore equity and ethics considerations that future research should address. One AI cohort student wrote, *“I know everyone tells me to think for myself,*

however just having an extra tool to help manage my time, especially as someone with anxiety, helps me out so much,” while a traditional cohort peer warned that *“when I need to do something on my own, instead of trying I think I would just use AI instead of thinking for myself.”* These paired statements highlight AI’s dual role as both support and potential crutch, reinforcing the need for designs that emphasize self-regulation and critical evaluation alongside efficiency. Because behavior changes in planning, monitoring, and strategy revision typically require sustained practice and repetition, this study should be replicated with longer term, multi-unit cycles that systematically rehearse key SRL behaviors in both AI and traditional conditions to test whether stronger, statistically significant achievement differences emerge over time. One promising direction is to design longer term interventions that explicitly rehearse behavior changes which promote reflection and exploration, not just efficiency, especially in text heavy courses where AI tools and large language models can mediate most content access. In these settings, robust routines for pausing to reflect, asking exploratory questions, and comparing multiple explanations could turn AI from a convenient shortcut into a more important scaffold for deep reading and sense making over time. Studies in higher poverty settings, symbol heavy subjects like mathematics, and classrooms with more limited device access are also needed to probe equity implications and to adapt AI assisted studying for contexts where access, rather than strategy, is the primary constraint.

Impact of Action Research on the Author

This project fundamentally changed how I think about studying in my classroom. Rather than focusing on AI or traditional tools as the main variables, I now see self-regulated learning routines such as planning, self-testing, and monitoring as the primary levers for change. The data

convinced me that simply permitting a variety of tools is not enough; without explicit SRL coaching, frequent check ins, and structured chances to repair confusion and adjust difficulty in real time, gaps in both content knowledge and tool use persist for many students.

Students' own words pushed me hardest. Comments about cramming, distraction, and anxiety sat alongside small but powerful examples of genuine planning and self-correction, like turning off a phone to "*lock in for 30 minutes*" or learning to "*visualize a plan beforehand instead of just jumping into it.*" These reflections led me to open pretest review days with brief SRL Do Nows that ask all students to write better questions, plan specific steps, and rehearse the exact moves they will use when they get stuck, rather than assuming those habits will emerge on their own.

Student interviews also complicated my assumptions about AI. Several AI cohort students framed AI tools as time savers and confidence builders, while others said AI "*made things a lot more confusing for me so I don't use AI,*" or that they shifted to "*only flashcards*" after being misled on a quiz. A third group described moving from passive to active AI use, copying in study guides, asking AI to quiz them one question at a time, and pushing for more detail or explanations of incorrect answers, which nudged them toward deeper self-testing and error analysis. Together, these voices convinced me that my job is less to promote or discourage AI and more to teach students how to integrate any tool into a thoughtful study routine that bridges prior learning to new ideas, surfaces gaps in understanding, and promotes healthier self-regulation over time.

The project showed me that confidence and easy access to tools do not automatically translate into sophisticated strategy use. A smaller group modeled the metacognitive repair

moves I now want to center, such as asking AI to “*re explain in a memorable way,*” using practice tests to “*find out what I already know and what I need to know,*” or realizing midnight that “*memorizing notes was a pretty bad idea*” and shifting toward flashcards, which showed me the level of awareness I need to help more students reach.

In response, I plan to build asynchronous supports for each unit by modeling techniques for curating a “study helper” with a preferred LLM around the core readings, diagrams, and data, tuned to reduce over-offloading by prioritizing quick access to practice quizzes, flashcards, and mixed-difficulty checks rather than long polished summaries. Within those spaces, I will also model more complex, metacognitive prompts for students to build into their routines, such as, “Have me practice my explanations of key concepts,” “Give me vocabulary to practice using in a sentence and in a quiz-style question,” “Make this simpler while still using vocabulary from the study guide,” or “Make each question harder as I answer more correctly.” Within those spaces, and in class, I now think in terms of a recommended, repeatable study sequence: when a student asks how to study for biology, my default routine is to start with active recall from notes or study guides, quiz with a peer when possible, make targeted review flashcards, and only then use AI to generate additional practice tests and flashcards that extend and explore, rather than replace, those efforts. Taken together, these routines ask students to treat themselves as individual learners with additional tools: AI as one tool in a broader self-regulation toolkit—useful for helping them build study plans and repeatable routines, and also powerful for letting some learners jump straight into low-friction quizzing and exploration, one of the most effective ways to study, without the extra barriers that usually keep them from getting started.

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APPENDICES

APPENDIX A: RESEARCH QUESTIONS, INSTRUMENTS,
AND CONSTRUCTS

Table A.1. Matrix of Research Questions, Instruments, and Constructs

Research Question	Instrument 1	Rationale 1	Instrument 2	Rationale 2	Target Construct	Timepoint
How does AI study support affect assessment scores?	Pre/post unit summative assessment	Objective growth measure	Student work samples	Evidence of mastery	Summative performance	Pre/post
How are SRL habits impacted?	LASSI-aligned survey	Quantifies habit change	Reflection journals	Captures qualitative shifts	SRL/metacognitive skills	Pre/post, ongoing
What is the relationship between AI usage and engagement?	AI usage analytics	Tracks tool engagement	Self-report perception survey	Gauges attitudes and use	Student engagement	Ongoing/post
What barriers/facilitators are identified?	Interviews	Depth of insight	Cohort questionnaire	Patterns in population	Barriers/facilitators	Post-intervention

Table A.2. Confidence Progression by Cohort and Timepoint (N=83)

Prompt	Treatment Mean	Treatment Median	Comparative Mean	Comparative Median	Difference
Confident in Planning & Managing Study Time	3.55	4.0	3.84	4.0	-0.29 (Comparative higher)
Can Explain SRL Concepts	3.58	4.0	3.70	4.0	-0.12 (Comparative higher)
Likely to Use New Study Strategies	3.76	4.0	3.93	4.0	-0.17 (Comparative higher)
Know How to Check if Study Methods Are Working	3.76	4.0	3.77	4.0	-0.01 (Essentially equal)

Table A.3. AI Adoption Timeline (Comparative Group) (N=35)

Timepoint	Percentage Reported Using/Planning to Use AI (%)
Pre-instruction	21.2
Day 2 Do Now	54.5
Day 2 Exit Ticket	96.7

Table A.4. Metacognitive Skills Gap Post-Instruction (N=83)

Skill	Comparative Mean	Traditional Mean
Write good AI prompts	3.83	---
Check if study methods working	3.76	3.70

Table A.5. Pre- and Post-Assessment Performance Across Units 3–5 by Cohort (N=240)

Unit	Cohort	MEAN PRE	MEAN POST	Mean gain	Median Gain	SD of Gain	count	MEDIAN PRE	MEDIAN POST
3,4,5	AI	36.88	70.99	33.2	27.5	24.52108	104	40	75
3,4,5	Traditional	42.29	76.86	28.64	30	16.94645	136	45	82.35

APPENDIX B: TEMPLATES AND GUIDES

Table A.6. AI Study Tools Reference Guide

AI Study Tools & How to Use Them

Prompt for Chatgpt or Perplexity:

1. (Paste study guide or or notes or Topic you are studying for)
2. Then, "Test me on this until I get 5 questions right in a row, and increase the intensity for every one I get right." You can ask as many questions as you want or ask it to explain it further.

What AI Helps With •  Practice questions •  Flashcards •  Summaries •  Explanations •  Organizing material What AI Does Not Do •  Take your quiz •  Predict teacher's test •  Guarantee all answers are right •  Replace honest study  NotebookLM Steps  Go to: https://notebooklm.google.com 1.  Upload your study guide. 2.  Ask clear questions, e.g.: ◦ "Summarize classification." ◦ "Make 5 quiz questions." 3.  Check output against your notes. 4.  Fix mistakes and repeat.	 Best AI Prompts • "Make 10 multiple choice questions on photosynthesis for 9th grade, with answers." • "Explain cell respiration in simple terms. Give an example." • "Turn these 3 sentences into flashcards." Tips: •  State topic, grade, type (quiz/flashcards). •  Say "with answer key" if you want answers.  Study Workflow 1. AI makes questions or flashcards. 2.  Answer without looking at the key. 3.  Check with your guide. 4.  Fact-check. 5.  Fix errors. 6.  Repeat until ready.	 Fact-Check All Answers • Compare AI output to your notes and textbook • Ask teacher if unsure  What NOT to Do •  Copy AI answers for homework •  Trust AI without checking •  Use AI during quizzes or tests  Mix AI & Traditional •  Draw diagrams •  Quiz with classmates •  Use AI for practice, not shortcuts
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YOUR AI STUDY TOOLBOX

What AI Can Do For You:

- ✓ Generate practice questions and quizzes
- ✓ Create flashcards from your notes
- ✓ Explain tough concepts in simple words
- ✓ Give you feedback on your answers
- ✓ Help you organize study materials

What AI CANNOT Do:

- ✗ Take the quiz for you (that's cheating!)
 - ✗ Know your teacher's exact test questions
 - ✗ Always give 100% correct answers (you must fact-check!)
 - ✗ Replace actual studying and understanding
-

AI PLATFORMS YOU CAN USE

1. NotebookLM (Google)

Link:

<https://notebooklm.google.com>

Best for: Uploading YOUR study guide and asking questions about it

How to use it:

1. Go to notebooklm.google.com and create a notebook
2. Upload your study guide (PDF, Google Doc, or paste text)
3. Ask questions directly about YOUR materials
4. NotebookLM will answer based only on what you uploaded (more accurate!)

Example Prompts:

- "Summarize the key points about classification in this study guide."
 - "Create 5 quiz questions from this document."
-

2. Google Gemini

Link:

<https://gemini.google.com>

Best for: Similar to ChatGPT—practice questions, explanations, study help

How to use it:

1. Go to gemini.google.com (works with your Google/school account)
2. Type your study question or request
3. Check the response against your study guide

Example Prompts:

- "Make 10 flashcards for the 6 kingdoms of life with key characteristics."
 - "Quiz me on biodiversity and food webs with 5 questions."
-

3. Perplexity AI

Link:

<https://www.perplexity.ai>

Best for: Research-style questions with sources/citations

How to use it:

1. Go to perplexity.ai (no account needed for basic use)
2. Ask a specific biology question
3. Perplexity will give you an answer WITH sources—check those sources!

Example Prompts:

- "What are the differences between prokaryotic and eukaryotic cells?"
- "Explain the 3 domains of life with examples."

4. ChatGPT

Link:

<https://chat.openai.com>

Best for: Generating practice questions, explaining concepts, getting feedback on answers

How to use it:

1. Go to chat.openai.com and create a free account (or use school login if available)
2. Type a clear question or request (called a "prompt")
3. Review the AI's response
4. Always fact-check using your study guide or notes!

Example Prompts:

- "Create 5 multiple choice questions on microscope parts for 9th grade biology. Include an answer key."
- "Explain homeostasis using a desert lizard as an example in simple terms."
- "Give me feedback on this answer: [paste your answer]"

5. Quizlet (AI Features)

Link:

<https://quizlet.com>

Best for: Auto-generating flashcards and practice tests

How to use it:

1. Go to quizlet.com and create a free account
2. Create a new study set
3. Use "Magic Notes" or paste in notes—Quizlet AI will turn them into flashcards
4. Study with flashcards, practice tests, or matching games

Example Use:

- Paste 5-10 sentences from your study guide
- Quizlet creates flashcards automatically
- Quiz yourself and track your progress



HOW TO WRITE A GOOD AI PROMPT

Formula for Success:

[Action] + [Topic] + [Grade Level] + [Format]

Examples:

- Bad: "biology quiz"
- Good: "Create 10 multiple choice questions on cell organelles for 9th grade biology with an answer key."
- Bad: "help me study"
- Good: "Explain photosynthesis vs. cellular respiration in simple terms with examples."

Tips for Better Prompts:

- Be specific about the topic
- Say what grade level (9th grade biology)
- Ask for what you need (quiz, flashcards, explanation, feedback)
- Include "with answer key" if you want answers

✓ BEST WAYS TO USE AI FOR BIOLOGY

1. Generate Practice Questions

Steps:

1. Go to ChatGPT or Gemini
2. Prompt: *"Make 10 practice questions on [topic from study guide] for 9th grade. Include answers."*
3. Take the quiz WITHOUT looking at answers
4. Check your answers
5. Fact-check the AI answers using your study guide!

2. Create Flashcards

Steps:

1. Go to Quizlet or use ChatGPT/Gemini
2. Prompt: *"Turn these notes into flashcards: [paste 3-5 sentences from study guide]"*
3. Review the flashcards
4. Fix any mistakes
5. Study using the flashcard app or print them

3. Get Feedback on Your Answers

Steps:

1. Write a short answer to a study guide question
2. Paste it into ChatGPT or Perplexity
3. Prompt: *"Give me feedback on this biology answer. Is it accurate and complete for 9th grade?"*
4. Read the feedback
5. Revise your answer based on feedback
6. Double-check with your notes or ask your teacher if unsure!

4. Simplify Tough Concepts

Steps:

1. Find a concept you don't understand in your study guide
2. Go to ChatGPT, Gemini, or Perplexity
3. Prompt: *"Explain [concept] in simple, easy-to-understand language with an example."*
4. Read the explanation
5. Try to explain it in your own words—if you can't, ask AI to clarify more

5. Build a Study Plan

Steps:

1. Go to ChatGPT or Gemini
2. Prompt: *"Help me create a 3-day study plan for a biology quiz on [topics]. Break it into daily tasks."*
3. Follow the plan AI gives you
4. Adjust it to fit your schedule

 **IMPORTANT: ALWAYS FACT-CHECK AI!**
Why?

- AI can make mistakes
- AI doesn't know your teacher's exact test
- AI might give outdated or wrong information

How to Fact-Check:

1. Compare AI answers to your study guide
2. Check with your class notes or textbook
3. Ask your teacher if something seems wrong
4. Use Perplexity (it shows sources) to verify facts

✗ AI DON'Ts (Avoid These!)

✗ DON'T	✓ DO
Copy AI answers for homework	Use AI to generate practice questions
Trust AI 100% without checking	Always fact-check with your study guide
Use AI during the actual quiz	Use AI to prepare BEFORE the quiz
Let AI do your thinking for you	Use AI to test your understanding
Assume AI knows your exact test	Use AI as a study assistant, not a shortcut

📌 QUICK REFERENCE: AI STUDY WORKFLOW

Step 1: Use AI to create practice questions or flashcards

Step 2: Try to answer WITHOUT looking

Step 3: Check your answers

Step 4: Fact-check AI answers with your study guide

Step 5: Fix mistakes and study what you got wrong

Step 6: Repeat until you can answer everything correctly!

Pro Tip: Combine AI with traditional methods! Draw diagrams, quiz with friends, AND use AI tools for the best results.

Table A.7. Biology Study Strategies Reference Guide

Biology Study Strategies Reference Guide

Save this guide! Use it every time you prepare for a quiz or test.



BEFORE YOU START: Make a Plan

Set Clear Goals

- Write down exactly what you need to learn (ex: "Master all microscope parts by Thursday")
- Break big topics into smaller chunks (ex: Monday = Characteristics of Life, Tuesday = Classification)
- Set a specific time and place to study each day

Organize Your Materials

- Gather your study guide, class notes, lab packets, and textbook
- Make a checklist of every topic on the study guide
- Check off each topic as you master it



QUICK REFERENCE: BEST PRACTICES

✓ DO THIS	✗ NOT THIS
Test yourself with practice questions	Just re-read notes passively
Draw diagrams from memory	Only look at pictures
Explain concepts out loud	Highlight everything
Study in short sessions over time	Cram the night before
Use flashcards actively	Copy definitions without thinking
Check answers and fix mistakes	Assume you know it all



ACTIVE STUDYING STRATEGIES (Proven to Work!)

1. Self-Testing (Active Recall)



Why it works: Testing yourself = 2x better memory than re-reading



How to do it:

- Cover your notes and try to write everything you remember
- Use the study guide to quiz yourself without looking at answers first
- Make practice questions from your notes and answer them later
- Try online practice quizzes (check with teacher for good sites)

2. Flashcards (Paper or Digital)



Why it works: Forces you to actively retrieve information



How to do it:

- Write the term/question on one side, definition/answer on the other
- Quiz yourself regularly—put cards you know in one pile, don't know in another
- Focus extra time on the "don't know" pile
- Shuffle cards so you don't just memorize the order

3. Drawing & Labeling Diagrams



Why it works: Visual learning + active practice = strong memory



How to do it:

- Draw diagrams from memory (microscope, food webs, cell parts, etc.)
- Label everything without looking at your notes
- Check your drawing against the correct version and fix mistakes
- Redraw it until you can do it perfectly from memory

4. Explain It Out Loud (Teach Someone)

- ✓ Why it works: If you can teach it, you truly understand it
- ✓ How to do it:
 - Explain a concept to a family member, friend, or even a pet!
 - Pretend you're the teacher—use simple words
 - If you get stuck, that's what you need to study more
 - Record yourself explaining and listen back

5. Cornell Notes Method

- ✓ Why it works: Organized notes = easier review
- ✓ How to do it:
 - Divide your paper: notes on right, key questions/terms on left, summary at bottom
 - Use the left column to quiz yourself
 - Review summaries before the test

6. Rewrite Notes in Your Own Words

- ✓ Why it works: Forces deeper understanding
- ✓ How to do it:
 - Don't copy word-for-word from the study guide
 - Summarize each section in 1-2 sentences
 - Use examples that make sense to YOU

7. Study with a Partner or Group

- ✓ Why it works: Peer teaching improves retention by up to 60%
- ✓ How to do it:
 - Quiz each other on vocabulary or key concepts
 - Explain tough topics to each other
 - Create practice tests together
 - Do card sorts or matching games as a team

8. Use Mnemonics & Memory Tricks

- ✓ Why it works: Makes complex info easier to remember
- ✓ How to do it:
 - Create acronyms (ex: "King Philip Came Over For Good Soup" = Kingdom, Phylum, Class, Order, Family, Genus, Species)
 - Make silly sentences or stories to remember lists
 - Use rhymes or songs



SPACING & TIMING

Space Out Your Study Sessions

- ✓ Why it works: Spaced practice is 9x more effective than cramming
- ✓ How to do it:
 - Study 20-30 minutes per day instead of 3 hours the night before
 - Review the same material multiple times over several days
 - Take 5-10 minute breaks between study sessions

Use the Pomodoro Technique

- ✓ How to do it:
 - Study for 25 minutes (focused, no distractions)
 - Take a 5-minute break

- Repeat 3-4 times, then take a longer break (15-30 min)

CHECK YOUR UNDERSTANDING

Self-Check Questions to Ask:

- Can I explain this concept without looking at my notes?
- Can I draw or label this diagram from memory?
- Could I teach this to someone who's never heard of it?
- Can I answer practice questions correctly?
- Do I know WHY, not just WHAT?

Fix Your Mistakes

- Every time you get something wrong, write it down
- Make a "mistake list" and review it extra
- Figure out WHY you got it wrong (didn't study it? misunderstood? guessed?)

STAY FOCUSED & MOTIVATED

Remove Distractions

- Put your phone in another room or on "Do Not Disturb"
- Close unnecessary tabs on your computer
- Find a quiet study spot
- Tell family/friends you're studying so they don't interrupt

Reward Yourself

- After finishing a study session, do something you enjoy
- Set mini-goals and celebrate when you hit them

Ask for Help When You Need It

- Email or ask your teacher for clarification
- Work with a classmate or study buddy
- Use office hours or tutoring if available
- Don't wait until the night before!

Remember: The study guide is your roadmap—use it to check your progress every day!

Table A.8. AI Cohort – Themes-Aligned Study Check-In Items

AI Study Check-In – Treatment Cohort

Description: Rate each statement from 1–5 (1 = Strongly Disagree, 5 = Strongly Agree).

Self-Regulated Learning (SRL) – Likert

1. I set specific goals for what I want to accomplish when I use AI to study for science.
2. I have a clear plan for when and how long I will use AI to study before this test.
3. I use AI to self-test (for example, by generating quizzes or practice questions).
4. I regularly check whether my AI-based study methods are actually helping me learn.

5. I use feedback from quizzes, AI, or my teacher to decide what to focus on next when I study.

Engagement – Likert

6. Using AI tools makes studying for science more interesting for me.
7. When I use AI to study, I feel more motivated to keep going.
8. I am willing to stick with challenging topics longer when I use AI to help me.

Barriers – Likert

9. I sometimes feel confused by answers or explanations that AI gives me.
10. Technical issues or access problems make it hard for me to use AI to study.
11. Distractions (like my phone, notifications, or other apps) get in the way when I try to study with AI.

Facilitators – Likert

12. AI makes it easier for me to find out what I do and do not understand.
13. AI feedback (for example, telling me what I got wrong and why) helps me improve my understanding.
14. AI tools are easy enough to use that I can study on my own without much help.

AI Impact / Habits – Likert

15. Using AI has changed the way I usually study for science.
16. Because of AI, I start studying earlier or more often than I used to.
17. Overall, AI tools help me feel more prepared for quizzes and tests in this class.

Open-Ended (Paragraph)

18. Give one specific example of a time AI helped you with self-regulated learning (for example, planning, time management, self-testing, or using feedback). What did you do, and how did it help?
 19. Describe a time when using AI created a barrier for you (for example, confusion, bad answer, technical problem, distraction). How did you respond, and what could help you handle this better next time?
 20. List the specific AI tools you plan to use for this unit (for example: ChatGPT, Gemini, NotebookLM, Quizlet, Perplexity). For each one, explain what you will mainly use it for (quizzes, explanations, summaries, study schedules, flashcards, something else).
 21. Looking ahead to the next unit, which AI tools and study routines do you definitely want to keep using, and which do you want to change or stop using? Explain why for each.
 22. If you could change one thing about how AI tools work or how we use them in this class to make studying easier or more effective, what would you change, and why?
- Note: This form was administered at approximate check-in intervals (2 weeks, 1 week, and 1 day before each post-unit test).

Table A.9. Traditional Cohort – Themes-Aligned Study Check-In Items

Study Check-In – Traditional Cohort

Description: Rate each statement from 1–5 (1 = Strongly Disagree, 5 = Strongly Agree).

Self-Regulated Learning (SRL) – Likert

1. I set specific goals for what I want to accomplish when I study for science without AI.

2. I have a clear plan for when and how long I will study before this test.
3. I use self-testing strategies (for example, practice questions, making my own quizzes, or having someone quiz me).
4. I regularly check whether my usual study methods are actually helping me learn.
5. I use feedback from quizzes or my teacher to decide what to focus on next when I study.

Engagement – Likert

6. The study strategies I use (notes, study guide, flashcards, peer quizzing, etc.) make studying for science more interesting for me.
7. When I use my usual study strategies, I feel motivated to keep going.
8. I am willing to stick with challenging topics longer when I use my preferred study methods.

Barriers – Likert

9. I sometimes feel confused by my notes, study guide, or textbook when I study on my own.
10. It is hard for me to find time or stay on a schedule to study for this class.
11. Distractions (like my phone, TV, or other responsibilities) get in the way when I try to study.

Facilitators – Likert

12. The materials I have (notes, study guide, textbook, practice questions) make it easier for me to see what I do and do not understand.
13. Feedback from quizzes or my teacher helps me improve my understanding.

14. My study strategies are easy enough to use that I can study on my own without much help.

Impact / Habits – Likert

15. The way I study for this unit is different (better or more focused) than how I used to study for science.
16. Because of what we have talked about in class, I start studying earlier or more often than I used to.
17. Overall, my traditional study strategies help me feel prepared for quizzes and tests in this class.

Open-Ended (Paragraph)

18. Give one specific example of a time your study habits showed good self-regulated learning (for example, planning, time management, self-testing, or using feedback). What did you do, and how did it help?
19. Describe a time when your usual study method did not work well (for example, confusion, not enough time, too passive like just rereading). How did you respond, and what could you do differently next time?
20. List the specific traditional strategies you plan to use for this unit (for example: rereading notes, using the study guide, flashcards, peer quizzing, textbook reading, practice problems). For each one, explain what you will mainly use it for.
21. Looking ahead to the next unit, which traditional strategies and routines do you definitely want to keep using, and which do you want to change or stop using? Explain why for each.

22. If you could change one thing about the study materials or routines we use in this class to make studying easier or more effective, what would you change, and why?

Note: This form was administered at the same approximate check-in intervals as the AI cohort (2 weeks, 1 week, and 1 day before each post-unit test).

Table A.10. Pre- and Post-Unit Embedded Test Items by Cohort and Construct
AI Cohort – Pre-Unit Check-In

Instructions for Students: Answer the following questions honestly based on how you plan to study for this unit. Rate each statement from 1–5 (1 - Strongly Disagree, 2 – Disagree, 3 - Neutral, 4 - Agree, 5 - Strongly Agree).

Likert Scale Questions (A–Q)

- A. I have a clear plan for when and how I will use AI to study for this unit. (SRL)
- B. I plan to use AI to self-test (for example, by generating quizzes or practice questions) for this unit. (SRL)
- C. I feel confident that I can use AI tools effectively to prepare for this test. (Facilitators)
- D. I believe AI tools will help me identify what I do and do not understand in this unit. (Facilitators)
- E. I am concerned that distractions or technical issues will get in the way of using AI to study. (Barriers)
- F. Using AI will make studying for this unit more interesting for me. (Engagement)
- G. When I use AI to study, I plan to ask it for different types of questions or explanations to see the topic in new ways.
- H. When I use AI to study, I plan to use it mainly to improve work I already started (like

fixing answers, adding details, or cleaning up notes).

I. When I do not understand an AI explanation, I plan to ask it to explain again using simpler words or a different example. (SRL – monitoring/strategy adjustment)

J. Technical issues or access problems might make it hard for me to use AI to study for this unit. (Barriers)

K. Distractions (like my phone, notifications, or other apps) might get in the way when I try to study with AI for this unit. (Barriers)

L. AI will make it easier for me to find out what I do and do not understand in this unit. (Facilitators)

M. AI feedback (for example, telling me what I got wrong and why) will help me improve my understanding in this unit. (Facilitators)

N. AI tools will be easy enough to use that I can study on my own without much help in this unit. (Facilitators)

O. Using AI will change the way I usually study for science in this unit. (Impact / Habits)

P. Because of AI, I plan to start studying earlier or more often than I used to for this unit. (Impact / Habits)

Q. Overall, I believe AI tools will help me feel more prepared for quizzes and tests in this class for this unit. (Impact / Habits)

Open-Ended Questions (R–W)

R. Think about this upcoming unit. Describe one specific way you plan to use AI to be a self-regulated learner (for example, planning, time management, self-testing, or using feedback). What will you actually do, and when will you do it?

S. Imagine you ask AI a question and the answer is confusing or too advanced. What is the very first thing you plan to do next? Please write the exact kind of sentence or request you would type to fix the confusion.

T. When you use AI to study, how do you want it to help you see the topic in new ways (for example, different kinds of questions, examples, or explanations) versus improving work you already started (like fixing answers or adding details)? Give one example of each.

U. List the specific AI tools you plan to use for this unit (for example: ChatGPT, Gemini, NotebookLM, Quizlet, Perplexity). For each one, explain what you will mainly use it for (quizzes, explanations, summaries, study schedules, flashcards, something else).

V. Looking ahead to this unit, which AI tools and study routines do you definitely want to keep using, and which do you want to change or stop using? Explain why for each.

W. If you could change one thing about how AI tools work or how we use them in this class to make studying easier or more effective, what would you change, and why?

Traditional Cohort – Pre-Unit Check-In

Instructions for Students: Answer the following questions honestly based on how you plan to study for this unit. Rate each statement from 1–5 (1 = Strongly Disagree, 5 = Strongly Agree).

Likert Scale Questions (A–Q)

A. I have a clear plan for when and how I will study for this unit. (SRL)

B. I plan to use self-testing strategies (for example, practice questions, making quizzes, or having someone quiz me) for this unit. (SRL)

C. I feel confident that my usual study strategies will help me prepare for this test.

(Facilitators)

D. I believe my study materials (notes, study guide, textbook) will help me identify what I do and do not understand in this unit. (Facilitators)

E. I am concerned that distractions or lack of time will get in the way of studying for this unit. (Barriers)

F. My study strategies will make studying for this unit interesting for me. (Engagement)

G. When I study, I plan to use different sources or types of practice (like videos, extra questions, or diagrams) to see the topic in new ways.

H. When I study, I plan to spend most of my time reworking or fixing the same notes or assignments I already have.

I. When I do not understand my notes, study guide, or textbook, I plan to rewrite the idea in my own words or ask someone to explain it more simply. (SRL – monitoring/strategy adjustment)

J. Access to my study materials (notes, study guide, textbook, or online resources) might make it hard for me to study the way I want for this unit. (Barriers – access)

K. Distractions (like my phone, notifications, or other people) might get in the way when I try to study for this unit. (Barriers – distraction)

L. My study materials will make it easier for me to find out what I do and do not understand in this unit. (Facilitators)

M. Feedback from my teacher, classmates, or practice questions (for example, telling me what I got wrong and why) will help me improve my understanding in this unit.

(Facilitators)

N. My study strategies and materials will be easy enough to use that I can study on my own without much help in this unit. (Facilitators)

O. Using my usual study strategies will change the way I usually study for science in this unit. (Impact / Habits)

P. Because of my current study strategies, I plan to start studying earlier or more often than I used to for this unit. (Impact / Habits)

Q. Overall, I believe my study strategies will help me feel more prepared for quizzes and tests in this class for this unit. (Impact / Habits)

Open-Ended Questions (R–W)

R. Think about this upcoming unit. Describe one specific way your study habits can show good self-regulated learning (for example, planning, time management, self-testing, or using feedback). What will you actually do, and when will you do it?

S. Imagine you are studying with your notes or study guide and a part of it is confusing. What is the very first thing you plan to do next? Explain how you would try to fix the confusion using your materials or people around you.

T. When you study, how do you want to use different kinds of practice (like new question types, diagrams, videos, or examples) compared to reworking the same notes or assignments? Give one example of each for this unit.

U. List the specific traditional tools or strategies you plan to use for this unit (for example: notes, textbook, study guides, flashcards, peer quizzing, review games). For each one, explain what you will mainly use it for (quizzes, explanations, summaries,

study schedules, flashcards, something else).

V. Looking ahead to this unit, which traditional study routines do you definitely want to keep using, and which do you want to change or stop using? Explain why for each.

W. If you could change one thing about how our study materials or routines work in this class to make studying easier or more effective, what would you change, and why?

AI Cohort – Post-Unit Check-In

Instructions for Students: Now that you have completed this unit, answer the following questions honestly based on your actual study experience. Rate each statement from 1–5 (1 = Strongly Disagree, 5 = Strongly Agree).

Likert Scale Questions (A–Q)

- A. I had a clear plan for when and how I used AI to study for this unit. (SRL)
- B. I used AI to self-test (for example, by generating quizzes or practice questions) for this unit. (SRL)
- C. AI tools were effective in helping me prepare for this test. (Facilitators)
- D. AI helped me identify what I did and did not understand in this unit. (Facilitators)
- E. Distractions, confusion, or technical issues got in the way of using AI to study for this unit. (Barriers)
- F. Using AI made studying for this unit more interesting for me. (Engagement)
- G. Overall, AI tools helped me feel prepared for this test. (Impact)
- H. I verified AI-generated information using other sources (notes, textbook, teacher feedback) in this unit. (SRL)
- I. When I used AI to study, I often asked it for new kinds of questions, examples, or

explanations about the topic in this unit.

J. When I used AI to study, I mostly used it to check or improve things I had already written or answered in this unit.

K. When I did not understand an AI explanation in this unit, I usually asked it to explain again using simpler words or a different example. (SRL – monitoring/strategy adjustment)

L. Technical issues or access problems often made it hard for me to use AI to study during this unit. (Barriers)

M. Distractions (like my phone, notifications, or other apps) often got in the way when I tried to study with AI during this unit. (Barriers)

N. AI made it easier for me, in reality, to find out what I did and did not understand in this unit. (Facilitators)

O. AI feedback (for example, telling me what I got wrong and why) actually helped me improve my understanding in this unit. (Facilitators)

P. AI tools were easy enough to use that I could study on my own without much help in this unit. (Facilitators)

Q. Because of AI, I studied earlier or more often than I used to for this unit. (Impact / Habits)

Open-Ended Questions (R–W)

R. Give one specific example from this unit when AI helped you with self-regulated learning (planning, time management, self-testing, or using feedback). What did you do, and how did it change the way you studied or felt before the test?

S. Describe a time in this unit when an AI answer or explanation was confusing or unhelpful. What did you actually do in response, and what do you wish you had done differently to fix the confusion faster?

T. During this unit, did you use AI more to explore the topic in new ways (different questions, examples, or explanations) or more to polish/fix work you had already started (checking answers, adding details, cleaning up notes)? Give one real example and explain why you chose to use it that way.

U. Thinking back on this unit, what is one concrete change you want to make in how you use AI to study next time so that it better matches how you actually learn (for example, question types, timing, or how you handle confusion)?

V. Looking ahead to the next unit, which AI tools and study routines do you definitely want to keep using, and which do you want to change or stop using? Explain why for each.

W. If you could change one thing about how AI tools worked for you in this unit to make studying easier or more effective, what would you change, and why?

Traditional Cohort – Post-Unit Check-In

Instructions for Students: Now that you have completed this unit, answer the following questions honestly based on your actual study experience. Rate each statement from 1–5 (1 = Strongly Disagree, 5 = Strongly Agree).

Likert Scale Questions (A–Q)

A. I had a clear plan for when and how I studied for this unit. (SRL)

B. I used self-testing strategies (for example, practice questions, making quizzes, or

having someone quiz me) for this unit. (SRL)

C. My usual study strategies were effective in helping me prepare for this test.

(Facilitators)

D. My study materials helped me identify what I did and did not understand in this unit.

(Facilitators)

E. Distractions, confusion, or lack of time got in the way of studying for this unit.

(Barriers)

F. My study strategies made studying for this unit interesting for me. (Engagement)

G. Overall, my study strategies helped me feel prepared for this test. (Impact)

H. I used feedback from previous quizzes or class activities to guide my studying in this unit. (SRL)

I. When I studied, I often tried new kinds of practice or different ways of looking at the topic (like new examples, diagrams, or question types) in this unit.

J. When I studied, I mostly went back over the same notes or assignments to polish or fix them, instead of trying new kinds of practice, in this unit.

K. When I did not understand my notes, study guide, or textbook in this unit, I usually rewrote the idea in my own words or asked someone to explain it more simply. (SRL – monitoring/strategy adjustment)

L. Access to my study materials (notes, study guide, textbook, or online resources)

sometimes made it hard for me to study the way I wanted during this unit. (Barriers)

M. Distractions (like my phone, notifications, or other people) often got in the way when I tried to study during this unit. (Barriers)

N. My study materials actually made it easier for me to find out what I did and did not understand in this unit. (Facilitators)

O. Feedback from my teacher, classmates, or practice questions (for example, telling me what I got wrong and why) helped me improve my understanding in this unit.
(Facilitators)

P. My study strategies and materials were easy enough to use that I could study on my own without much help in this unit. (Facilitators)

Q. Because of my current study strategies, I studied earlier or more often than I used to for this unit. (Impact / Habits)

Open-Ended Questions (R–W)

R. Give one specific example from this unit when your study habits showed good self-regulated learning (planning, time management, self-testing, or using feedback). What did you do, and how did it help your learning or test readiness?

S. Describe a time in this unit when your usual study method did not work well (for example, confusion, not enough time, or just rereading). What did you actually do in the moment, and what will you try differently next time?

T. During this unit, did you spend more time trying new kinds of practice or different ways of looking at the topic (new examples, diagrams, question types) or more time going back over the same notes or assignments to polish or fix them? Give one real example and explain why you used your time that way.

U. After this unit, what is one concrete change you want to make in how you study for the next unit so that it better matches how you actually learn (for example, how early you

start, which tools you use, or how you handle confusion)?

V. Looking ahead to the next unit, which traditional study routines do you definitely want to keep using, and which do you want to change or stop using? Explain why for each.

W. If you could change one thing about how our study materials or routines worked for you in this unit to make studying easier or more effective, what would you change, and why?

Table A.11. Pre/Post Embedded Item Alignment by Construct Summary

Label	Item Type	Cohort(s)	Pre-Unit Wording Focus	Post-Unit Wording Focus	Construct
A	Like rt	Both	“I have a clear plan for when and how I will (use AI) / study for this unit.”	“I had a clear plan for when and how I (used AI) / studied for this unit.”	SRL – planning
B	Like rt	Both	“I plan to use AI to self-test...” / “I plan to use self-testing strategies...”	“I used AI to self-test...” / “I used self-testing strategies...”	SRL – self-testing
C	Like rt	Both	Confidence that AI tools / usual strategies will help prepare for this test	AI tools / usual strategies were effective in helping prepare for this test	Facilitators – perceived effectiveness
D	Like rt	Both	Belief that AI tools / study materials will help identify what they do and do not understand	AI tools / study materials helped identify what they did and did not understand	Facilitators – gap detection
E	Like rt	Both	Concern that distractions, tech issues, or lack of time will get in the way of	Distractions, confusion, tech issues, or lack of time got in the way of (AI)	Barriers – perceived vs. experienced

Label	Item Type	Cohort(s)	Pre-Unit Wording Focus	Post-Unit Wording Focus	Construct
			(AI) studying	studying	
F	Like rt	Both	Expectation that (AI-based / usual) studying will be interesting	(AI-based / usual) studying was interesting	Engagement
G	Like rt	AI only	Plan to ask AI for different types of questions or explanations to see the topic in new ways	Overall, AI tools helped me feel prepared for this test	Impact – preparedness (AI)
H	Like rt	Trad only	Plan to spend most time reworking/fixing existing notes or assignments	Mostly went back over the same notes/assignments to polish or fix them	SRL – exploitation (traditional)
H	Like rt	AI only	Plan to use AI mainly to improve work already started (fixing answers, adding details, cleaning up notes)	Mostly used AI to check or improve things already written or answered	SRL – exploitation (AI)
I	Like rt	Both	Plan to repair confusion by asking AI to re-explain / rewriting in own words or asking someone for help	Usually repaired confusion by asking AI to re-explain / rewriting in own words or asking someone for help	SRL – monitoring & strategy adjustment
G (Trad post)	Like rt	Trad only	—	Overall, my study strategies helped me feel prepared for this test	Impact – preparedness (traditional)
H (AI post)	Like rt	AI only	—	Verified AI information with other sources (notes, textbook, teacher feedback)	SRL – verification
H	Like	Trad	—	Used feedback from	SRL – feedback

Label	Item Type	Cohort(s)	Pre-Unit Wording Focus	Post-Unit Wording Focus	Construct
(Trad post)	rt	only		previous quizzes or class activities to guide my studying	use
I (AI post)	Like rt	AI only	Plan to ask AI for new kinds of questions, examples, or explanations	Often asked AI for new kinds of questions, examples, or explanations	SRL – exploration with AI
I (Trad post)	Like rt	Trad only	Plan to use different sources or practice types (videos, extra questions, diagrams)	Often tried new kinds of practice or different ways of looking at the topic	SRL – exploration with traditional resources
J (AI post)	Like rt	AI only	Plan to use AI mainly to improve existing work (see H–AI pre)	Mostly used AI to check or improve things already written or answered	SRL – exploitation with AI
J (Trad post)	Like rt	Trad only	Plan to spend most time reworking/fixing same notes/assignments (see H–Trad pre)	Mostly went back over the same notes/assignments to polish or fix them	SRL – exploitation with traditional resources

Table A.12. Open-Ended Item Families, Cohorts, and Constructs

Label Family	Item Type	Cohort(s)	Pre-Unit Focus	Post-Unit Focus	Construct

OE-SRL- Plan	Open- ended	Both	One specific way you plan to use AI / your traditional habits to show self-regulated learning in this upcoming unit	One specific example from this unit when AI / your study habits showed self-regulated learning and how it affected readiness	SRL – planning, time, self- testing
OE- Confusion- Repair	Open- ended	Both	First thing you plan to do when an AI answer / your notes or study guide are confusing	What you actually did when an AI answer / usual method was confusing, and what you wish you had done differently	SRL – monitoring & repair
OE- Explore-vs- Polish	Open- ended	Both	How you want AI / practice to help you see the topic in new ways versus improving work you already started	Whether you actually used AI / practice more to explore new ways or to polish/fix existing work, with one real example	SRL – exploration vs. exploitation

OE-Keep- Change	Open- ended	Both	One AI / traditional habit you want to keep and one you want to change so you feel more prepared for this unit	One concrete change you want to make in how you use AI / study next unit so it better matches how you actually learn	SRL – reflection & strategy reset
OE-Tools- Use	Open- ended	AI only	List AI tools you plan to use and what you will mainly use each for this unit	— (paired descriptively with post comments on actual AI use, but no direct parallel embedded post item)	Descriptive – AI tool selection & intentions

APPENDIX C: CITI IRB

Table A.13. Montana State University's CITI IRB

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)
COMPLETION REPORT - PART 1 OF 2
COURSEWORK REQUIREMENTS*

* Scores on this [Requirements Report](#) (Part 1) reflect quiz completions at the time all requirements for the course were met. The Transcript Report (Part 2) lists more recent quiz scores, including those on optional (supplemental) course elements.

• **Name:** Trey Jaworski (ID: 14231276)
 • **Institution Affiliation:** Montana State University (ID: 1096)
 • **Institution Email:** jaworskitrey@gmail.com

• **Curriculum Group:** Students
 • **Course Learner Group:** IRB Students and Class Projects
 • **Stage:** Stage 1 - Basic Course
 • **Description:** This course is appropriate for students doing class projects that qualify as "No More Than Minimal Risk" human subjects research.

• **Record ID:** 68182919
 • **Completion Date:** 23-Feb-2025
 • **Expiration Date:** 23-Feb-2030
 • **Minimum Passing:** 80
 • **Reported Score*:** 96

REQUIRED AND ELECTIVE MODULES ONLY	DATE COMPLETED	SCORE
Belmont Report and Its Principles (ID: 1127)	23-Feb-2025	3/3 (100%)
Students in Research (ID: 1321)	23-Feb-2025	4/5 (80%)
History and Ethical Principles - SBE (ID: 490)	23-Feb-2025	5/5 (100%)
Defining Research with Human Subjects - SBE (ID: 491)	23-Feb-2025	5/5 (100%)
Informed Consent - SBE (ID: 504)	23-Feb-2025	5/5 (100%)

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

This document was generated on 06-Nov-2025. Verify at:
www.citiprogram.org/verify/?kf361f740-f542-46e9-9c07-782e3b303f1c-68182919

Collaborative Institutional Training Initiative (CITI Program)
 101 NE 3rd Avenue
 Suite 320
 Fort Lauderdale, FL 33301 US

Email: support@citiprogram.org
 Phone: 888-529-5929
 Web: <https://www.citiprogram.org>

**COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)
COMPLETION REPORT - PART 2 OF 2
COURSEWORK TRANSCRIPT****

** Scores on this Transcript Report (Part 2) reflect the most current quiz completions, including quizzes on optional (supplemental) elements of the course. The Requirements Report (Part 1) lists the reported scores at the time all requirements for the course were met.

- **Name:** Trey Jaworski (ID: 14231276)
- **Institution Affiliation:** Montana State University (ID: 1096)
- **Institution Email:** jaworskitrey@gmail.com

- **Curriculum Group:** Students
- **Course Learner Group:** IRB Students and Class Projects
- **Stage:** Stage 1 - Basic Course
- **Description:** This course is appropriate for students doing class projects that qualify as "No More Than Minimal Risk" human subjects research.

- **Record ID:** 68182919
- **Current Score**:** 96

REQUIRED, ELECTIVE, AND SUPPLEMENTAL MODULES	MOST RECENT	SCORE
History and Ethical Principles - SBE (ID: 490)	23-Feb-2025	5/5 (100%)
Defining Research with Human Subjects - SBE (ID: 491)	23-Feb-2025	5/5 (100%)
Belmont Report and Its Principles (ID: 1127)	23-Feb-2025	3/3 (100%)
Informed Consent - SBE (ID: 504)	23-Feb-2025	5/5 (100%)
Students in Research (ID: 1321)	23-Feb-2025	4/5 (80%)

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

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www.citiprogram.org/verify/2kf361f740-f542-46e9-9c07-782e3b303f1c-68182919

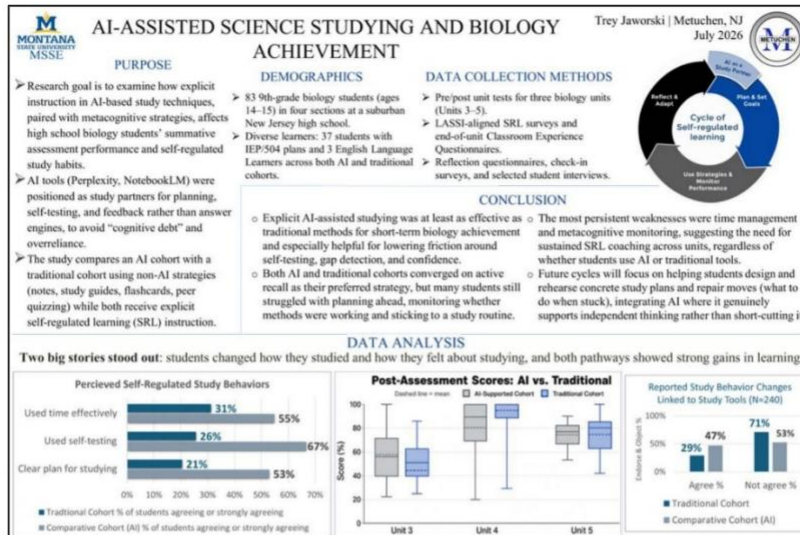
Collaborative Institutional Training Initiative (CITI Program)
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Web: <https://www.citiprogram.org>

APPENDIX D: PRESENTATION SLIDES

Figure 12: Presentation

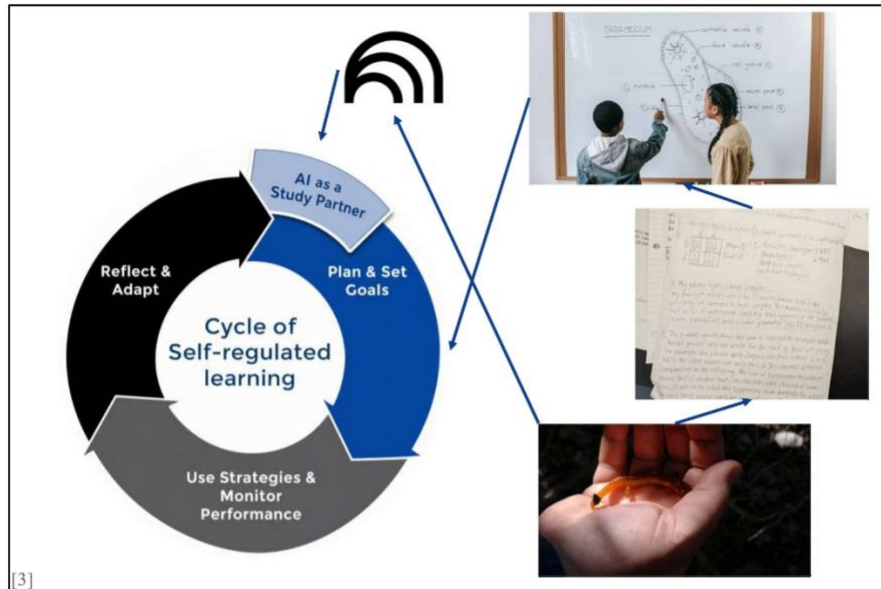
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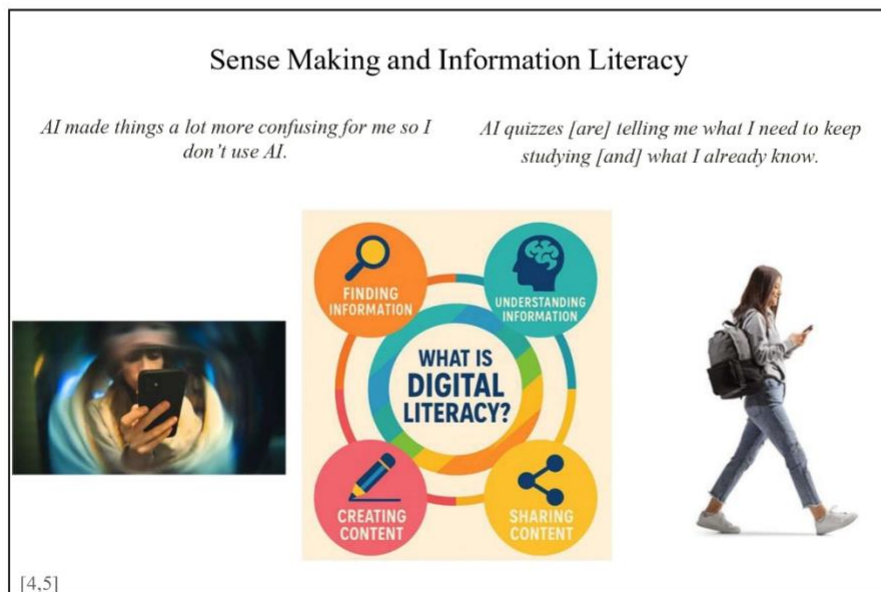
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Research Questions

MAIN RESEARCH QUESTION

How does the use of AI assisted studying affect high school biology students' summative assessment performance and study habits?

Sub-Questions

psychology

How does AI-studying affect science understanding and retention?

auto_stories

How does using AI change students' study habits and self-regulation?

insights

How much does metacognitive support improve AI-assisted learning outcomes?

schedule

How do AI tools affect students' time management and self-testing?

How do students' views of AI (helpful vs. overreliance) relate to their test performance?

5

Methods

Adapt Zimmerman's 2002 "**self-directive process**" through regular practice of learning cycles like goal setting and self-monitoring.

Monitoring Progress

12 Weeks · 3 Units

- Learning Community
- Summative assessments
- Surveys
- Check-ins
- Reflection responses
- Classroom experience questionnaire
- Individual interviews

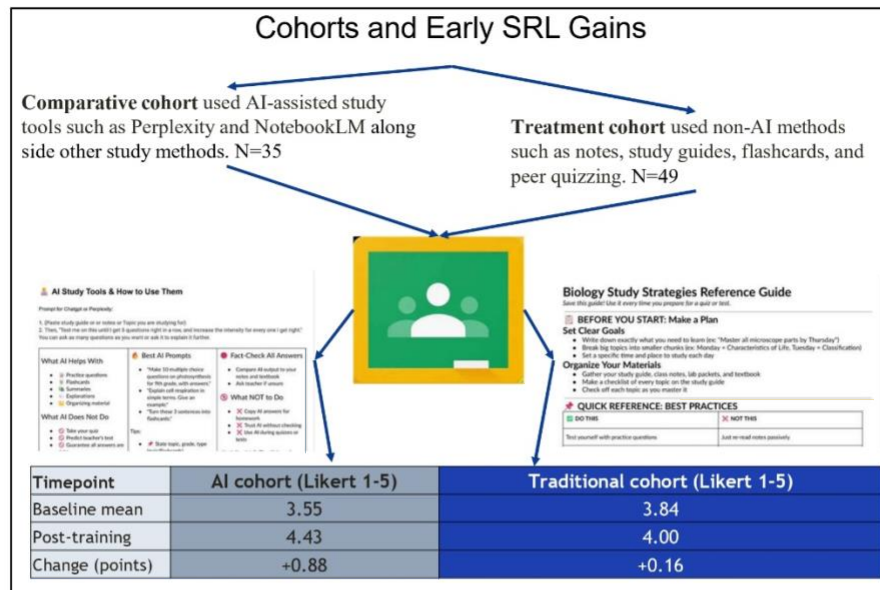


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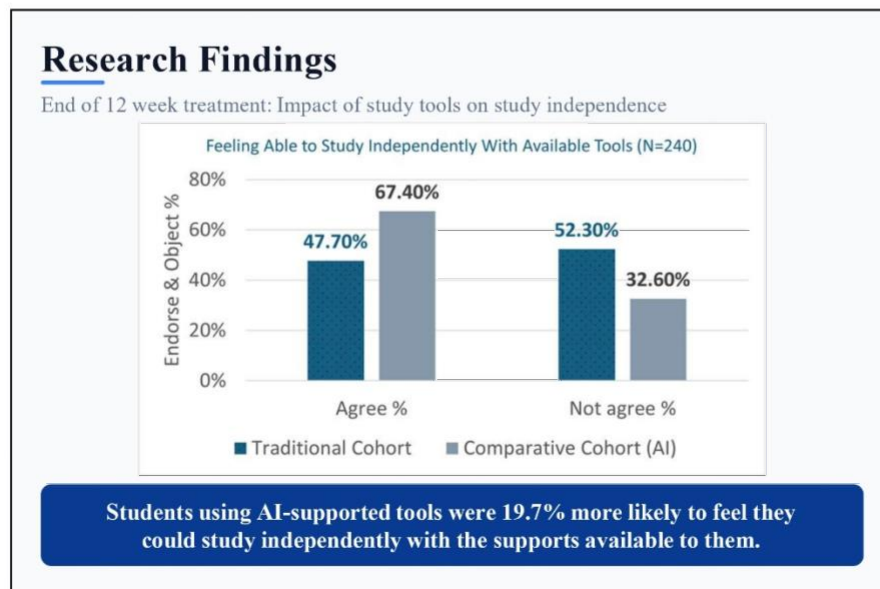
LASSI (Learning and Study Strategies Inventory) is a 10-scale, 60-item assessment of students' study skills, motivation, and self-regulation (e.g., time management, self-testing, concentration).

[6,7]

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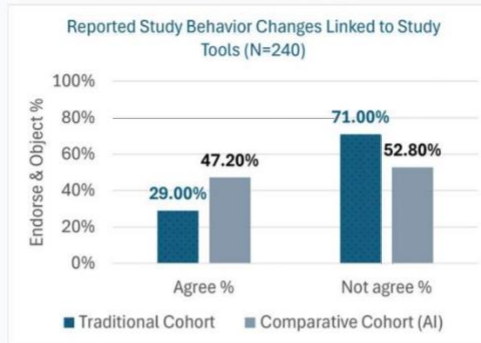
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Research Findings

End of 12 week treatment: Impact of study tools on studying behavior changes

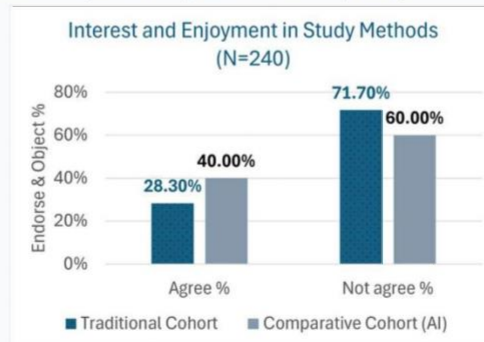


Students using AI-supported tools were 18.2% more likely to feel there study behaviors change in a positive (more agree) way.

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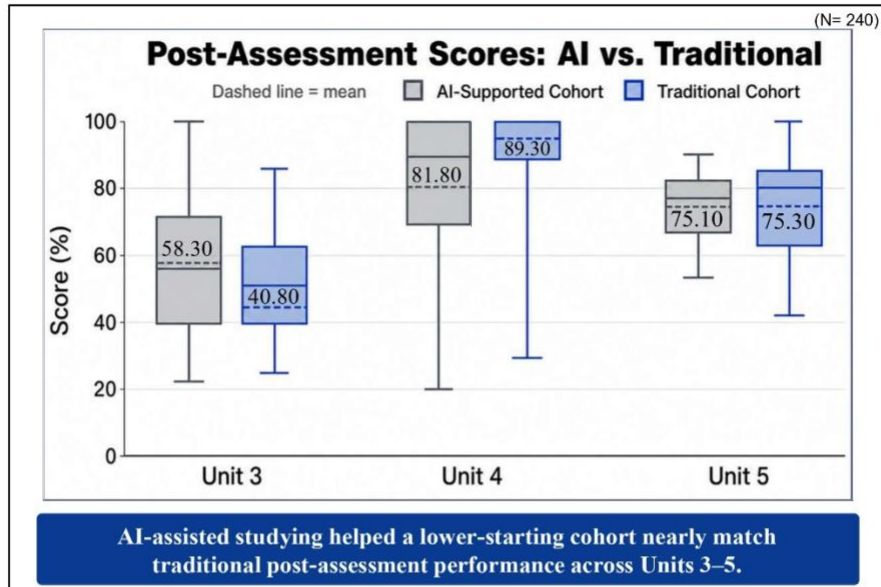
Research Findings

End of 12 week treatment: Impact of study tools on curiosity and pleasure.

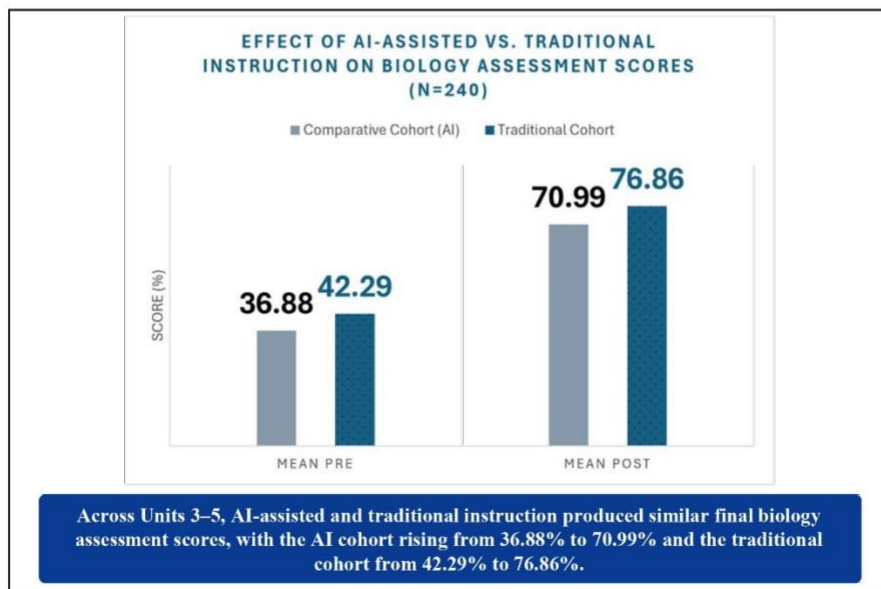


Students using AI-supported tools were 11.7% more likely to perceive more curiosity, interest, and enjoyable attitudes.

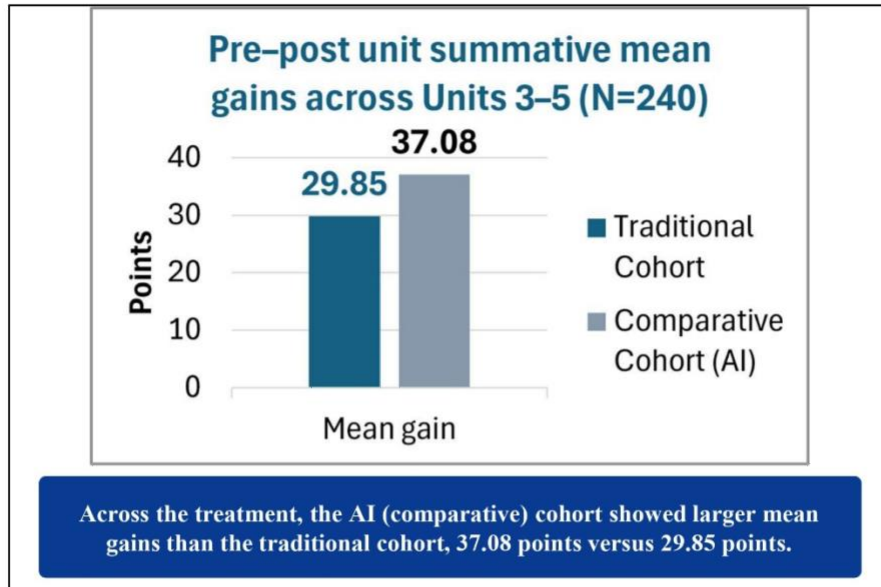
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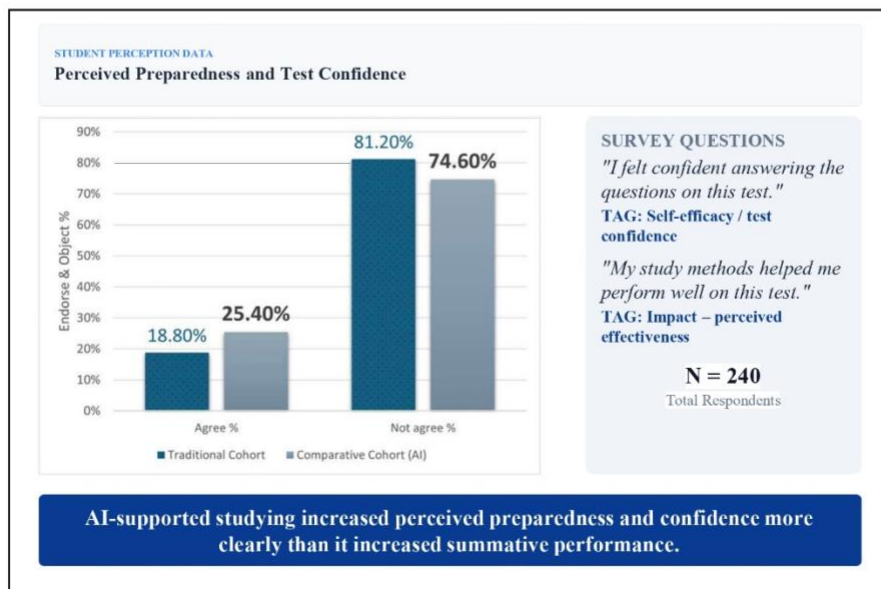
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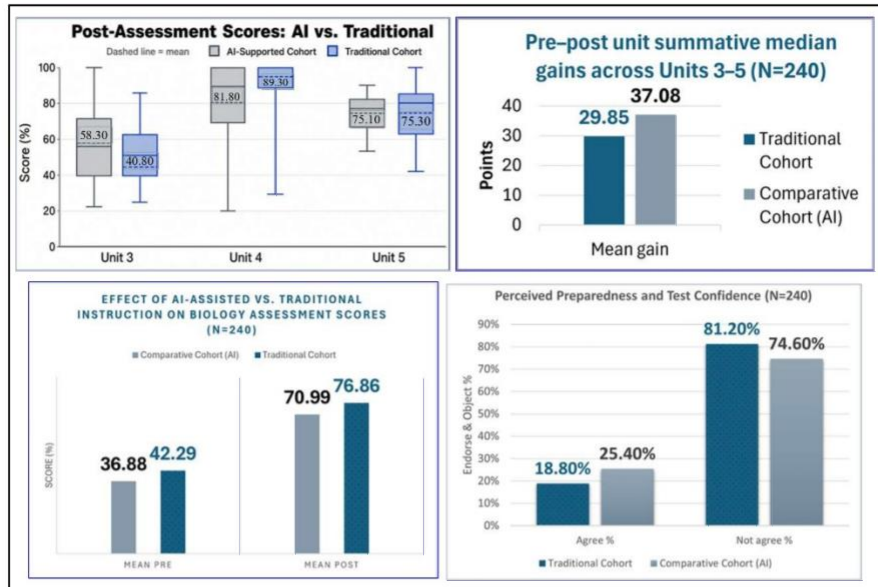
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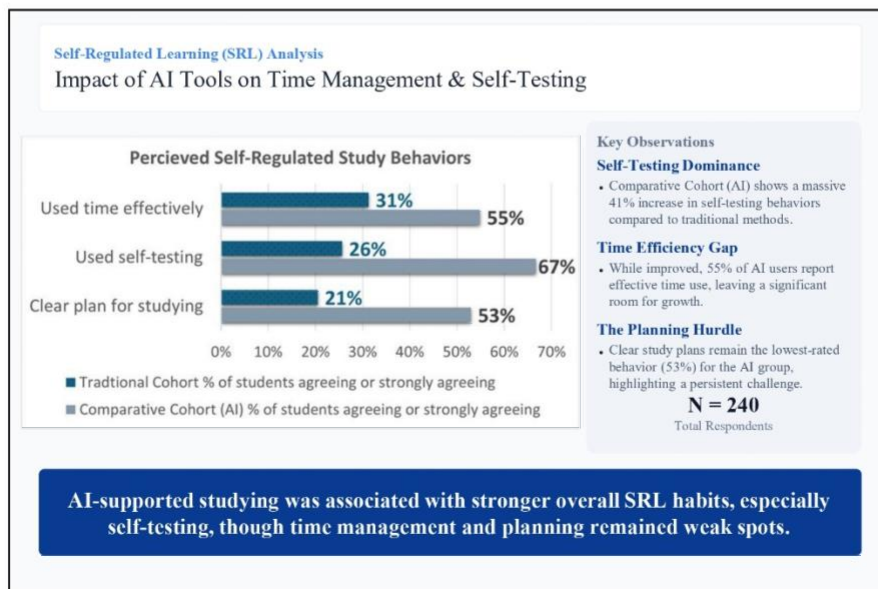
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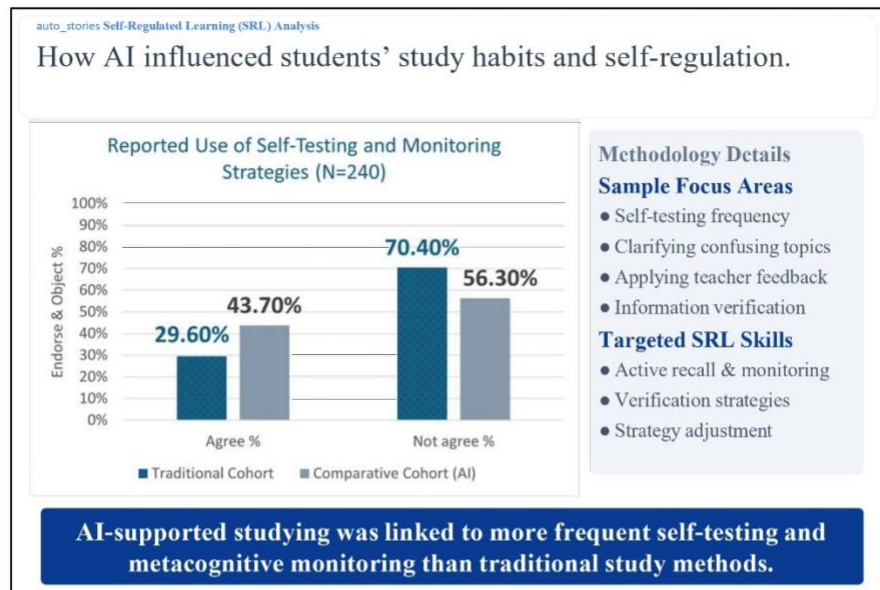
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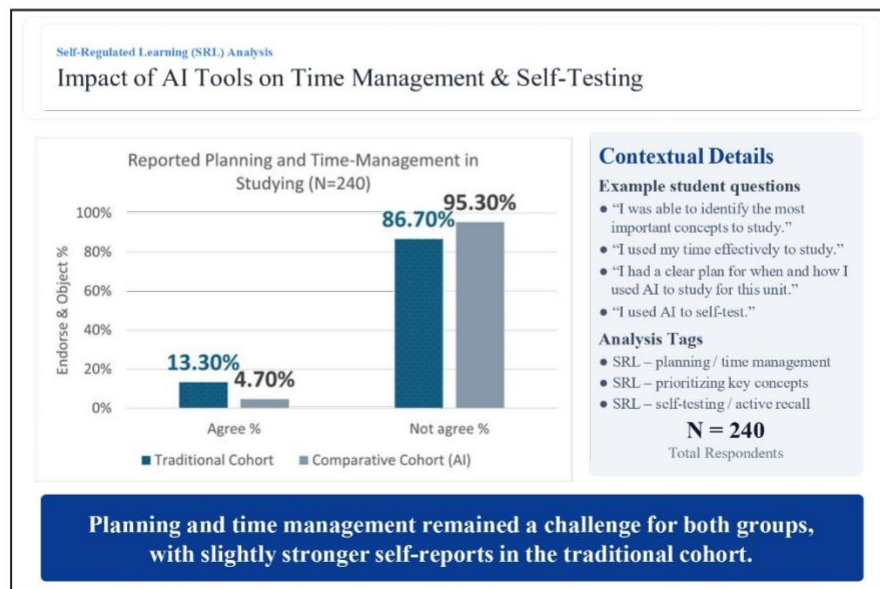
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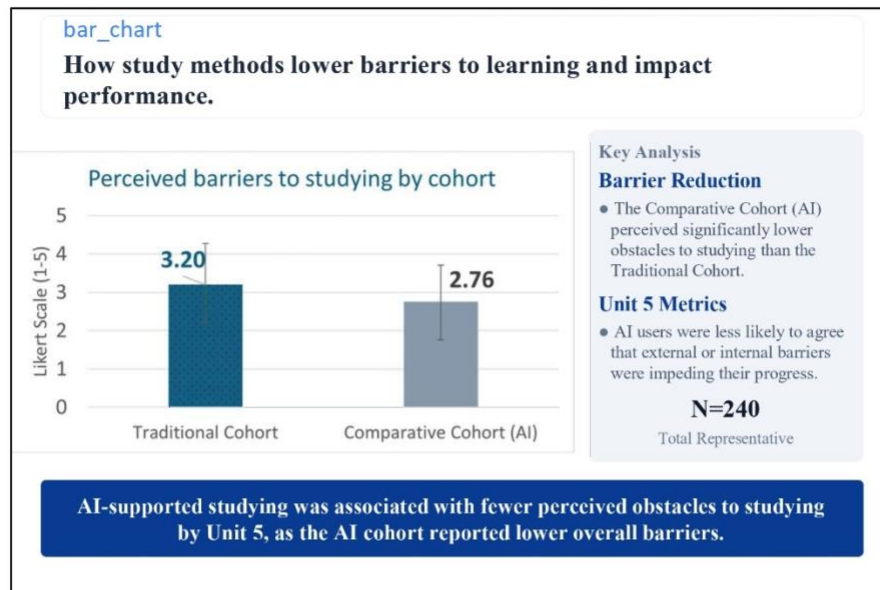
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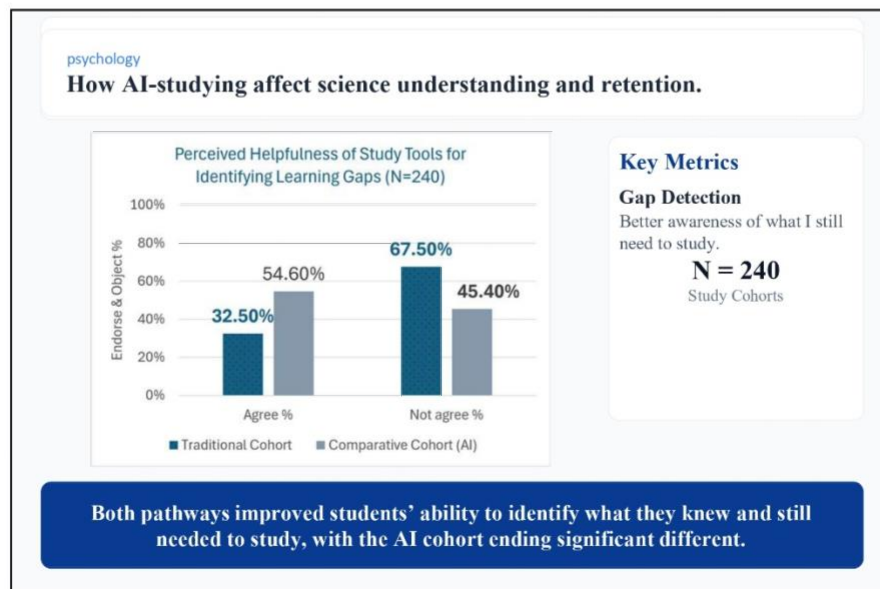
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MAIN RESEARCH QUESTION
How does the use of AI assisted studying affect high school biology students' summative assessment performance and study habits?

Student Voices

"AI increased efficiency by cutting down on time just trying to find material so I could get straight to the point."

EFFICIENCY

"I input the study guide to make flashcards on Quizlet as well as a practice quiz on ChatGPT that explained my wrong answers right away."

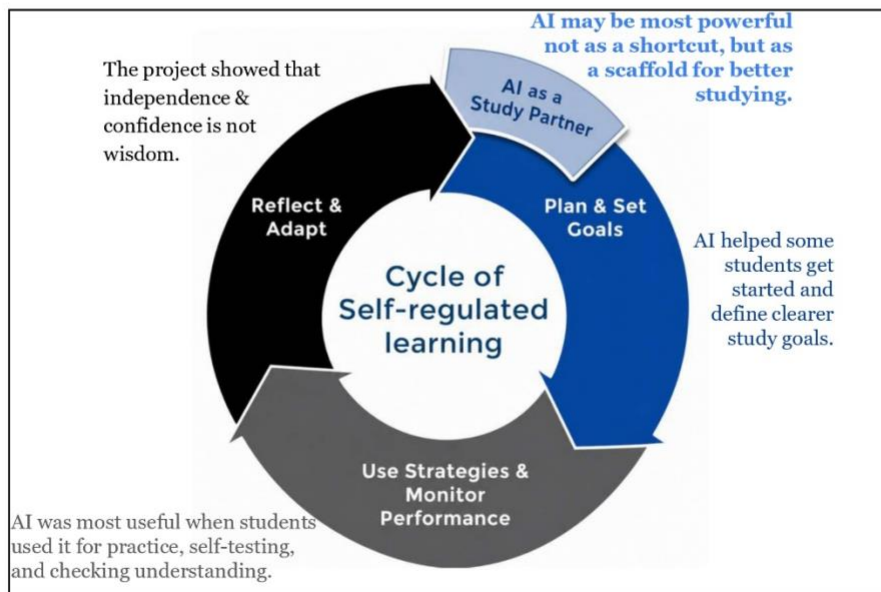
ADAPTIVE STUDYING

"I used past assignments to highlight information I don't know or should know more about."

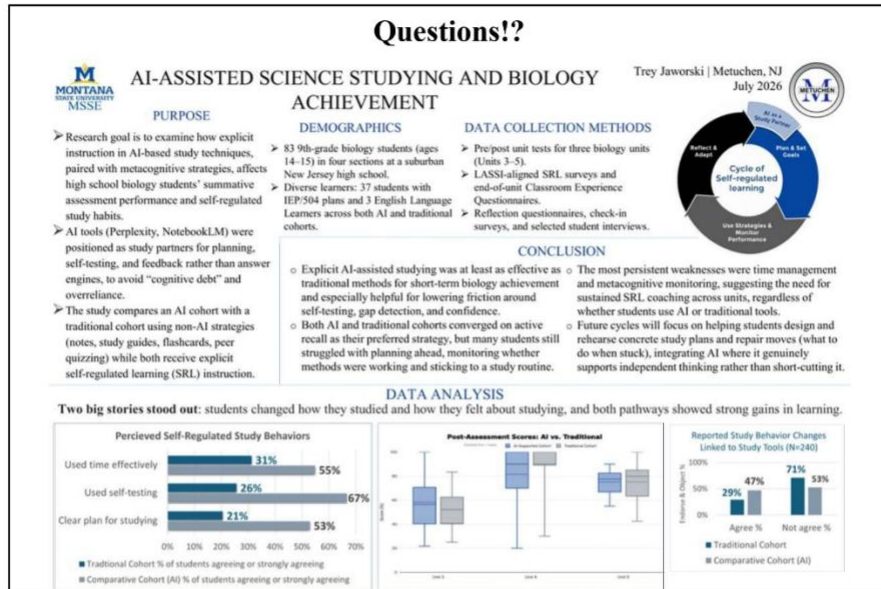
GAP DETECTION

Students are leveraging AI primarily for **content synthesis**, **self-testing**, and **targeted review** to improve study efficiency.

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Citations & References

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