

METACOGNITIVE STRATEGIES IN SECONDARY SCIENCE EDUCATION

by

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of

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TABLE OF CONTENTS

1. INTRODUCTION & BACKGROUND.....	1
Context of the Study	1
Focus Statement/Questions	2
2. CONCEPTUAL FRAMEWORK.....	3
Metacognition in Education	3
Challenges Towards Effective Cognitive Learning	3
The Relationship Between Metacognition, Motivation, and Emotional Regulation.....	4
Direct Instruction of Metacognition Strategies	5
The Planning-Monitoring-Evaluation Metacognitive Cycle	6
Metacognition in Science Education	7
3. METHODOLOGY	9
Demographics.....	9
Treatment.....	9
Data Collection and Analysis Strategies	15
Primary Focus Collection Instruments.....	15
Secondary Focus 1 Collection Instruments.....	15
Secondary Focus 2 Collection Instruments.....	16
4. DATA ANALYSIS	19
Results	19
5. CLAIM, EVIDENCE, AND REASONING	30
Claims From the Study	30
Value of the Study and Consideration for Future Research	32
Impact of Action Research on the Author	34
REFERENCES CITED	36
APPENDICES	39
APPENDIX A: Institutional Review Board MSU Exemption Letter	40
APPENDIX B: Planning Metacognition Strategy #1: Stem Statements.....	42
APPENDIX C: Planning Metacognition Strategy #2: Roll the Dice	44
APPENDIX D: Planning Metacognition Strategy #3: Pie in the Face.....	47

TABLE OF CONTENTS CONTINUED

APPENDIX E: Planning Metacognition Strategy #4: Prime the Pump	49
APPENDIX F: Planning Metacognition Strategy #5: The Goal Post	51
APPENDIX G: Monitoring Metacognition Strategy #1: Memoing	54
APPENDIX H: Monitoring Metacognition Strategy #2: Transfer Talk	56
APPENDIX I: Monitoring Metacognition Strategy #3: Verbal Cue Cards	58
APPENDIX J: Monitoring Metacognition Strategy #4: Mental Menus	61
APPENDIX K: Monitoring Metacognition Strategy #5: Two-Way Talk	63
APPENDIX L: Evaluation Metacognition Strategy #1: Mrs. Potter's Questions	65
APPENDIX M: Evaluation Metacognition Strategy #2: Plus. Minus. Interesting.	67
APPENDIX N: Evaluation Metacognition Strategy #3: Choose Your Spot	69
APPENDIX O: Evaluation Metacognition Strategy #4: Connecting Elephants	72
APPENDIX P: Evaluation Metacognition Strategy #5: Checkmate	74
APPENDIX Q: Complete Metacognition Cycle Strategy #1: Prime the Pump	76
APPENDIX R: Complete Metacognition Cycle Strategy #2: Stem Statements	78
APPENDIX S: Complete Metacognition Cycle Strategy #3: Memoing	80
APPENDIX T: Complete Metacognition Cycle Strategy #4: Two-Way Talk	82
APPENDIX U: Complete Metacognition Cycle Strategy #5: Connecting Elephants	84
APPENDIX V: Complete Metacognition Cycle Strategy #6: Plus. Minus. Interesting ...	86
APPENDIX W: Post-Treatment Metacognition Strategies Student Surveys	88
APPENDIX X: Focus on Metacognition Strategies Exit Interview	94
APPENDIX Y: 11-Point Learning Confidence Likert Scale and Student Survey	96
APPENDIX Z: Learning Confidence Reflection Survey	98

LIST OF TABLES

Table	Page
1. Semester Timeline of Metacognition Interventions	10
2. Data Triangulation Matrix	18
3. Friedman Two-Way Analysis of Variance by Ranks Test Results	20
4. Post-Hoc Test for Pairwise Comparisons Results	20
5. Spearman Rank-Order Correlation Analysis Results	27

LIST OF FIGURES

Figure	Page
1. An Illustration of the Planning-Monitoring-Evaluation Metacognition Cycle	6
2. Overview of the implementation of metacognitive strategies throughout the project.....	11
3. Metacognitive Strategies Utilized During Each Session.....	11
4. Comparative Box and Whisker Plots for Treatment Assessment Scores.....	19
5. Post-Treatment Planning Metacognition Strategies Student Survey.....	21
6. Post-Treatment Monitoring Metacognition Strategies Student Survey.....	23
7. Post-Treatment Evaluation Metacognition Strategies Student Survey	24
8. Post-Treatment Combination Metacognition Strategies Student Survey	26
9. Collective assessment rankings on the 11-point learning confidence Likert scale across all five sessions.....	29

ABSTRACT

Students often struggle to meaningfully reflect on their conceptual understandings, establish well-defined learning goals, and employ strategies that effectively bridge learning gaps. The benefits of metacognitive strategies in the science curriculum to enhance student self-awareness is well-documented in the research literature. Metacognition refers to one's considerations for their own thinking and learning. Metacognitive strategies can be subdivided into three categories: planning, monitoring, and evaluation. Planning strategies are utilized prior to a task or unit to encourage goal setting, establish prior knowledge, and identify learning objectives. Monitoring strategies aid students in actively gauging their learning progress. Evaluation strategies nurture student reflection on learning success and assessment preparation techniques. The effectiveness of planning, monitoring, and evaluation metacognitive strategies on assessment performance and perceived learning was investigated within an Alberta Biology 20 class of 19 students. The project time frame was subdivided into five, approximately two-week sessions, and the first session represented a non-treatment stage. Students implemented planning, monitoring, evaluation, and combined strategies for the subsequent four treatment sessions. At the conclusion of each session, students were summatively assessed on their recent content knowledge. Box and Whisker Plots were generated for a visual comparison of the assessment score distributions. A Friedman Two-Way Analysis of Variance by Ranks and a Post-hoc test examined significance between assessment scores for the five sessions. Assessment score ranks sums were statistically significant between the no treatment sample and treatments 2, 3, and 4 respectively, suggesting that metacognitive strategies may contribute to an increase in assessment performance. Likert-style surveys with accompanying open-ended questions were provided to participants at the conclusion of each treatment. The anonymous surveys required students to compare strategy effectiveness between and within treatments, to consider how likely they were to independently use metacognitive strategies in future classes, and to express their interest in learning additional strategies for a particular type. Survey data supported the claim that the incorporation of metacognitive strategies within the curriculum improved the perception of learning. Most students retained a favorable opinion of metacognition strategies throughout the study, and believed the strategies were effective at fostering the development of conceptual understandings.

INTRODUCTION & BACKGROUND

Context of the Study

Margaret Mead, the famous American anthropologist, stated that “children must be taught how to think, not what to think” (Mead, 1928, n.p.). This belief is foundational to my personal teaching philosophy: all students can be successful with the right mindset and toolkits. Teachers feel compelled to emphasize and assess content knowledge, typically driven by the pressures of standardized tests. However, the development of success skills, including fostering stress management techniques, nurturing resilience, and cultivating self-awareness and reflective thinking, should be fundamental to pedagogical practices.

During my current teaching experiences, I have observed that students are noticeably deficient in the cognitive skills needed to manage their own education. My students struggle to recognize their strengths and weaknesses and are uncertain about strategies they can self-implement to bridge gaps in their learning. Students often make comments that they are not good at math or they struggle in science. The presence of a fixed mindset still seems predominant in students.

Over my teaching tenure, I have observed an increase in general anxiety, a decrease in patience and grit, and a decline in self-confidence in students. Through the implementation of recent formative assessments, students’ self-perception of learning is often mismatched with their actual learning, and they struggle to self-regulate when faced with challenges. I began to read many articles and books related to the topic of metacognition and frequently engage in discussions with colleagues on the topic.

I presently work at West Island College, a grades 7-12 institution in Calgary, Alberta, Canada. West Island College is a private school with approximately 600 students in attendance. The students typically stem from affluent circumstances, and 15% of students are identified with documented special needs. Tenth grade represents the beginning of the senior high science experience. Currently, I serve as the district Science, Technology, Engineering, Art, and Mathematics (STEAM) Coordinator, the Science Department Teaching and Learning Leader, the Health Sciences Institute Coordinator, and teach science.

Focus Statement/Questions

My experiences with students and conversations with colleagues this year have contributed to my interest in exploring the effectiveness of metacognition strategies in the secondary science classroom. My primary focus question was, Can the implementation of metacognitive strategies in the classroom contribute to an increase in assessment performance?

My secondary focus questions included the following:

1. Does the incorporation of metacognitive strategies within the curriculum improve the perception of learning, and what types (e.g., planning, monitoring, evaluating, combination) are most effective?
2. Do students' perceptions of content understanding correlate with assessment performance?

CONCEPTUAL FRAMEWORK

Metacognition in Education

Successful educational pedagogies engage students in metacognition, or self-regulated learning (SRL), terms used to describe active thinking about one's learning. Developmental psychologist, John Flavell, first established the term metacognition in 1976, and metacognitive research in education has spanned the age gamut, focusing on SRL from kindergarten through graduate school (Cromley & Kunze, 2020). Metacognition is defined as the action of reflecting on one's thinking and recognizing approaches for managing novel experiences and obstacles (Jacobson, 2021). Metacognitive strategies instill self-awareness in students and encourage them to focus on personal gaps in understanding, the implementation of approaches that bridge those gaps, and the regulation of timing for approaches used (Thiede & Dunlosky, 2013). Metacognitive growth is maximal at the onset of adolescence, substantiating the critical need to incorporate metacognition during students' secondary school experiences (Price-Mitchell, 2015).

Challenges Towards Effective Cognitive Learning

Although metacognitive strategies empower students to monitor their learning, research has demonstrated that most youth cannot accurately monitor their progress (Thiede & Dunlosky, 2013). Many students do not utilize self-monitoring tools, such as the creation of task lists, frequent reflections, self-assessment rubrics, or flexible learning environments (Miller, 2016). Additionally, students are unable to realistically assess their development towards learning goal achievement, and struggle to ascribe classroom expectations to action goals (Thiede & Dunlosky, 2013).

Teachers are often provided professional development opportunities that emphasize instructional pedagogies. An attention to improving teaching skills may inadvertently reduce the essential focus on student learning, which should be the principal priority (McGuire & McGuire, 2015a). There exists a deficiency in professional development opportunities for teachers centered on metacognitive approaches in the classroom (Zohar & Barzilai, 2013). Student interviews have revealed that assessments and current grading systems are not rigorous enough to encourage cognitive learning that requires reflective thinking (McGuire & McGuire, 2015a).

The Relationship Between Metacognition, Motivation, and Emotional Regulation

Numerous factors influence a student's motivation for learning, including their engagement with the topics, their overall learning success, and the development of positive emotions. Students recognize value in learning if they feel supported in the educational process and believe they can execute a task successfully. Students' inability to regulate their behaviors, manage their time, or reflect on their learning, engender negative emotions which relinquish motivation (McGuire & McGuire, 2015b).

In a study involving upper elementary math students, emotional recognition was inextricably linked to metacognition and motivation. Although mathematical performance was not statistically impacted by negative emotions, the students that expressed pessimistic feelings cited a reduction in the perception of joy and confidence in their learning (Pennequin et al., 2020). Similarly, a large sampling of junior high science students from Indonesia were interviewed about their academic success and learning motivation. Students demonstrated self-regulation and motivation when their environment was conducive to learning and there was an emphasis on metacognition strategies (Tanti et al., 2020).

Direct Instruction of Metacognition Strategies

Strong evidence exists that student success on learning outcomes is correlated with the direct instruction of metacognition in the classroom (Perry et al., 2019). Researchers developed a six-hour metacognitive intervention session, aimed at providing instruction on methodologies for planning and executing physics problems. Forty-eight eighth graders were assigned to a control group, with extensive problem-solving challenges provided, or a treatment group, with problem-solving opportunities offered in conjunction to the metacognitive intervention. Students provided with metacognitive strategies demonstrated an augmented awareness for their learning and improved knowledge transfer (Zepeda et al., 2015).

A multitude of strategies exist that benefit students in planning, reflecting, and regulating their learning. More importantly, these strategies must be used strategically and consciously to address authentic challenges. Teachers need to scaffold learning experiences involving metacognition and provide student feedback that is descriptive and evidence-based. Metacognition is best taught in context to curricular outcomes and practiced in collaborative student groups (Perry et al., 2019).

Metacognition is a type of reflective thinking, which is broadly defined as the ability for an individual to ponder recent observations and experiences to inform future decisions about learning. Metacognitive writing and discussion prompts provide students with opportunities to identify misconceptions so they can adapt their learning strategies (Antonio, 2020). Directly teaching the development of concept maps and visual study tools encourages students to create connections between curricular concepts (Vancouver Island University, 2021.)

The Planning-Monitoring-Evaluation Metacognitive Cycle

Within the past fifteen years, the metacognitive process for students was first proposed as a cycle. Initially, the proposed cyclical model presented five steps to be completed in conjunction with a thinking task, including assessing, evaluating, planning, applying, and reflecting (Ambrose et al., 2010). A variety of metacognitive model permutations have evolved, recently resulting in the planning-monitoring-evaluation metacognition cycle (Figure 1).

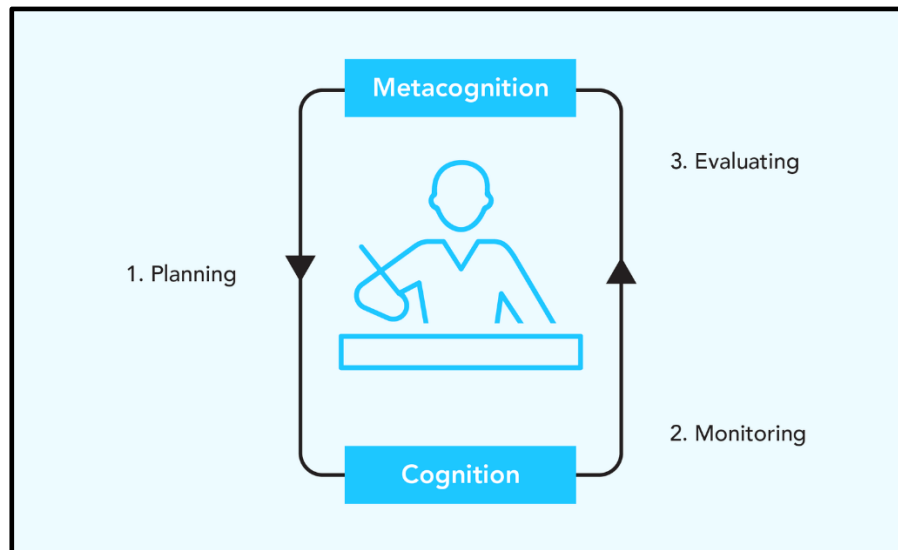


Figure 1. An illustration of the planning-monitoring-evaluation metacognition cycle (Evidence for Learning, 2020).

The planning-monitoring-evaluation metacognition cycle promotes the use of differentiated strategies within each stage so students can effectively address specific questions throughout the learning journey (Stephenson, 2019). Prior to starting a new unit or curricular task, students engage in planning strategies that identify curricular objectives, their misconceptions or past knowledge, information they hope to ascertain, and resources necessary to achieve their personal learning goals. During the learning tenure, the implementation of monitoring strategies aid students in gauging their learning progress and establishing content

relevance. At the conclusion of an academic task or unit, students reflect on their learning success and assessment preparation by employing evaluation strategies (Kwantlen Polytechnic University, 2018).

Metacognition in Science Education

Many foundational skills in science education, including reading texts, conducting inquiry, posing scientific questions, problem solving, and technical writing, require metacognitive skills. Proficient readers of scientific content engage in text by reflecting on patterns, activating prior knowledge, inferring the meaning of unknown terms, highlighting key passages, and asking questions in the margin (Zohar & Dori, 2012). The infusion of problem-based learning, particularly focused on tasks involving mathematical computations, involves self-regulated learning. The effectiveness of structured problem-solving challenges in boosting metacognition awareness was explored through an incorporation of these strategies in physics and chemistry classrooms. Inventory surveys and pre- and post- tests were administered, and improvements in self-awareness were observed. Students increased their capacity to decompose, transfer, and manage information when provided with open-ended, problem-solving experiences (Akben, 2018).

The use of modeling and visualizations in science promote cognitive learning and conceptual change. Physics students who use interactive questioning and individual reflection improved their ability to develop accurate models of electricity phenomena (Wade-Jaimes et al., 2018). Chemistry students were shown to develop improved cognitive connections and self-monitoring skills using interactive, dynamic visualizations that showcased challenging concepts (Zohar & Dori, 2012).

Science students utilize argument-driven inquiry (ADI), an approach introduced in 2009, to record observations and data centered on a scientific question. Students are invited to develop scientific claims and engage in argumentation sessions to defend their evidence and reasoning. Pre-service science teachers engaged in ADI, expanded their reflective skills, ability to identify flaws in lines of argumentation, and metacognitive awareness (Antonio, 2020).

METHODOLOGY

Demographics

This study was conducted within a semester-long, Biology 20 course at West Island College in Calgary, Alberta, Canada. West Island College is a grades 7-12, private institution with approximately 600 students in attendance. The students typically stem from affluent circumstances, and 15% of students are identified with documented special needs. Tenth grade represents the beginning of the senior high school science experience.

The effectiveness of planning, monitoring, and evaluation metacognition strategies was explored in a Biology 20 class consisting of 16 tenth-grade and 3 eleventh-grade students. Biology 20 is the most common science elective selected upon completion of the mandatory pre-requisite, Science 10. The course includes four units: energy and matter exchange in the biosphere, ecosystems and population change, photosynthesis and cellular respiration, and human systems. Participating students were relatively homogenous academically, and most students enrolled in West Island College plan to attend university.

Treatment

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A). The implementation of the action research project spanned eleven school weeks, or thirteen calendar weeks with the inclusion of a two-week spring break. The project time frame was subdivided into five, approximately two-week sessions. The first session represented a non-treatment stage, and the four subsequent treatments represented sessions two

through five. At the conclusion of each session, students were summatively assessed on their recent content knowledge (Table 1).

Table 1. Semester timeline of metacognition interventions.

Intervention	Time Frame	Curricular Topic	Assessment & Weighting (% of Course Grade)
No Treatment (Session 1)	9 school days (2/1 – 2/11)	Unit 1: Human Systems (Topic: Biochemistry)	Quiz #1 (2%)
Treatment #1 (Session 2): Planning Strategies	9 school days (2/14 – 3/1)	Unit 1: Human Systems (Topics: Enzymes and Digestion)	Quiz #2 (2%)
Treatment #2 (Session 3): Monitoring Strategies	9 school days (3/2 – 3/15)	Unit 1: Human Systems (Topics: Biochemistry, Enzymes, Digestion, Respiratory System)	Unit 1 Assessment (11%)
Treatment #3 (Session 4): Evaluation Strategies	10 school days (3/16 – 4/13)	Unit 1: Human Systems (Topics: Cardiovascular System, Blood, and Immune System)	Quiz #3 (2%)
Treatment #4 (Session 5): Complete Metacognition Cycle	12 school days (4/14 – 5/3)	Unit 2: Energy and Matter Exchange in the Biosphere (Topics: Kidney System and Biosphere Interactions)	Unit 2 Assessment (11%)

During the action research project tenure, students received direct instruction regarding the planning-monitoring-evaluation metacognition cycle. Implemented strategies were selected exclusively from the text, *Metacognition: The Neglected Skill Set for Empowering Students* (Fogarty & Pete, 2018). The students were not presented with an intervention during the first two weeks, and session 1 was used as the non-treatment for future comparisons. Students engaged in five, teacher-designated strategies within each metacognitive cycle category (e.g., planning, monitoring, and evaluation) for sessions 2, 3, and 4 respectively. Session 5 combined two previous strategies from each category so students could experience the complete planning-monitoring-evaluation cycle in succession (Figures 2 & 3).

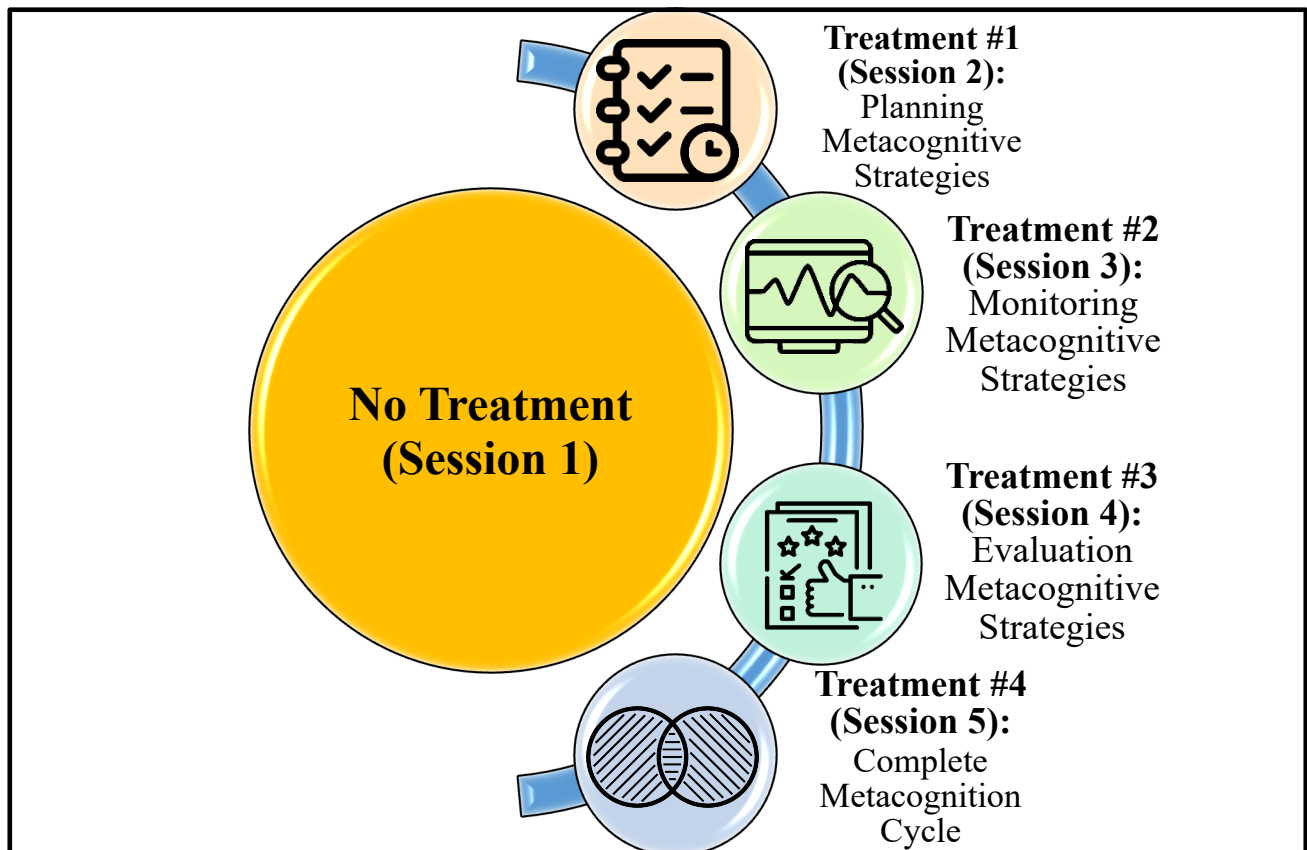


Figure 2. Overview of the implementation of metacognitive strategies throughout the project.

Treatment 1: Planning Strategies	Treatment 2: Monitoring Strategies	Treatment 3: Evaluation Strategies	Treatment 4: Complete Metacognition Cycle Strategies
• Stem Statements • Roll the Dice • Pie in the Face • Prime the Pump • The Goal Post	• Memoing • Transfer Talk • Verbal Cue Cards • Mental Menus • Two-Way Talk	• Mrs. Potter's Questions • Plus. Minus. Interesting. • Choose Your Spot • Connecting Elephants • Checkmate	• Prime the Pump • Stem Statements • Memoing • Two-Way Talk • Connecting Elephants • Plus, Minus, Interesting

Figure 3. Metacognitive strategies utilized during each session (Fogarty & Pete, 2018).

During the first treatment stage, students were introduced to five examples of metacognitive strategies categorized as planning tasks: Stem Statements, Roll the Dice, Pie in the Face, Prime the Pump, and The Goal Post (Fogarty & Pete, 2022). Planning metacognitive strategies are often utilized prior to an academic task or curricular unit to encourage goal setting, establish prior knowledge, and identify learning objectives. Stem Statements are beginning sentence fragments that foster thoughtful responses to “I wonder how...,” “A question I have is...,” “What if...,” and “Something I know about this topic is...” Prior to a Gizmo STEM case on enzymes, students completed teacher-provided stem sentences to stimulate thinking (Appendix B). Roll the Dice is a strategy that encourages students to make predictions and is often used in conjunction with science inquiries or laboratory investigations. Students prepared prediction statements for a macromolecules lab in which a murderer was uncovered based on suspect alibis and chemical test results of the victim’s stomach contents (Appendix C). Pie in the Face prompts the development of inferences. Students sketched illustrations for events preceding and succeeding an occasion depicted in an enzyme cartoon (Appendix D). Prime the Pump is characterized as a traditional Know-Wonder-Learned (KWL) activity, and students completed a KWL chart for the digestive system (Appendix E). The Goal Post strategy supported students in setting attainable goals in preparation for an assessment (Appendix F).

In the second treatment stage, students were introduced to five examples of metacognitive strategies categorized as monitoring tasks: Memoing, Transfer Talk, Verbal Cue Cards, Mental Menus, and Two-Way Talk (Fogarty & Pete, 2022). Monitoring metacognitive strategies aid students in gauging their learning progress and discovering content relevance. Memoing captures our mental notes during active learning and permits the repair and

questioning of our conceptions. Students developed a student guide to a respiratory system video and memoed their deliberations during video viewing (Appendix G). Transfer Talk is a strategy that encourages a reflection on the importance, relevance, and application on content knowledge. Students completed an exit ticket survey on D2L following a lesson on respiratory system content (Appendix H). Verbal Cue Cards promote collaborative discussions based on visual prompts. Students rotated amongst different peers and discussed their current understanding of several learning objectives, and prompts were displayed on PowerPoint slides (Appendix I). Mental Menus, or mnemonic devices, assist in the recall of content or sequences. Students created mental menus focused on biochemistry, digestion, enzymes, and respiratory system topics (Appendix J). Two-Way Talk is a conferencing strategy that cultivates meaningful face-to-face interactions. Students answered peer-generated “why” and “how” content questions and conversed about appropriate responses (Appendix K).

During the third treatment stage, students were introduced to five examples of metacognitive strategies categorized as evaluation tasks: Mrs. Potter’s Questions, Plus. Minus. Interesting., Choose Your Spot, Connecting Elephants, and Checkmate (Fogarty & Pete, 2022). Evaluation metacognitive strategies nurture student reflection on learning success and assessment preparation techniques. Mrs. Potter’s Questions is a strategy that invites students to consider the purpose, protocol effectiveness, and challenges associated with a completed task. Students addressed a series of D2L reflection questions following a hands-on, cardiac output investigation (Appendix L). Plus. Minus. Interesting. is commonly employed as a tool to generate diverse perspectives of a learning journey. Students participated in a Plus. Minus. Interesting. activity that probed the positive, negative, and interesting experiences noted during

their cardiovascular system mini-unit (Appendix M). Choose Your Spot is an approach that requires participants to evaluate statements and share their positions through a human bar graph. Students were presented with several immune system statements and asked to physically stand in one of five columns, from strongly agree to strongly disagree (Appendix N). Connecting Elephants is an exercise promoting big idea generation. Students specified a big idea following their cardiovascular and blood mini-unit, and explored connections between their big idea and others proposed by peers (Appendix O). Checkmate is an effectual evaluation strategy that enforces accountability for addressing criteria when completing prescribed tasks. Students generated and applied a checklist that could be used in evaluating science reasoning and data interpretation passages (Appendix P).

In the fourth treatment stage, students reused two planning, two monitoring, and two evaluation strategies in succession to engage holistically in the planning-monitoring-evaluation metacognition cycle. Students completed a Prime the Pump chart ahead of their biosphere unit content (Appendix Q). Additionally, the Stem Statements planning strategy activated thinking about ecological pyramids (Appendix R). The monitoring strategies of Memoing and Two-Way Talk were repeated in context to food webs and biogeochemical cycles. Students memoed their mental notes and questions while fashioning a complex food web for Darien, Panama (Appendix S). Students conferenced with colleagues to discuss peer-developed questions about the biosphere learning objectives (Appendix T). Big ideas were re-established and coupled with classmates' ideas in a Connecting Elephants evaluation exercise (Appendix U). The Plus. Minus. Interesting. strategy encouraged students to pinpoint highlights and barriers in their biosphere unit learning pathway (Appendix V).

Data Collection and Analysis Strategies

Primary Focus Collection Instruments

The primary focus of the research project explored whether the implementation of metacognitive strategies in the secondary science classroom contributed to an increase in learning as measured by assessment scores. The median, maximum, minimum, and interquartile values for each of the five session assessments were computed and Box and Whisker Plots were generated for comparative analyses. The five sessions were comprised of one non-treatment sample and four treatment samples. The overall shape of the distributions and the existence of outliers were noted. A Friedman Two-Way Analysis of Variance by Ranks examined significance between assessment scores for the five sessions. The null hypothesis stated that no significant differences between the dependent samples existed. A Post-hoc test was included to distinguish significance between rank sums for pairwise comparisons. Similarly, the null hypothesis maintained no statistical significance between sample pairs. Rank sum analyses were selected as non-parametric alternatives to a traditional ANOVA due to the smaller sample of students. Lastly, a Teacher Observations and Reflection Journal was compiled to document general classroom considerations during the implementation of metacognitive strategies. Student engagement, behaviors, attitudes, comments, and confusions for each metacognitive modality were noted.

Secondary Focus 1 Collection Instruments

A secondary focus of the research project investigated whether the incorporation of metacognitive strategies within the curriculum improved the perception of learning, and what types (e.g., planning, monitoring, evaluation, combination) were most effective. A Post-

Treatment Metacognitive Strategies Student Survey was distributed as the conclusion of each treatment session (Appendix W). Survey questions for the four treatment samples differed slightly; however any Likert-style inquiries were organized with a comparable 7-point scale: Strongly Disagree (1), Disagree (2), Somewhat Disagree (3), Neutral (4), Somewhat Agree (5), Agree (6), and Strongly Agree (7). The anonymous surveys required students to compare strategy effectiveness between and within treatments, to consider how likely they were to independently use metacognitive strategies in future classes, and to express their interest in learning additional strategies for a particular type. Open-ended questions were intertwined with the Likert-style inquiries and invited students to describe the purpose of each metacognition strategy type in their own words, and which strategies they found the most and least effective. Open-ended questions also provided students with an opportunity to articulate their rationales for selecting a particular Likert-style query ranking.

Eight students volunteered to complete the Focus on Metacognition Strategies Exit Interview (Appendix X). The interviews represented one-on-one, student-teacher conferences, and were conducted at the conclusion of the fifth session. The same four questions were asked to all students, and responses were color-coded for common themes and key ideas. Supplementary notes for this secondary focus were compiled in the Teacher Observations and Reflection Journal utilized throughout the project.

Secondary Focus 2 Collection Instruments

An additional secondary focus of the research project examined whether students' perceptions of content understanding correlated with assessment performance. The 11-Point Learning Confidence Likert Scale and Student Survey was included on each post-session

assessment (Appendix Y). Students were encouraged to rank their confidence in content proficiency on an 11-point scale ranging from Not At All Confident (0) to Extremely Confident (10). Spearman Rank-Order Correlation Analyses examined significance between the two ranked variables of assessment score and learning confidence for each session. The null hypothesis for this non-parametric test stated that no significant correlation exists, or that the correlation coefficient, ρ , is 0.

Students reflected on their initial learning confidence rankings and survey responses after each assessment was returned and discussed. Learning Confidence Reflection Surveys were completed via Microsoft Forms, and students rated the accuracy of their original confidence rankings in conjunction with assessment performance (Appendix Z). Any surprising results or considerations for future assessments were described.

All focus questions were cross-referenced with several sources of quantitative and qualitative data. Data triangulation is important to validate results, and a triangulation matrix was constructed (Table 2).

Table 2. Data Triangulation Matrix.

Focus Question	Source 1	Source 2	Source 3
<i>Primary Focus:</i> Can the implementation of metacognitive strategies in the secondary science classroom contribute to an increase in assessment performance?	Comparative Box and Whiskers Plots for Treatment Assessment Scores	Friedman Two-Way Analysis of Variance by Ranks and Post-hoc Test for Treatment Assessment Scores	Teacher Observations and Reflection Journal
<i>Secondary Focus 1:</i> Does the incorporation of metacognitive strategies within the curriculum improve the perception of learning, and what types (e.g., planning, monitoring, evaluating, combination) are most effective?	Post-Treatment Metacognitive Strategies Student Survey (7-Point Likert Scales and Open-ended Questions; 4 Total)	Focus on Metacognition Strategies Exit Interview	Teacher Observations and Reflection Journal
<i>Secondary Focus 2:</i> Do students' perceptions of content understanding correlate with assessment performance?	11-Point Learning Confidence Likert Scale and Student Survey (During Quiz; 5 Total)	Spearman Rank-Order Correlation Analysis for Learning Confidence and Assessment Scores	Learning Confidence Reflection Survey (Post-Quiz; 5 Total)

DATA ANALYSIS

Results

The results of the Comparative Box and Whisker Plots for Treatment Assessment Scores revealed that assessment score distributions for each session were negatively skewed ($N=19$) (Figure 4). While means were consistently lower than the median scores for all five sessions, the score ranges steadily decreased between Treatments 1 and 4. No outliers were calculated and included graphically. The non-normal distributions further substantiated the need for a non-parametric measure of statistical significance between samples.

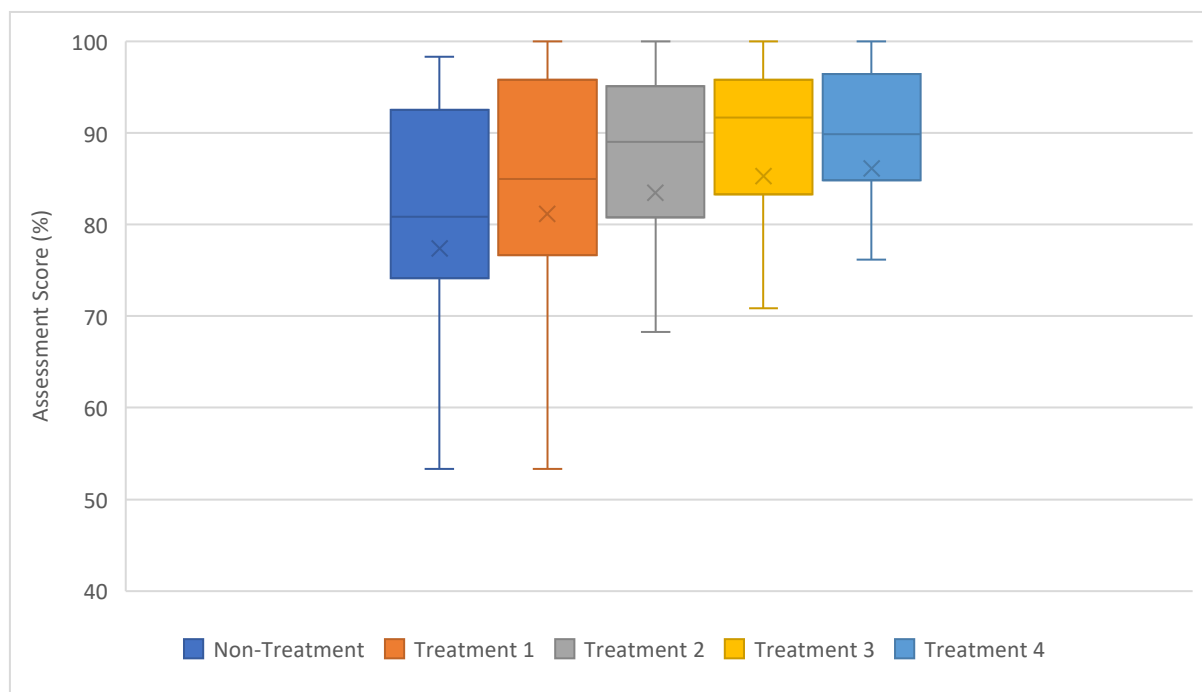


Figure 4. Results for the comparative box and whisker plots for treatment assessment scores, ($N=19$).

The Friedman Two-Way Analysis of Variance by Ranks Test resulted in a calculated chi-square value that exceeded the chi-square critical value, with average mean ranks progressively

increasing across successive sessions ($N=19$) (Table 3). The p-value was 0.0018, denoting a statistical significance between assessment scores for the dependent session samples. The null hypothesis was ultimately rejected because the calculated p-value was less than 0.01, which indicated that mean ranks were statistically different.

Table 3. Friedman Two-way Analysis of Variance by Ranks Test results, ($N=19$).

Ranks Results		Test Statistics	
Session	Mean Rank	N	19
No Treatment	1.76	Chi-Square Critical Value	9.488
Treatment 1	3.00	Calculated Chi-Square	17.928
Treatment 2	3.21	df	4
Treatment 3	3.24	Asymp. Sig	0.001
Treatment 4	3.79		

The Post-hoc Test for Pairwise Comparisons indicated statistical significance between assessment scores for three sample pairs, with a p-value < 0.05 ($N=19$) (Table 4). Ranks sums significantly differed between the no treatment sample and treatments 2, 3, and 4 respectively. The null hypothesis was subsequently rejected.

Table 4. Post-hoc Test for pairwise comparisons results, ($N=19$).

Sample 1 – Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.*
No Treatment – Treatment 1	-1.237	0.513	-2.411	0.016	0.159
No Treatment – Treatment 2	-1.447	0.513	-2.821	0.005	0.048
No Treatment – Treatment 3	-1.474	0.513	-2.873	0.004	0.041
No Treatment – Treatment 4	-2.026	0.513	-3.950	<0.001	0.001
Treatment 1 – Treatment 2	-0.211	0.513	-0.410	0.682	1.000
Treatment 1 – Treatment 3	-0.237	0.513	-0.462	0.644	1.000
Treatment 1 – Treatment 4	-0.789	0.513	-1.539	0.124	1.000
Treatment 2 – Treatment 3	-0.026	0.513	-0.051	0.959	1.000
Treatment 2 – Treatment 4	-0.579	0.513	-1.129	0.259	1.000
Treatment 3 – Treatment 4	-0.553	0.513	-1.077	0.281	1.000
<i>*Significance values have been adjusted by the Bonferroni correction for multiple tests.</i>					

The results of the Post-Treatment Metacognitive Planning Strategies Student Survey indicated that 57.9% of participants agreed that planning strategies increased content understanding in some capacity, and 68.4% cited an interest in learning additional planning strategies ($N=19$) (Figure 5). Satisfied students commonly cited that planning strategies increased motivation, content engagement, and conceptual organization. One student noted, “It forced me to interact with the content which helped me with some understanding.” Another participant reported, “I agree because I was able to set goals and make better notes on concepts. I was better off with them than without them.”

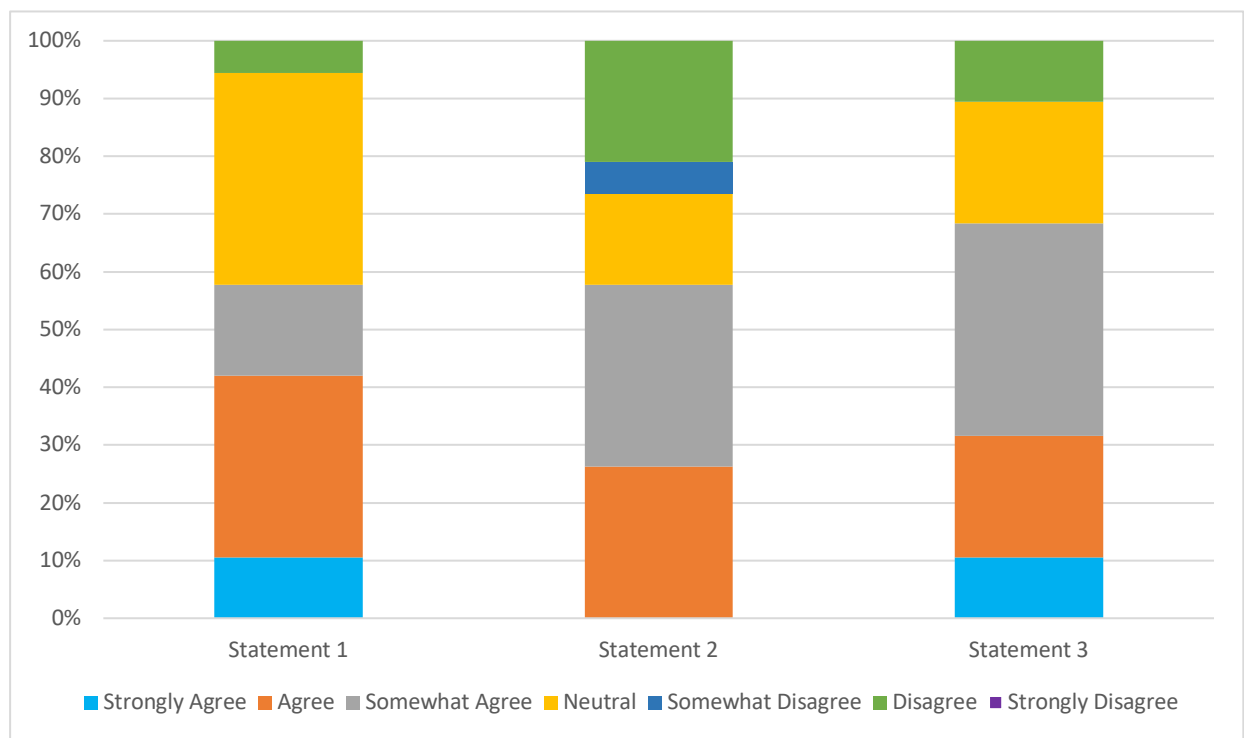


Figure 5. Post-Treatment Planning Metacognitive Strategies Student Survey results, ($N=19$). Statement 1: Using metacognitive planning strategies increased my understanding of the content in comparison to when I did not use any metacognition strategies at the beginning of the semester. Statement 2: I am likely to independently use metacognitive planning strategies for future courses. Statement 3: I am interested in learning additional metacognitive planning strategies.

Several students were unable to distinguish any tangible benefits of employing planning strategies because of their short-term usage, and 38.4% selected a neutral response when asked if their content understanding increased. One student mentioned, “I don’t think they decreased my learning abilities and also don’t think there was a significant benefit,” while another individual stated, “I haven’t done enough to tell.” Only one participant disagreed that planning strategies increased content understanding, and 57.9% of students considered using planning strategies independently in future courses. The Prime the Pump and Goal Post activities were overwhelmingly identified by the class as the most effective and engaging strategies.

The results of the Post-Treatment Metacognitive Monitoring Strategies Student Survey revealed that 73.7% of participants agreed that monitoring strategies increased content understanding in comparison to the beginning of the semester, and 63.2% documented that monitoring strategies were better tools than planning strategies ($N=19$) (Figure 6). Students that perceived a benefit from employing monitoring strategies articulated an improved understanding of the curricular objectives. One student recorded, “The strategies definitely helped me to remember the content better,” while another peer remarked, “I feel it helped me understand the questions on the test.” While a few neutral students were unable to discern a clear benefit, only one student clearly observed, “I did not see any change in my marks/understanding since using metacognition strategies.” A majority of students (i.e., 68.4%) predicted that they were likely to utilize monitoring strategies independently in future courses and were interested in learning additional strategies. The Verbal Cue Cards, Mental Menus, and Two-Way Talk activities were overwhelmingly identified by the class as the most effective and engaging strategies.

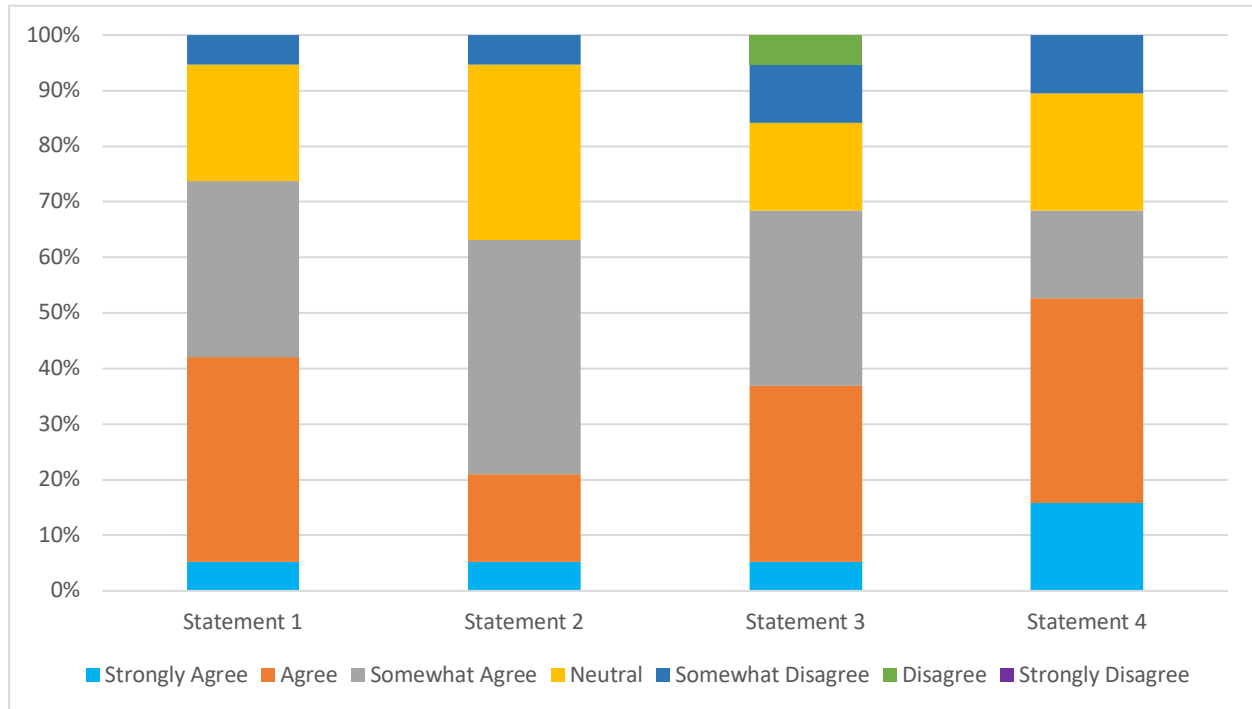


Figure 6. Post-Treatment Monitoring Metacognitive Strategies Student Survey results, ($N=19$). Statement 1: Using metacognitive monitoring strategies increased my understanding of the content in comparison to when I did not use any metacognition strategies at the beginning of the semester. Statement 2: Using metacognitive monitoring strategies were better tools for increasing my understanding of the content in comparison to when I used metacognitive planning strategies. Statement 3: I am likely to independently use metacognitive monitoring strategies for future courses. Statement 4: I am interested in learning additional metacognitive monitoring strategies.

The results of the Post-Treatment Metacognitive Evaluation Strategies Student Survey disclosed that 63.16% of participants agreed and 0% disagreed that evaluation strategies increased content understanding in comparison to the beginning of the semester ($N=19$) (Figure 7). A common theme communicated by students finding evaluation strategies effective, related to improved assessment preparation. One participant observed, “I found studying easier,” while another student remarked that the strategies, “helped with the test.” Connecting Elephants, Choose Your Spot, and Checkmate were acknowledged by the class as the most effectual and enjoyable strategies.

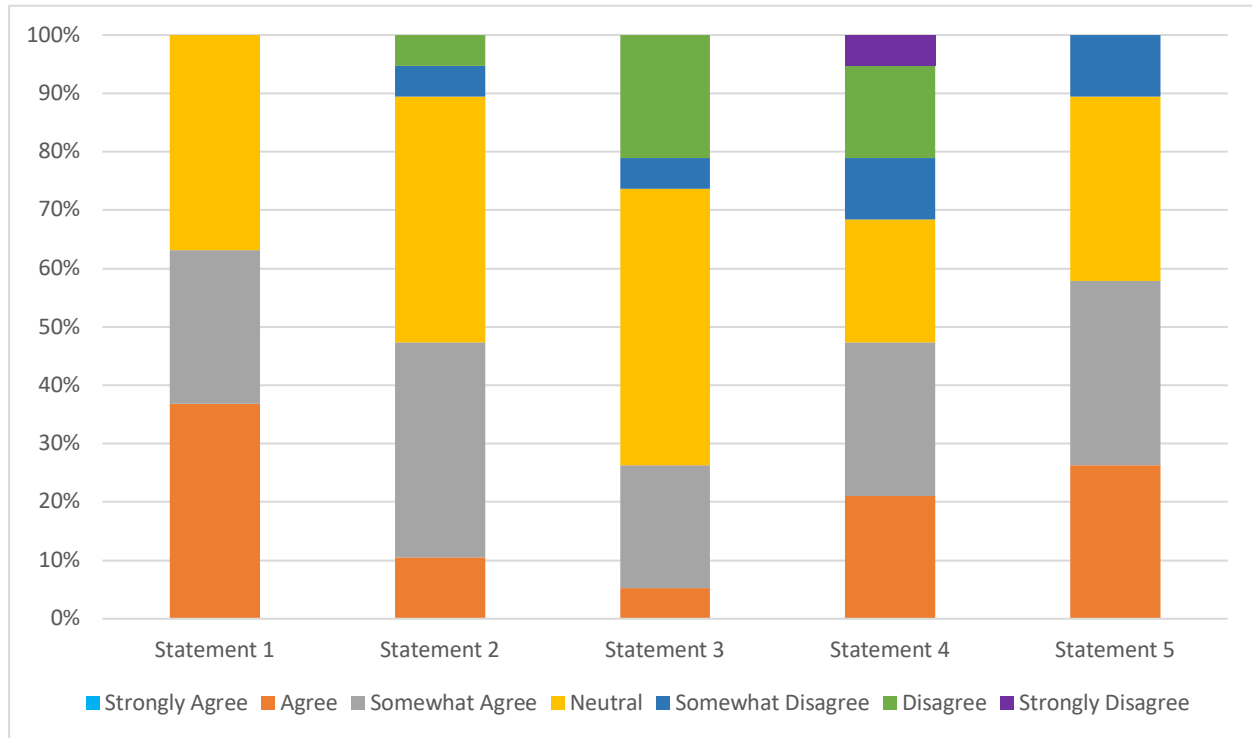


Figure 7. Post-Treatment Evaluation Metacognitive Strategies Student Survey results, ($N=19$). Statement 1: Using metacognitive evaluation strategies increased my understanding of the content in comparison to when I did not use any metacognition strategies at the beginning of the semester. Statement 2: Using metacognitive evaluation strategies were better tools for increasing my understanding of the content in comparison to when I used metacognitive planning strategies. Statement 3: Using metacognitive evaluation strategies were better tools for increasing my understanding of the content in comparison to when I used metacognitive monitoring strategies. Statement 4: I am likely to independently use metacognitive evaluation strategies for future courses. Statement 5: I am interested in learning additional metacognitive evaluation strategies.

Inconsistencies in responses emerged when students were asked to compare the types of metacognitive strategies. Forty-seven percent of students perceived evaluation strategies as more effectual than planning activities; however, only 26.3% of participants sensed that evaluation strategy effectiveness exceeded monitoring strategies. An individual felt that evaluation strategies “were less effective that the other strategies and I didn’t really add too much to my learning.” Another student reported, “I found evaluating and monitoring strategies to be the

same in effectiveness.” Forty-seven percent of students expected to employ evaluation strategies independently in future courses, and 57.9% were interested in learning additional strategies.

The results of the Post-Treatment Metacognitive Combination Strategies Student Survey indicated that 63.16% of participants agreed and 0% disagreed that using a combination of strategies in the planning-monitoring-evaluation cycle increased content understanding in comparison to the beginning of the semester ($N=19$) (Figure 8). Students who agreed observed a numerical increase in marks, enhanced content understanding, and improved learning awareness. A student mentioned, “I think I made more connections,” and a classmate recorded, “I have noticed a change in my learning.” Some neutral participants were undecided on whether the combination of strategies were beneficial. One student stated, “I don’t think they made a significant difference in my understanding.” Sixty-three percent of students additionally perceived an increase in understanding when the complete metacognition cycle was utilized throughout a session, rather than remaining exclusively focused on a single strategy type. A participant noted that the cycle “helped me understand content more than one type at a time.” Some students didn’t believe that applying the metacognitive cycle contributed to any perceptible difference in understanding.

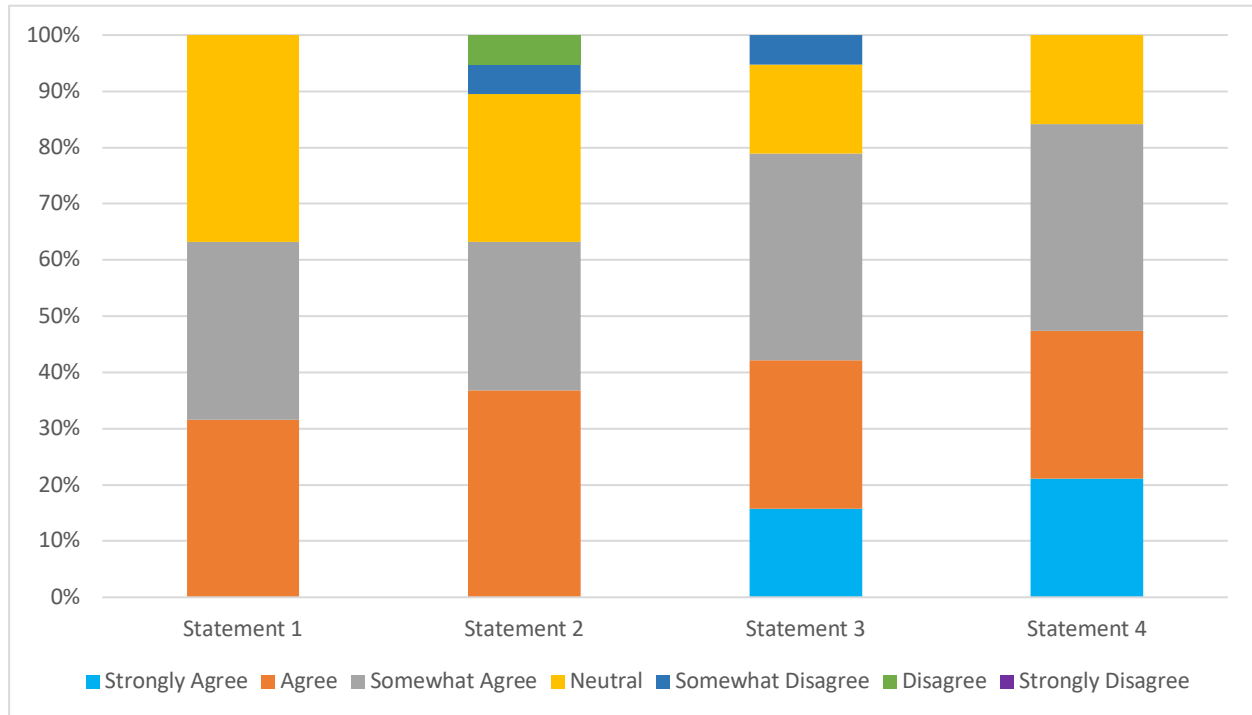


Figure 8. Post-Treatment Combination Metacognitive Strategies Student Survey results, ($N=19$). Statement 1: Using a combination of strategies in the planning-monitoring-evaluation cycle increased my understanding of the content in comparison to when I did not use any metacognition strategies at the beginning of the semester. Statement 2: Using a combination of metacognitive strategies in the planning-monitoring-evaluation cycle increased my understanding of the content in comparison to when I used one type of metacognition strategy at a time. Statement 3: Overall, I enjoyed this process of learning about metacognition strategies. Statement 4: Overall, I recognize the importance of metacognition strategies in improving learning.

Seventy-nine percent of students agreed that they enjoyed the process of learning about metacognition strategies, and 84.2% of participants agreed that metacognition strategies are important to learning improvement. One student remarked, “I think that even though some strategies didn’t help me as much, it is good to try them because they can help you learn faster and more efficiently.” Another participant who thought metacognition strategies were interesting but did not believe they influenced their personal learning journey, reported, “I think they are capable of improving learning for some people.”

The Focus on Metacognition Strategies Exit Interview revealed that most students were confident in selecting their own metacognition strategies for future units ($n=8$). Students supported their affirmative responses by noting an improved awareness of their own learning styles and which metacognition strategies they deemed personally relevant. One interviewee stated that she “was able to tell which strategies really helped me and which did not.” One student mentioned that she was not comfortable with personally selecting strategies as “it is hard to do on your own.” Interviewed participants were completely split on whether planning or monitoring strategies required a greater time investment; however, no student selected evaluation strategies as time-consuming. Despite a majority of students previously noting a willingness to incorporate metacognition strategies in the future, none of the interviewees reflected on the strategies outside of class or in other courses at the conclusion of the project tenure. With reference to metacognition strategies, one student reported that “none of my other classes really need them. I can’t think of a way to use them in math or English.”

The results of the Spearman Rank-Order Correlation Analysis demonstrated that the calculated correlation coefficients for Treatments 1 and 2 were statistically significant ($p < 0.05$) ($N=19$) (Table 5). Therefore, the ranked variables of assessment score and learning confidence were correlated for two of the five sessions.

Table 5. Spearman Rank-order Correlation Analysis results, ($N=19$).

Session	Spearman Correlation Coefficient, ρ	t statistic	df	p-value
No Treatment	0.42	1.88	17	0.08
Treatment 1	0.49	2.31	17	0.03
Treatment 2	0.47	2.21	17	0.04
Treatment 3	0.45	2.05	17	0.06
Treatment 4	0.45	2.10	17	0.05

The results of the 11-Point Learning Confidence Likert Scale and Student Survey revealed that students only selected extreme learning confidence rankings (i.e., $x \leq 2$ or $x > 8$) 11.6% of the time ($N=19$) (Figure 9). Although 82.1% of the selected rankings were within the 4.01 – 8.00 range, discrepancies in scale interpretation were evident. One student selected a ranking of 5 on the Treatment 1 assessment and provided the rationale, “I think I understand the subject well.” A second student chose a ranking of 5.5 on the same assessment and explained their selection by stating, “I was very unsure of the content.” Conversely, inconsistencies occurred between rankings for students with different assessment score outcomes. A student received an 80.5% on the Treatment 2 assessment and selected a confidence ranking of 8.5. A classmate achieved a 90.2% on the same assessment and assigned herself a learning confidence ranking of 3.5, noting, “I feel like it was much harder than what I expected.” Contradictions in rankings for the same student across sessions existed. One student received a 56.7% on the No Treatment assessment and self-designated a learning confidence ranking 7, remarking, “I didn’t know a few things but very familiar with most of the content.” The same learning ranking of 7 was selected for his Treatment 3 assessment and a score of 85.4% was achieved. He noted, “I did find that this was a much more difficult test by nature.”

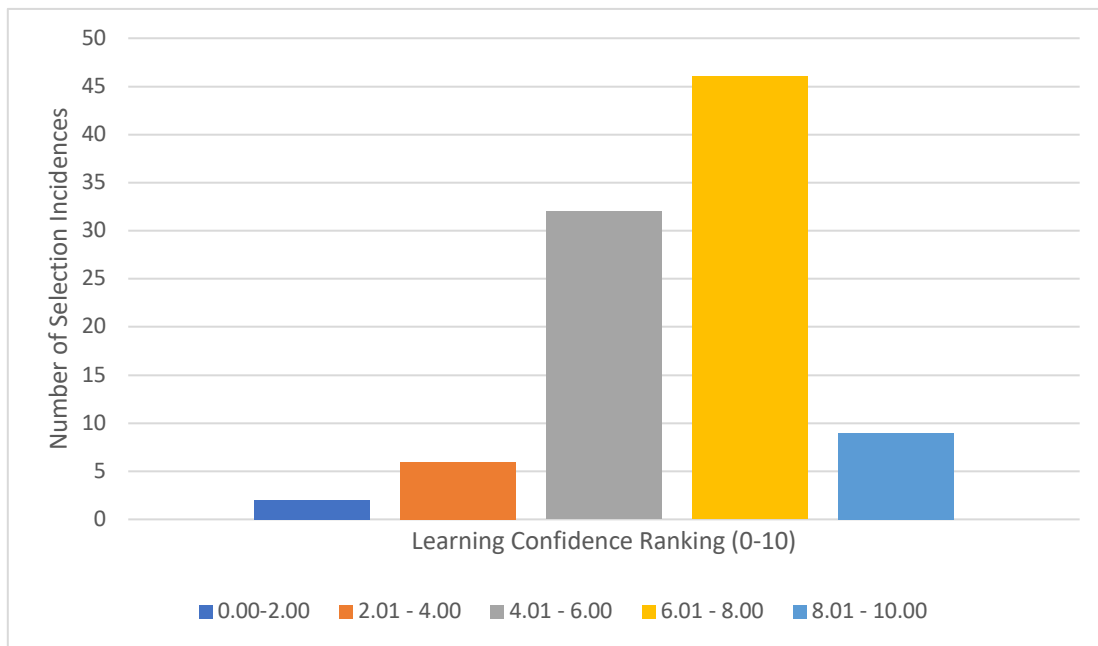


Figure 9. Collective assessment rankings on the 11-Point Learning Confidence Likert Scale across all five sessions, ($N=19$).

The results of the Learning Confidence Reflection Surveys disclosed that students on average perceived their confidence rankings as very accurate 12.3% of the time, following a thorough review of their assessment ($N=19$). A few students were consistently aware of their performance and learning confidence at the conclusion of the assessment; however, several students articulated astonishment with the actual results. One student mentioned, “I was surprised by how well I did. I felt relatively unconfident in the material during the test but got a good result,” while a classmate observed, “I tend to think I did worse than I actually get so I was a little surprised.” On the contrary, some students anticipated an enhanced assessment score. A participant mentioned, “I was really disappointed...I think my preparation affected the result; I had a very busy week and should have put more time in preparing.”

CLAIM, EVIDENCE, AND REASONING

Claims from the Study

Three scientific claims addressing the proposed focus questions emerged from this study. First, the quantitative data supported the claim that the implementation of metacognitive strategies in the secondary science classroom augmented assessment performance. Assessment mean ranks numerically increased following the completion of each session. Statistically significant improvement was evident after only two treatments of metacognitive strategies. Students may have needed an adjustment period to gain familiarity with the routine of metacognition implementation, which supports the lack of significance between the No Treatment and Treatment 1 samples.

It is important to consider additional factors that contributed to enhanced assessment performance, as metacognitive strategies alone may not explain the results. This action research project commenced at the beginning of the semester, and perhaps students required time to understand the expectations of a new teacher and course. However, students typically enroll in Biology 20 directly from Science 10 in the fall semester. This year, these courses were designed in tandem in terms of pedagogies used, assessment styles, study guides, and lab expectations. Three of the four Science 10 teachers also instructed Biology 20. Therefore, students were very familiar with the course procedures and assessment approaches at the outset of the semester.

Second, quantitative data from the Likert scales and qualitative remarks from students supported the claim that the incorporation of metacognitive strategies within the curriculum improved the perception of learning. Students retained a favorable opinion of metacognition strategies throughout the study, and most participants agreed that the strategies were effective at

fostering the development of conceptual understandings. While the combined percentage of ‘strongly agree,’ ‘agree,’ and ‘somewhat agree’ responses exceeded the ‘neutral’ category selections, it is crucial to recognize that ‘neutral’ was selected often. Students appeared to have difficulty in consistently discerning whether they were positively impacted by certain strategies. Several participants articulated that they found select strategies to be entertaining and interesting, but a direct influence on personal learning was not observed. This prompts the question as to what intrinsic markers students are using to measure success. Given that this was the first exposure to metacognitive strategies for most students, it is understandable that students may struggle with self-assessing their learning progress before and after an intervention.

The first secondary focus question also explored which types of strategies were most effective. Students expressed mixed results regarding which category (e.g., planning, monitoring, evaluating, combination) was most valuable for their content understanding. Based on the survey results, students may have identified that the implementation of the planning-monitoring-evaluation cycle was advantageous because the strategies were employed in a natural progression. Additionally, the cycle strategies utilized were the more popular activities identified by students in Treatments 1-3. Students noted that some of the single-type strategies felt forced within a given context, and several participants maintained that metacognition type was less important in identifying preferred strategies. Overall, students favored strategies across all types involving movement or collaborative discussions, including Verbal Cue Cards, Two-Way Talk, Choose Your Spot, and Connecting Elephants. Boosting metacognition awareness arises from both collaborative endeavors and individual reflections. Students can model questioning and self-regulation for each other during cooperative activities.

Third, quantitative and qualitative data supported the claim that students' perceptions of content understanding did not correlate with assessment performance consistently throughout the semester. Statistical significance for the correlation coefficient was moderate for two treatments and non-existent for the remaining three. Learning confidence was included in this study because accurate rankings require self-awareness, which is a foundational skill for metacognition and learning motivation. Fortunately, most often students underestimated their assessment achievement and ranked their confidence as lower. This pattern is important to monitor as a teacher. If students are very confident in the content but consistently perform poorly on an assessment, the teaching pedagogies, study guide, and learning objectives are not well-aligned with the assessment. The learning confidence scale was arbitrarily interpreted by students, and perhaps a more consistent scale of learning confidence is required. In hindsight, ascertaining a learning confidence ranking for content understanding prior to an assessment may have proven valuable. Learning confidence before an assessment depends solely on assessment preparation and would eliminate test-taking biases.

Value of the Study and Consideration for Future Research

In a world of constant mental diversions, there is an unequivocal value in establishing intentional time for reflection and self-awareness. Self-regulation and self-awareness are fostered through activities that necessitate metacognition. Metacognitive skills for students are enhanced through explicit teacher instruction and consistent practice. Metacognition strategies actively engage students in their own learning and prompt them to regularly consider their academic progress.

The research conducted in association with this study prompted future research considerations. First, an overarching goal of implementing metacognition skills with students is to empower them to utilize these strategies in other courses and life capacities. The students articulated difficulty extending these strategies outside of the science classroom and did not recognize their interdisciplinary applications. Additionally, strategies were teacher-selected throughout the study tenure. A future research project could examine students' assurance with selecting their own metacognitive strategies and using them in appropriate contexts. It is important for students to develop a repository of strategies through facilitated guidance and peer collaboration, but they must skillfully engage in metacognition independently.

A second research consideration relates to the scaffolding of metacognitive strategies across multiple grade-levels. Junior high students exhibit different patterns of cognitive development than students participating in this study. As a grades 7-12 institution, it may prove beneficial to vertically examine the effectiveness of metacognitive strategies for multi-aged students, and observe improvements in student self-awareness across a multi-year time frame.

A third future project could investigate how time invested into a particular metacognitive strategy correlates with perceived effectiveness. The implementation of strategies can be characterized by duration and effort requirements. All strategies used in conjunction with this project were individually completed within 20 minutes. If more time is invested into a given strategy, perceptions of learning and motivation may be influenced.

A fourth project proposal could encourage students to design a personal method for measuring metacognition strategy success. Many students expressed difficulty in distinguishing whether a particular strategy was effective, as indicated by the number of neutral responses and

survey comments. Students would proceed less haphazardly in terms of determining their learning progress if they employed a customized measurement scale.

Impact of Action Research on the Author

This project was very motivating and exciting, and I acquired considerable comfort with incorporating action research studies into my teaching practice. I appreciated gaining experience with the ethics approval process, researching effective metacognition strategies, designing collection methods that ensured data triangulation, conducting statistical analyses, and dissecting the study results for trends. I recognize the need to collect both quantitative and qualitative data to substantiate outcomes and cross-reference patterns. Action research is an iterative and collaborative endeavor that cultivates in professional growth and student success.

This study possessed a few limitations. First, I was new to the Biology 20 curriculum this spring, and I was simultaneously learning content and managing the research study. Different metacognitive strategies may have been more effective at addressing student misconceptions than those implemented, since teachers' understanding of challenging concepts for students is always improved with course repetition. Second, time is a common limitation. Biology 20 is a semester-long course, and the completion of an action research study for a year-long course provides students long-term consistency in expectations. I anticipate that the students may have felt inundated at the project's conclusion with continual attention to metacognitive strategies. It is important to find a balance between routine and excessive amplification of an initiative. Lastly, the student sample size was a limitation. Non-parametric analyses were required to accommodate results for only nineteen students. The outcomes may have improved with data from two or three classes.

The fundamental implication from this study relates to the importance of establishing transparent communication with students. Students need to be active contributors in the action research process, and they must have a forum to ask questions and provide input anonymously. Teachers should be explicit in the logistics of an intended research study and provide a rationale for project implementation. Maintaining trust and flexibility throughout a classroom study ensures that students feel supported in their learning journeys.

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APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD MSU EXEMPTION LETTER

MONTANA STATE UNIVERSITY
Request for Designation of Research as Exempt
MSSE Research Projects Only

(6/16/14)

THIS AREA IS FOR INSTITUTIONAL REVIEW BOARD USE ONLY. DO NOT WRITE IN THIS AREA.

Confirmation Date: 12/20/21

Mark J. Quinn

Application Number:

DATE of SUBMISSION: December 7th, 2021

-Okay as exempt
 -MSSE Classroom assessment
 -Little/no risk
 Principal approved
 -No concerns
 MQ 12/20/21

Address each section - do not leave any section blank.

I. INVESTIGATOR:

Name: Stacey R. Benson

Home or School Mailing Address: 1003-3500 Varsity Drive NW, Calgary, Alberta, Canada T2L 1Y3

Telephone Number: (717) 645-4151

E-Mail Address: benson.staceyr@gmail.com

DATE TRAINING COMPLETED: February 28th, 2021 [Required training: CITI training; see website for link]

Investigator Signature *Stacey R. Benson*

Name of Project Advisor: (Carl) John Graves

E-Mail Address of Project Advisor: carl.graves@ecat1.montana.edu

II. TITLE OF RESEARCH PROJECT: Metacognitive Strategies in Secondary Science Education

III. BRIEF DESCRIPTION OF RESEARCH METHODS (If using a survey/questionnaire, provide a copy).

This project is designed to explore the effectiveness of metacognition strategies in the secondary science classroom. The primary focus for the project examines: Can the implementation of metacognitive strategies/types in the classroom contribute to an increase in assessment performance? Additionally, two secondary focus questions will be investigated:

1. Why types (e.g., planning, monitoring, evaluating, combination) of metacognitive strategies in particular are most effective at improving content understanding and the perception of learning?
2. Do students' perceptions of content understanding correlate with assessment performance?

The implementation of the action research-based classroom project will span ten school weeks (excluding the two weeks of spring break during the spring of 2022, and will be subdivided into five, two-week sessions. The first session represents a non-treatment period, and the four subsequent treatments represent sessions two through five. At the conclusion of each session, students will be assessed on their recent learning with a quiz (Figure 1).

APPENDIX B

PLANNING METACOGNITION STRATEGY #1: STEM STATEMENTS

NAME _____ DATE _____



Preparing for the Enzymes STEM Case

(<https://gizmos.explorellearning.com/>, 2022)

Introduction: Claire, a Great Dane, is experiencing extreme weight loss and lethargy despite maintaining a normal appetite. As a veterinary technician, students must learn about metabolism, digestion, and enzymes to help Claire. They must then examine Claire, run lab tests, and analyze data to determine the cause and treat her weight loss.



Learning Objectives: STEM Cases are designed to assist in learning the core concepts and practice critical thinking skills (data analysis, data interpretation, hypothesis and reasoning, predictions and communicating findings). Students are assessed on each of these, and their progress can be monitored in real time by teachers. The following vocab/concepts are addressed in the Enzymes STEM Case:

- Enzymes: chemical reactions, reactants, products, rates, metabolism, catalysis, activation energy, and denaturing
- Amino acids, folding into proteins, enzyme active sites and specificity based on shape, effects of temperature and pH
- Graphing enzyme activity, interpreting graphs
- Proteases, carbohydrases, lipases (brief overview)
- Anatomy: stomach, small intestine, pancreas
- Digestion, absorption of nutrients



***Participation or non-participation will not affect your grade or class standing.**

Metacognition Planning Strategy #1: Stem Statements

Description: “**Stem statements** guide thinking in a number of directions, stirring the pot with prior knowledge and past experiences. Often stem statements are given by the teacher as facilitator, but eventually, as students become more sophisticated in their use of metacognitive strategies, they generate their own stems. This is appropriate as students can select stems that are personally relevant.” (Fogarty and Pete, 2018).

I wonder how enzymes...

Vocabulary terms I have heard before (from list above) include...

A question I have is...

I think Claire is experiencing weight loss because...

APPENDIX C

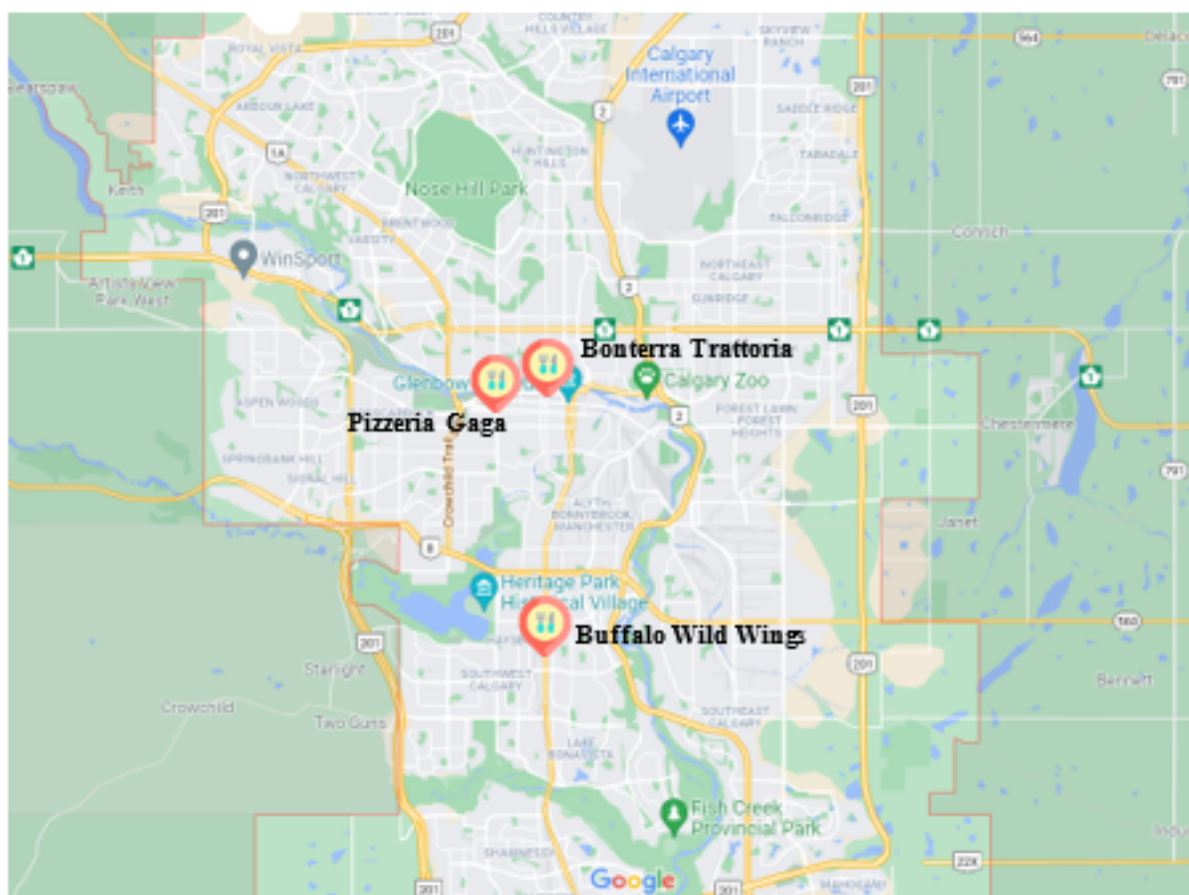
PLANNING METACOGNITION STRATEGY #2: ROLL THE DICE

NAME _____ DATE _____

Macromolecules Lab: Murder and a Meal



The Case: A murder has occurred in Calgary, and the Calgary police are reaching out to you to assist in solving the crime. Central to identifying the individual who committed this crime is establishing where the victim was the day of the crime so that detectives can question the individuals with who the victim came into contact. An autopsy was performed on the victim and has revealed that the victim ate just prior to the time of death. Upon questioning the victim's friends and family, detectives working the case have learned that the victim enjoyed eating at the following Calgary restaurants:



***Participation or non-participation will not affect your grade or class standing.**

Pizzeria Gaga: The victim would never eat thick-crust pizza from anywhere else! The victim would typically order a pizza with sausage, pepperoni, and bacon.

- **Prediction:** What macromolecules would you expect to find in the stomach contents of the victim if his last meal was eaten here?

Buffalo Wild Wings: The victim would hang out here to watch sporting events while feasting on chicken wings and celery.

- **Prediction:** What macromolecules would you expect to find in the stomach contents of the victim if his last meal was eaten here?

Bonterra Trattoria: The victim would love to go here for a night of bread, olive oil, and buttery pasta.

- **Prediction:** What macromolecules would you expect to find in the stomach contents of the victim if his last meal was eaten here?

The forensic pathologist has removed the contents from the victim's stomach for you to analyze and determine where the victim had his last meal, and who he had it with. The following suspects submitted testimonies below.

Suspect #1 = The victim's boss, who claims to have been out that night with coworkers at Pizzeria Gaga.

Suspect #2 = The victim's roommate and best friend, who claims to have been out with other buddies at Buffalo Wild Wings, eating wings and watching football.

Suspect #3 = The victim's girlfriend, who claims to have been out at Bonterra Trattoria that evening with her parents who were in town.

- **Hypothesis:** Who do you believe is the killer?

APPENDIX D

PLANNING METACOGNITION STRATEGY #3: PIE IN THE FACE

NAME _____ DATE _____

Planning Metacognition Strategy #3: Pie in the Face (Making Inferences)

“Inferring” is defined as going beyond the given information, second guessing, implying, or reading between the lines. Pie in the Face is a strategy that encourages making inferences by considering observations and drawing possible conclusions (Fogarty & Pete, 2018). Examine the comic strip below.

***Participation or non-participation will not affect your grade or class standing.**

Enzyme Day 1	Enzyme Day 2	Enzyme Day 3
	Paramedicum Parlor @AmekoSchools 	

- Draw cartoons for Day 1 and Day 3 based on the figure for Day 2. Think of Day 1-3 as a chronological sequence.
- Describe what you think happened in Day 1:
- Describe what you think will happen now in Day 3:

APPENDIX E

PLANNING METACOGNITION STRATEGY #4: PRIME THE PUMP

NAME _____

DATE _____



Curiosity Catapult – Digestive System KWL

Metacognition Planning Strategy #4: Prime the Pump (KWL)



**Participation or non-participation will not affect your grade or class standing.*

K	W	L
What do I K now?	What do I W ant to know?	What have I L earned

APPENDIX F

PLANNING METACOGNITION STRATEGY #5: THE GOAL POST

NAME _____

DATE _____



Curiosity Catapult – The Goal Post



Introduction

Goal-setting is simply the act of planning desired benchmarks in one's personal or academic life. "The Goal Post" is a planning metacognition strategy that can be used to achieve short-term and long-term goals throughout the school day (Fogarty & Pete, 2018). In this activity you will aim to set reasonable/attainable goals for Tuesday's quiz.

Part 1 – Learning Objectives Checklist

Please check off learning objectives that you feel you could accomplish at this exact point in time.

Enzyme Learning Objectives (8 total)

- ☐ "I recognize what type of macromolecule an **enzyme** represents, and I know how enzymes impact **activation energy** and **reaction rate**."
- ☐ "I can identify **reactants (substrate)**, **products**, **active site**, **regulatory site**, and enzymes given text-based information or a diagram."
- ☐ "I can visually distinguish between **hydrolysis** and **dehydration synthesis** for an enzymatic reaction."
- ☐ "I can differentiate between the **lock and key model** and **induced fit model**, particularly from a visual of an enzymatic reaction."
- ☐ "I can describe how enzymatic reactions are affected by changes in enzyme or substrate concentrations, temperature, and pH (i.e., what is optimal for a given enzyme)."
- ☐ "I know what happens to enzymes after they are used in a reaction."
- ☐ "I can interpret diagrams presenting **competitive and non-competitive (allosteric activity) inhibition**, and recognize how products and enzymes are affected."
- ☐ "I can identify environmental conditions that may result in enzyme **denaturation**."

Digestive System Learning Objectives (13 total)

- ☐ "I can define what happens during the four stages of the digestive process: **ingestion**, **digestion**, **absorption**, and **elimination (egestion)**."
- ☐ "I can categorize **mastication** (teeth chewing), **peristalsis**, segmentation, digestion enzyme activity, stomach gastric juices, and bile as physical or chemical digestion aids."
- ☐ "I can label the following alimentary canal structures on a diagram: **mouth**, **pharynx**, **esophagus**, **stomach**, **duodenum**, **jejunum**, **ileum**, **colon (large intestine)**, **rectum**, and **anus**, and can order these structures in sequence."

- ☐ "I can label the following accessory structures on a diagram: **salivary glands, liver, gall bladder, and pancreas.**"
 - ☐ "I recognize that digestion begins in the mouth, and can describe what occurs in the oral cavity to impact digestion."
 - ☐ "I can describe the importance of the **epiglottis** in the swallowing reflex."
 - ☐ "For each main and accessory digestive structure/organ, I can describe how it contributes to chemical and/or physical digestion."
 - ☐ "I am familiar with the location and action of the following enzymes - **amylase, lipase, and pepsin** - and understand what macromolecules is broken down for each enzyme type."
 - ☐ "I recognize that **peristalsis is involuntary**, wave-like muscle contractions that occurs in the esophagus, the stomach, and the intestines."
 - ☐ "I know the name of the slender, vascular projections along the small intestine, and how their shape impacts absorption rates."
 - ☐ "I can identify the main role of the colon (or large intestine)."
 - ☐ "I can articulate where I would expect to find a **food bolus, chyme, and feces** along the digestive tract."
 - ☐ "I can summarize the name, symptoms, and the affected digestive tract locations for a few digestive system disorders."
-

***Participation or non-participation will not affect your grade or class standing.**

- 1) Based on the learning objectives you checked, how are you doing in your quiz preparation?

- 2) Identify 1-2 goals that you have for your quiz tomorrow. Make sure your goals can be measured for success.

- 3) How will you go about achieving this goal (or these goals)?

- 4) How will you feel if you are successful? How will you feel if you are unsuccessful?

APPENDIX G

MONITORING METACOGNITION STRATEGY #1: MEMOING

Metacognition Monitoring Strategy #1: “Sticky Note” (Memoing)

***Participation or non-participation will not affect your grade or class standing.**



What?

“Memoing is an extension of the written reminders on yellow sticky notes, and it is similar to an editorial comment of a parenthetical phrase that occurs as one reviews material” (Fogarty & Pete, 2018).

Why?

Memoing allows us to capture mental notes of our thinking as we actively engage in learning. It is a way to wrap our minds around the content and “repair” and “question” our understandings.

How?

Grab a pack of post-it notes and jot down notes related to the Topic 3 learning targets as you watch (and rewatch) the Amoeba Sisters respiratory system video.

APPENDIX H

MONITORING METACOGNITION STRATEGY #2: TRANSFER TALK

Respiratory System Transfer Talk (Bridging) - Exit Ticket -

[Exit Preview](#)

Transfer Talk Questions

"Transfer Talk" (Bridging) is our 2nd monitoring metacognition strategy that we will employ (Fogarty & Pete, 2018). Remember that monitoring strategies are used to check your active learning and content misconceptions. Please answer the following questions based on our learning today - learning objectives (Topic 3) 7, 8, 9, 11, 12, and 13. *Participation or non-participation will not affect your grade or class standing.

Question 1

When have you learned about the respiratory system prior to Biology 20?

Question 2

What would be an application of what any content that you learned about today?

Question 3

Why is today's content important to learn?

Question 4

How might you use something from today's content in the future?

APPENDIX I

MONITORING METACOGNITION STRATEGY #3: VERBAL CUE CARDS

Verbal Cue Cards:

The Respiratory System

1

Rules of the Game

**Participation or non-participation will not affect your grade or class standing.*

- 5 Rounds Total
- For each round, you will be asked to group in a certain way – do not group with someone you have talked to previously in this activity.
- Form groups of 2-3 peers – no more, no less
- In each round, every member will have 30 seconds to speak about the learning objective on the cue card.
 - *If you have 2 in your group, use the 3rd 30-second slot to discuss how this learning objective could be assessed on your Unit Test!

2

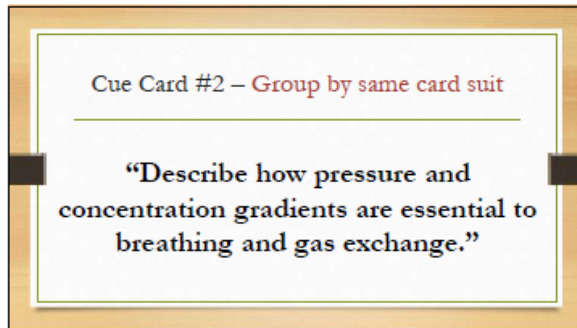
Get Ready for Cue Cards!

3

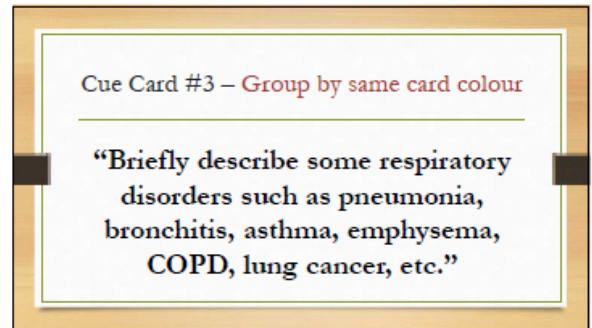
Cue Card #1 – Group by same card #'s

“Describe the difference between breathing, external respiration, internal respiration, and cellular respiration.”

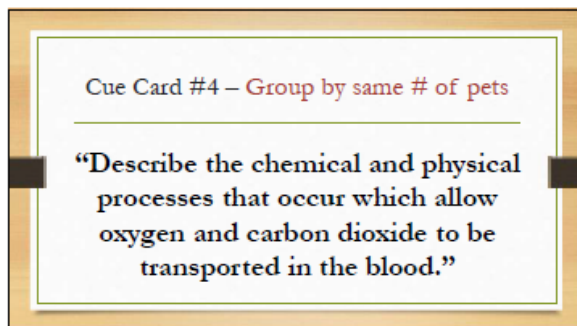
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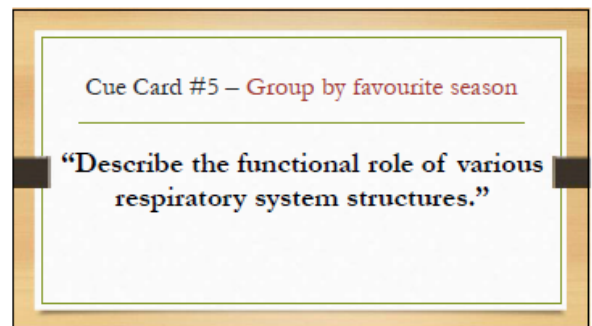
5



6



7



8

APPENDIX J

MONITORING METACOGNITION STRATEGY #4: MENTAL MENUS

NAME _____

DATE _____



Curiosity Catapult – Mental Menus



Introduction: We have been exploring several monitoring metacognition strategies over the past few days, including: memo-ing, transfer talk (bridging), and cue cards. Today we are going to try a fourth strategy called “Mental Menus.” Monitoring strategies help us to gauge our active learning and provide opportunities to repair misconceptions and identify gaps in our understanding (Fogarty & Pete, 2018).

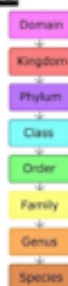
Mental menus are essentially mnemonic devices that can assist with the recall of content or sequences. One example was “DJ Ivan” for duodenum, jejunum, and ileum. Additional examples include:

Mnemonic	
Please	P - Parenthesis
Excuse	E - Exponent
My	M - Multiplication
Dear	D - Division
Aunt	A - Addition
Sally	S - Subtraction

Mnemonic Device

“Dear King Phillip came over for good spaghetti!”

• Domain, Kingdom, Phylum, Class, Order, Family, Genus, Species.



***Participation or non-participation will not affect your grade or class standing.**

We have reviewed a variety of sequences or relational vocabulary terms. Choose two table boxes below (circle your selections) and develop mental menus on the reverse side of this paper.

Carbohydrate: Monosaccharide Protein: Amino Acid Lipid: Glycerol and Fatty Acids Nucleic Acid: Nucleotide	Ingestion Digestion Absorption Elimination	Hydrolysis: Catabolism Dehydration Synthesis: Anabolism
Nasal Passage Larynx Pharynx Epiglottis Trachea Bronchi Bronchioles Alveoli	Mouth Pharynx Esophagus Stomach Small Intestine Colon Rectum Anus	Physical: Mastication Peristalsis Segmentation Chemical: Enzymes Gastric Juices Bile

APPENDIX K

MONITORING METACOGNITION STRATEGY #5: TWO-WAY TALK

NAME _____ DATE _____

Monitoring Metacognition Strategy #5: Two-Way Talk

Introduction: We have been exploring several monitoring metacognition strategies over the past few days, including: memo-ing, transfer talk (bridging), cue cards, and mental menus. Monitoring strategies help us to gauge our active learning and provide opportunities to repair misconceptions and identify gaps in our understanding. Today we are going to try a fifth strategy called “Two-Way Talk.” “Two-way Talk,” or “Conferencing,” is a “face-to-face interaction that yields a reflection on a given learning activity. It is a technique for soliciting one-on-one feedback – a personal, verbal transaction that focuses on the why and the how of something, not the what, who, when, and where of that something” (Fogarty & Pete, 2018). In this activity, you will first create two short answer questions related to our assessment content – they must be in the form of “why” or “how.” Be sure that you can answer your questions completely. Next, you will be matched with a partner randomly assigned by your teacher. Your partner must answer the questions without notes. You will then collaboratively engage in a verbal conversation about how you did answering each other’s questions and provide feedback.

***Participation or non-participation will not affect your grade or class standing.**

Question #1:

Question #2:

APPENDIX L

EVALUATION METACOGNITION STRATEGY #1: MRS. POTTER'S QUESTIONS

Metacognition Evaluation Strategy #1 - Mrs. Potter's Questions

Evaluating thinking means assessing what you know, and how and why you know it. Please complete the following reflective questions after your completion of the Cardiac Output inquiry. This evaluation strategy is termed, "Mrs. Potter's Questions" (Fogarty & Pete, 2018). ***Participation or non-participation will not affect your grade or class standing.**



Hi, Stacey. When you submit this form, the owner will see your name and email address.

* Required

1. What was the purpose of the Cardiac Output inquiry? *

Enter your answer

2. What went well for you while conducting this Cardiac Output inquiry? *

Enter your answer

3. What would you do differently next time? *

Enter your answer

4. What additional information from me do you need to feel successful with the Cardiac Output content? *

Enter your answer

Submit

APPENDIX M

EVALUATION METACOGNITION STRATEGY #2: PLUS. MINUS. INTERESTING.

6. A fetus has no need for pulmonary circulation. Oxygen diffuses from the mother's circulation into that of the fetus through the placenta. Therefore, the movement of blood through the heart is highly modified: blood flows from the right atrium through an opening in the septum to the left atrium and then to the left ventricle. The opening between the right and left atria becomes sealed at birth. Explain why any failure to seal the opening results in what has been termed a "blue baby".

7. A person's blood pressure is taken in a sitting position before and after exercise. Compare blood pressure readings before and after exercise as shown in the following chart:

Condition	Systolic B.P.	Diastolic B.P.	Pulse Rate
Resting	120	80	70
After Exercise	180	45	160

- a) Why does systolic blood pressure increase after exercise?
- b) Why does diastolic blood pressure decrease after exercise?

Think Critically:

8. Coronary heart disease is often related to lifestyle. Stress, smoking, alcohol consumption and poor diet are all considered to be contributing factors to heart disease. Should all people have equal access to heart transplants? Should people born with genetic heart defects be treated differently from people who have abused their hearts through lifestyle choices?

***Participation or non-participation will not affect your grade or class standing.**

Metacognition – Evaluation Strategy #2: Plus-Minus-Interesting (Thumbs Up/Thumbs Down)

*Please consider all of the content and learning objectives associated with Topic 4. Complete the following table based on your "PLUS experiences," "MINUS experiences," and "INTERESTING experiences."

P (+)	
M (-)	
I (?)	

APPENDIX N

EVALUATION METACOGNITION STRATEGY #3: CHOOSE YOUR SPOT

CHOOSE YOUR SPOT:

THE HUMAN GRAPH

*PARTICIPATION OR NON-PARTICIPATION WILL NOT AFFECT YOUR GRADE OR CLASS STANDING.

1

The immune system is related to many areas of the body including digestion, lungs, skin and the liver. For example, up to 70% of immunity is related to digestive function which in turn is related to the adrenal gland. Proper assessment and a treatment plan are important to optimize one's health.

Underlying conditions maybe allergies, sensitivities, hormone imbalance or digestive weakness.

This subjective questionnaire will give your health care practitioner a quick summary of symptoms or signs that may be related to immune system function. It is not a substitute for professional medical advice from your health care provider.

2

STATEMENT #1:
"I eat a diet high in fruits and vegetables."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
----------------	-------	---------	----------	-------------------

3

STATEMENT #2:
"I have a very stressful lifestyle. I am busy, I worry a lot, and sometimes/often have trouble sleeping."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
----------------	-------	---------	----------	-------------------

4

STATEMENT #3:
"I have reactions/allergies to certain foods."

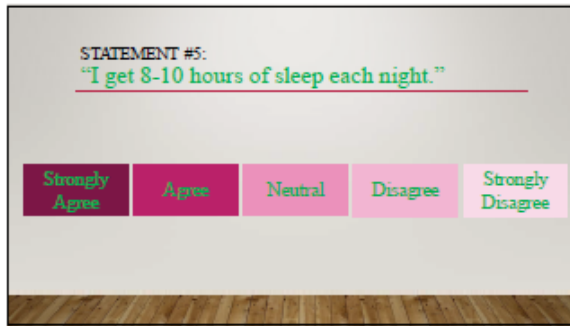
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
----------------	-------	---------	----------	-------------------

5

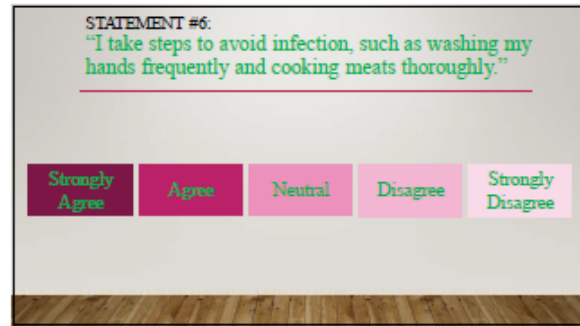
STATEMENT #4:
"I have sensitivities to chemicals and environmental allergens."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
----------------	-------	---------	----------	-------------------

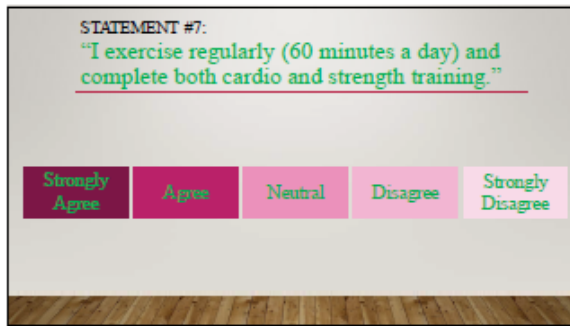
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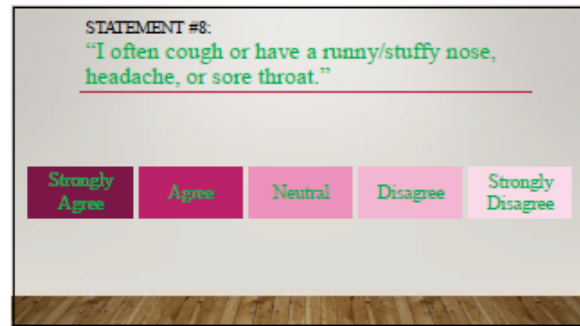
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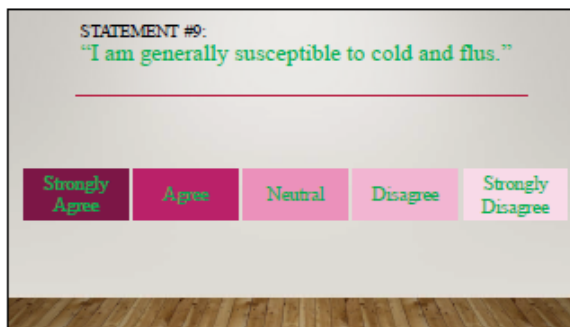
8



9



10



11

APPENDIX O

EVALUATION METACOGNITION STRATEGY #4: CONNECTING ELEPHANTS

What is the Rh Factor?

The Rh factor is a _____ that can be found on the surface of _____. If your blood cells have this protein, you are Rh positive. If your blood cells do not have this protein, you are Rh negative. During pregnancy, problems can occur if you are Rh negative and your fetus is Rh positive.



What type of blood can a recipient obtain?

Compatibility of BLOOD TYPES	Donor							
	O-	O+	B-	B+	A-	A+	AB-	AB+
Recipient	AB+	Red	Red	Red	Red	Red	Red	Red
	AB-	Red	Red	Red	Red	Red	Red	Red
	A+	Red	Red	Red	Red	Red	Red	Red
	A-	Red	Red	Red	Red	Red	Red	Red
	B+	Red	Red	Red	Red	Red	Red	Red
	B-	Red	Red	Red	Red	Red	Red	Red
	O+	Red	Red	Red	Red	Red	Red	Red
	O-	Red	Red	Red	Red	Red	Red	Red

*Why can't a B+ blood donor donate to an A+ blood recipient?

*Why can't B+ blood donor donate to B- blood recipient?

*Which blood type would be considered the **universal donor**?

*Which blood type would be considered the **universal recipient**?

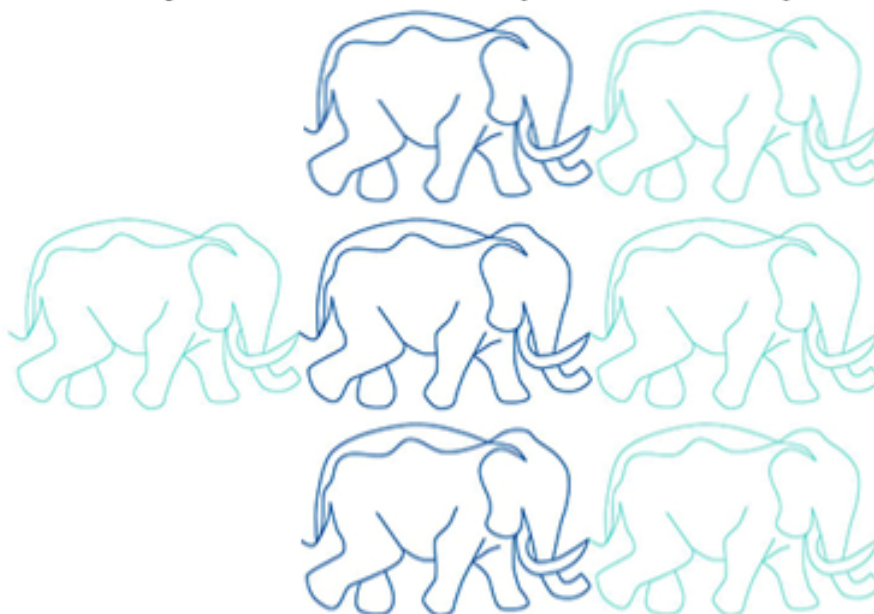
Metacognition Evaluation Strategy #4: Connecting Elephants

***Participation or non-participation will not affect your grade or class standing.**

Elephant 1
(Input)
BIG IDEA
What's the big idea?

Elephant 2
(Process)
OTHERS BIG IDEAS
How does this connect to other big ideas?

Elephant 3
(Output)
NEW BIG IDEAS
How can I use this big idea?



APPENDIX P

EVALUATION METACOGNITION STRATEGY #5: CHECKMATE

Name _____ Date _____

Evaluation Metacognition Strategy #5: Checkmate***Participation or non-participation will not affect your grade or class standing.**

"Checklists are listings of ideas or procedures that cue the learner to check for certain things. Checklists are long memos generated prior to doing a task that capture all the relevant pieces so they can later be reviewed for completion and subsequently ticked off as a means of self-evaluating" (Fogarty & Pete, 2018).

Science Reasoning and Data Interpretation Passage Checklist		
Criteria	Y	N

Name _____ Date _____

Evaluation Metacognition Strategy #5: Checkmate***Participation or non-participation will not affect your grade or class standing.**

"Checklists are listings of ideas or procedures that cue the learner to check for certain things. Checklists are long memos generated prior to doing a task that capture all the relevant pieces so they can later be reviewed for completion and subsequently ticked off as a means of self-evaluating" (Fogarty & Pete, 2018).

Science Reasoning and Data Interpretation Passage Checklist		
Criteria	Y	N

APPENDIX Q

COMPLETE METACOGNITION CYCLE STRATEGY #1: PRIME THE PUMP

Energy and Matter Exchange in the Biosphere KWL

Planning Metacognition Strategy: Prime the Pump (KWL)

**Participation or non-participation will not affect your grade or class standing.*

Examine the following Unit 2 vocabulary terms.

Primary Consumers	Phosphorus Cycle	Secondary Consumers	Cellular Respiration	Hydrologic Cycle
Water Properties	Ecological Pyramids	Chemosynthesis	Oxygen Cycle	Consumers
Photosynthesis	Biomass	Carbon Cycle	Eutrophication	Tertiary Consumers
Nitrogen Cycle	Decomposers	Trophic Levels	Producers / Autotrophs	Food Chains & Webs

Use words and/or pictures to complete the following chart (FIRST TWO COLUMNS NOW) based on the vocabulary words above.

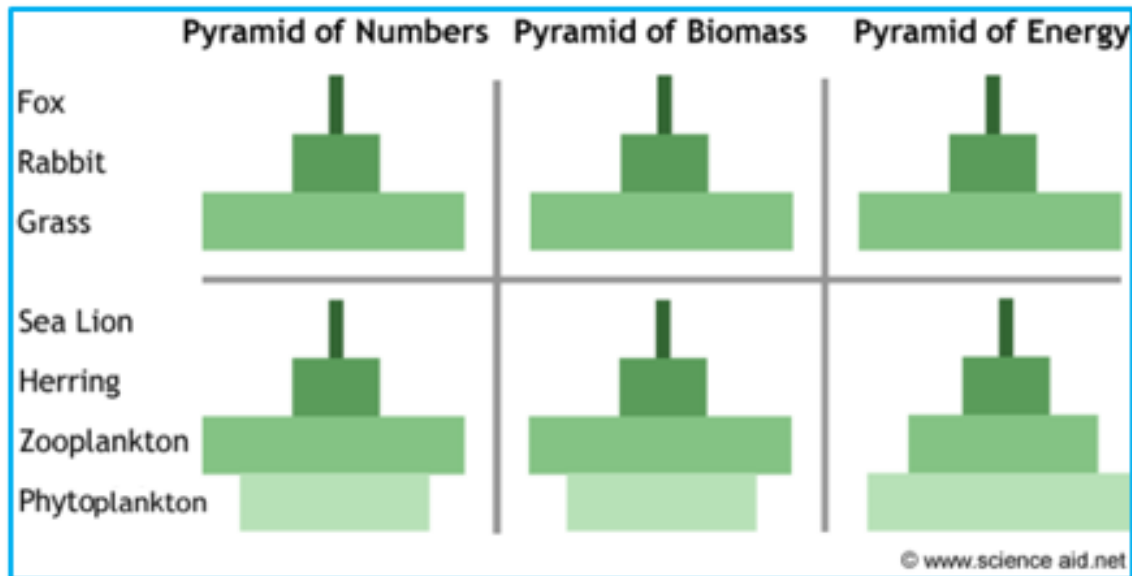
K	W	L
What do I Know?	What do I Want to know?	What have I Learned?

APPENDIX R

COMPLETE METACOGNITION CYCLE STRATEGY #2: STEM STATEMENTS

Name _____ Date _____

Ecological Pyramids Brainstorm



***Participation or non-participation will not affect your grade or class standing.**

Metacognition Planning Strategy: Stem Statements

Description: "Stem statements guide thinking in a number of directions, stirring the pot with prior knowledge and past experiences. Often stem statements are given by the teacher as facilitator, but eventually, as students become more sophisticated in their use of metacognitive strategies, they generate their own stems. This is appropriate as students can select stems that are personally relevant" (Fogarty and Pete, 2018).

Let's complete the following Stem Statements for the image pictured above.

I wonder...

Vocabulary terms I have heard before (from the image above) include...

One question I have is...

I think aquatic systems are different than terrestrial systems because...

APPENDIX S

COMPLETE METACOGNITION CYCLE STRATEGY #3: MEMOING

Metacognition Monitoring Strategy: “Sticky Note” (Memoing)

***Participation or non-participation will not affect your grade or class standing.**



What?

“Memoing is an extension of the written reminders on yellow sticky notes, and it is similar to an editorial comment of a parenthetical phrase that occurs as one reviews material” (Fogarty & Pete, 2018).

Why?

Memoing allows us to capture mental notes of our thinking as we actively engage in learning. It is a way to wrap our minds around the content and “repair” and “question” our understandings.

How?

Grab a pack of post-it notes and jot down clues and notes as you complete your complex food web for Darien, Panama.

APPENDIX T

COMPLETE METACOGNITION CYCLE STRATEGY #4: TWO-WAY TALK

NAME _____ DATE _____

Monitoring Metacognition Strategy: Two-Way Talk

Reminder: Monitoring strategies help us to gauge our active learning and provide opportunities to repair misconceptions and identify gaps in our understanding. We will be trying our “Two-Way Talk” again. “Two-way Talk,” or “Conferencing,” is a “face-to-face interaction that yields a reflection on a given learning activity. It is a technique for soliciting one-on-one feedback – a personal, verbal transaction that focuses on the why and the how of something, not the what, who, when, and where of that something” (Fogarty & Pete, 2018). In this activity, you will first create two short answer questions related to our Unit 2 assessment content – they must be in the form of “why” or “how.” Be sure that you can answer your questions completely. Next, you will be matched with a partner randomly assigned by your teacher. Your partner must answer the questions without notes. You will then collaboratively engage in a verbal conversation about how you did answering each other’s questions and provide feedback.

***Participation or non-participation will not affect your grade or class standing.**

Question #1:

Question #2:

APPENDIX U

COMPLETE METACOGNITION CYCLE STRATEGY #5: CONNECTING ELEPHANTS

Metacognition Evaluation Strategy: Connecting Elephants

***Participation or non-participation will not affect your grade or class standing.**

Elephant 1

(Input)

BIG IDEA

What's the big idea?

Elephant 2

(Process)

OTHERS BIG IDEAS

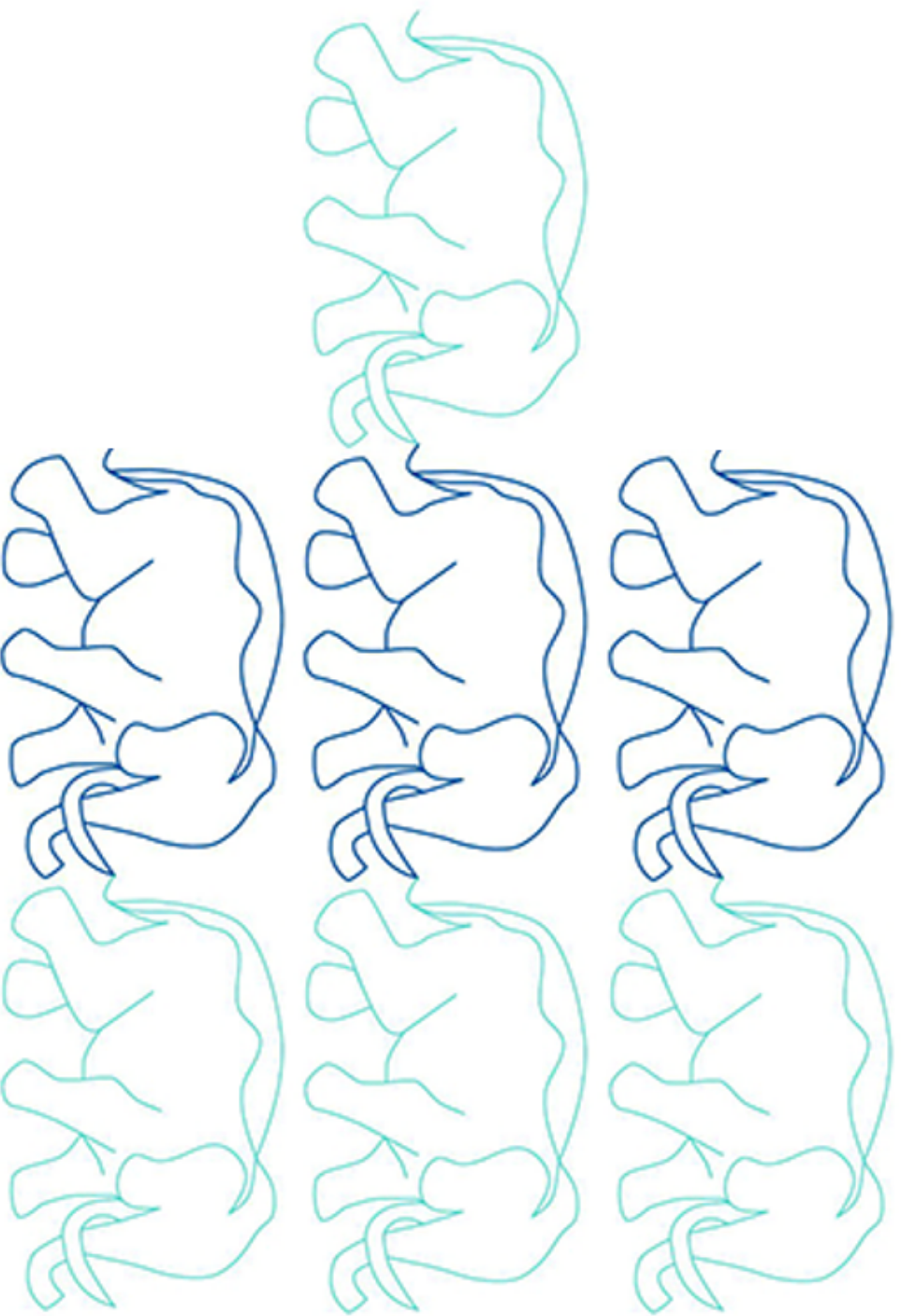
How does this connect to other big ideas?

Elephant 3

(Output)

NEW BIG IDEAS

How can I use this big idea?



APPENDIX V

COMPLETE METACOGNITION CYCLE STRATEGY #6: PLUS. MINUS. INTERESTING.

NAME _____ DATE _____

PLUS. MINUS. INTERESTING.***Participation or non-participation will not affect your grade or class standing.****Evaluation Metacognition Strategy : Plus-Minus-Interesting (Thumbs Up/Thumbs Down)**

*Please consider all the content and learning objectives associated with Unit 2. Complete the following table based on your "PLUS experiences," "MINUS experiences," and "INTERESTING experiences."

P (+)	
M (-)	
I (?)	

NAME _____ DATE _____

PLUS, MINUS. INTERESTING.***Participation or non-participation will not affect your grade or class standing.****Evaluation Metacognition Strategy : Plus-Minus-Interesting (Thumbs Up/Thumbs Down)**

*Please consider all the content and learning objectives associated with Unit 2. Complete the following table based on your "PLUS experiences," "MINUS experiences," and "INTERESTING experiences."

P (+)	
M (-)	
I (?)	

APPENDIX W

POST-TREATMENT METACOGNITION STRATEGIES STUDENT SURVEYS

- 6) Using metacognitive **evaluating strategies** were better tools for increasing my understanding of the content in comparison to when I used metacognitive **planning strategies**.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
☒	☒	☐	☐	☐	☐	☐

- 7) Please explain your selection from question number 6.

- 8) Using metacognitive **evaluating strategies** were better tools for increasing my understanding of the content in comparison to when I used metacognitive **monitoring strategies**.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
☒	☒	☐	☐	☐	☐	☐

- 9) Please explain your selection from question number 8.

- 10) I am likely to independently use metacognitive **evaluating strategies** for future courses.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
☒	☒	☐	☐	☐	☐	☐

- 11) I am interested in learning additional metacognitive **evaluating strategies**.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
☒	☒	☐	☐	☐	☐	☐

***Participation or non-participation will not affect your grade or class standing.**

Metacognitive COMBINATION Strategies Survey



- 1) Using a **combination of metacognitive strategies** in the planning-monitoring-evaluation cycle increased my understanding of the content in comparison to when I did not use any metacognition strategies at the beginning of the semester.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
☒	☒	☐	☐	☐	☐	☐

- 2) Please explain your selection from question number 1.

- 3) Using a **combination of metacognitive strategies** in the planning-monitoring-evaluation cycle increased my understanding of the content in comparison to when I only used one type of metacognition strategy at a time.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
☒	☒	☐	☐	☐	☐	☐

- 4) Please explain your selection from question number 3.

- 5) Overall, I enjoyed this process of learning about metacognition strategies.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
☒	☒	☐	☐	☐	☐	☐

- 6) Please explain your selection from question number 5.

- 7) Overall, I recognize the importance of metacognition strategies in improving learning.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
☒	☒	☐	☐	☐	☐	☐

- 8) Please explain your selection from question number 7.

APPENDIX X

FOCUS ON METACOGNITION STRATEGIES EXIT INTERVIEW

***Participation or non-participation will not affect your grade or class standing.**

Focus on Metacognition Strategies Exit Interview

Interview Questions:



- 1) Do you feel confident selecting your own strategies (i.e., planning, monitoring, and evaluation) that could be used in conjunction with the next unit? Why or why not?
- 2) Do you believe that one stage in the planning-monitoring-evaluating cycle takes a greater time investment? Please explain your response.
- 3) Did you spend any time outside of class reflecting on these strategies, and have you used them in another class since the beginning of semester two?
- 4) Do you have any additional comments or questions for me?

APPENDIX Y

11-POINT LEARNING CONFIDENCE LIKERT SCALE AND STUDENT SURVEY

- 6) **Identify** an organism from the food web above that has the *most* energy available to it and an organism that has the *least* energy available. **Explain** your responses. (1 pt)

- 7) **Describe** the effect of human activity on this community of organisms. (1 pt)

***Participation or non-participation will not affect your grade or class standing.**

Post-Assessment Student Survey

- 1) **How confident** are you in your understanding of this content? (*circle below*).

Not At All Confident			Neutral				Extremely Confident			
0	1	2	3	4	5	6	7	8	9	10

Explain your selection:

- 2) **How long** did you study for this assessment, and **what are ways** in which you prepared?

- 3) **What topics/content** were the most challenging?

APPENDIX Z

LEARNING CONFIDENCE REFLECTION SURVEY

Post-Assessment Survey - Circulatory and Immune Quiz

Please answer these questions following a review of your circulatory system, blood, and immune system assessment. ***Participation or non-participation will not affect your grade or class standing.**

...

Hi, Stacey. When you submit this form, the owner will see your name and email address.

* Required

1. Now that you have evaluated your learning confidence rankings in association with your assessment score/performance, how would you rate your alignment from 1 to 5; with 1 being "I was not accurate in distinguishing between my content understanding strengths and weaknesses" to 5 being, "I formed very accurate conceptions of my content understanding and limitations." *

	1 (Not Accurate)	2	3	4	5 (Very Accurate)
Rate Your Alignment	☐	☐	☐	☐	☐

2. Were you surprised by your results? What do you think influenced these results? *

Enter your answer

3. What did you learn that may help you prepare for the next assessment, particularly tomorrow's Unit 2 assessment? *

Enter your answer

4. Do you have any additional comments or questions for me?

Enter your answer

Submit