

TIER-3 VOCABULARY RETENTION AND TRANSFER WITH
STUDENT CREATED SCIENCE INFOGRAPHICS

by

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ABSTRACT

The sixty-three total Grade 7 students presented in this Capstone have been observed to lack using science vocabulary to explain science concepts and to express it concisely. As a comparison, students were provided a curriculum-created science infographic and students answered questions based on the curriculum-created science infographic. The treatment was to allow students to create individual science infographics using their data collected and learned from their paper notebooks, electronic science vocabulary notebooks, and extra relevant information from web searches. Student data was collected by taking count of quantified coded variables from student written work on an essay assessment without infographics, a curriculum-created science infographic, and student-created science infographic artifacts. Data tables and bar graphs were generated to compare the generation of a claim, using Tier-3 vocabulary, using evidence, and writing reasoning of why the evidence was used or supported the claim. Results revealed that student-created science infographics when compared to their assessment results when no infographic was present to them presented a 4.8% decrease in writing an appropriate & relevant claim when creating their own science infographic, a 17.4% increase in using Tier-3 vocabulary, 39.7% increase and 36.5% increase in data presented and evidence explained with Tier-3 vocabulary, respectively.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

Tier-3 vocabulary is an important tool to communicate between teachers, students, and the world. According to Rigolosi, Tier-3 vocabulary are words that “are highly specific for each content area and are housed within a particular subject.” This is not to be confused with Tier-3 reading intervention, which is when the learner is not reading at their designated grade level and requires special intervention.

At some point, students will have to choose a certain skill later in life. For those that choose the path of science, having a strong foundation in science vocabulary is a good way to start. Good communication is key to effective presentation of the information in one’s head. Infographics will be used as a measure of student communication of Tier-3 vocabulary with myself and them. Tier-3 vocabulary measured in this Capstone are atoms(s), molecule(s), open system, closed system, chemical reaction(s), Law of Conservation of Matter, and Law of Conservation of Mass.

This interest between infographics and Tier-3 vocabulary came about when observing patterns among a few students over the years. An infographic is a visual representation of information from the perspective of the author about the data or knowledge. It presents complex information quickly and clearly to reduce the reader’s cognitive load.

At first, it was something to pass the time during class or seen as busywork, but as the years went by, student application of concepts emerged in writing and drawing concepts and connecting Tier-3 vocabulary. This Capstone project will quantify these observations and gather evidence of change or stagnant learning.

If learning and retention improves, then evidence can be provided to administration that students creating infographics is a productive use of time and shows active application of vocabulary retention, my school's science curriculum, mission, and statement. If stagnant, then amplifying the application of infographics to student growth by pairing it with another learning tool. The amplification of treatment will include daily vocabulary reminders, encouraging use of vocabulary during verbal discussions (class shared or sharing with me), repeating the vocabulary used by students during discussions, and highlighting and complimenting students on using Tier-3 vocabulary appropriately.

Action Research Questions

- How will student-developed science infographics improve their scores and their application of Tier-3 vocabulary on summative assessments?
- What evidence of Tier-3 vocabulary retention will students display while creating student-developed science infographics?

More focused or refined questions developed during the action research are:

- How much Tier-3 vocabulary retention will Grade 7 students obtain when producing student-created science infographics?
- How much will Grade 7 students apply their knowledge to show their understanding of Tier-3 vocabulary with observations from their class data?
- How accurately will Grade 7 students apply Tier-3 vocabulary to explain the concepts from the unit they are learning from?

Since this capstone focus was student science writing with Tier-3 vocabulary, analysis assistance and feedback about the data collection process and data was conducted with my

science department. Discussions coincided with our school and science department's Data Wise process and schoolwide goal of focusing on improving student writing in the core subjects and elective courses.

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Alwadi and Moshen (2023)³ focused on the learning and acquisition data of L2 English vocabulary from 41, third-year, female undergraduate students in their first semester of English language classes at Najran University in Saudi Arabia. Twenty-one students were placed in an experimental group with infographics and twenty students were placed in a control group with traditional classroom methodology. All 41 students' native language was Arabic. In consideration of the subjects, subjects were told this was a voluntary participation and they could withdraw without consequences to their academic progress. The researchers created an instructional infographic using the Piktochart website with the idea that the infographic was planned with four phases of utility in mind: planning and studying, sketching out ideas, designing, and production. Instrumentation for the subjects were based on Nation's model of form-meaning connection and grammatical functions, both of which are based on "testing the same word in several different ways" (p.5) and a third measure of an oral interview to "assess the learners' production knowledge of vocabulary" (p.5). A questionnaire was also delivered to the subjects to "elicit the learners' perceptions" about using infographics and learning English vocabulary.

If methodologies imply application of theory in various ways and rationalization of certain educational tools and/or pedagogy to create authentic learning environments while producing quantitative and qualitative data, then Alwadi and Moshen proposes that infographics in education are "...visualization tools used in learning environments to provide information in a visually interesting, engaging style" (p.3). The authors also propose that infographics keep the

learner's curiosity and keeps them reading for more information through the combination of texts and images through the CTML model of information processing and retention.

According to the Alwadi and Moshen's interpretation of the data, students in the experimental group "significantly outscored the students' performance of the control group" (p. 8). In this study, they performed a delayed post-test of two-weeks after the first post-test for both groups and concluded the experimental group "outscored their counterparts in the control group in terms of vocabulary" (p.9).

The authors' analysis in limitations of their research acknowledged the following:

- the sample size was too small and had students withdraw from the study;
- a lack of English language proficiency tests;
- infographics created by the authors were not validated by graphic design experts;
- only two dimensions of L2 vocabulary learning acquisition were used, when there are 18 components to fully measure the understanding of a target word.

Alwadi and Moshen state the research of the effectiveness of infographics and English language acquisition is lacking. "EFL teaching literature yields sparse information regarding the use of infographics in EFL classrooms" (p.4). Also, true to the paper's nature, part of the research paper used infographics to explain the researchers' experiment, experiment timeline, and data.

According to Kozar (2022), the three benefits of student-created infographics are:

1. Increase engagement with otherwise 'dry' content, like reading;
2. Using infographics as 'assessment tools';
3. Use infographics to compare different theories or discipline controversies.

Before delving into these three ideas, Kozar states that infographics are a “true democratization of graphic tools” because it allows teachers to increase engagements and enhance assessments, and “foster a skill of visual communication” to students.

One of the premises behind Idea 1 is that reading is not something students engage in, and Kozar bases it on research results from a 2021 study by Deale and Lee. They state that “80% of university students currently do not read their assigned readings” (para. 3). Kozar proposes that students should “create simple infographics with the key information from their assigned readings” (para. 4) because it can deepen learning among students while providing a “quick-to-process” for the educator and other students. This quick-to-process is explained by Kozar as taking “less time to see an image with text and a visual representation of the relationships...than to read several paragraphs of text” (para. 7).

Kozar further states that student-create infographics provide deep learning because students organize key messages in their own words and arranges them visually according to their understanding. This engages in higher order processes and “more likely to both process content on a deeper level and retain it long-term” (para. 5).

Idea 2 of using infographics as assessment tools is based on the premise that “infographics gives students an opportunity to practice and develop their communication skills” (para. 11) since using communication skills is a critical in different industries. Infographics provide valuable information in less time and many areas of labor require workers to relay information quickly and efficiently.

Idea 3 is based on the premise that infographics “visually present a comparison of different theories and controversies” (para. 16) in an enriching and effective way. When students create their infographics to relay complex information that crosses different fields of

study or ideas, then a visual representation, along with concise writing, is key to others understanding those subjects or ideas.

But, the utility and worth of infographics was researched more in-depth by Abbazio and Yang (2022). In their study, their claim is “information literacy instruction in STEM fields overlaps with...arts-related disciplines...” (p.5) and the authors approach infographics from a music library literacy point-of-view with the intent that infographics communicate “information quickly in situations where instruction time may be in short supply” all the while help students “to more rapidly and easily understand complex concepts” (p.6). Regardless of the subject, Abbazio and Yang argued that infographics “...minimize cognitive load, create aesthetically appealing artifacts, activate or build schemas by using objects and information known to learners...” (as cited in Dunlap, 2016, p.45). Despite their premises, they stated the crucial guiding research concept: “...whether creating infographics for use in information literacy instruction is worth the time needed to produce these materials” (p.10). They raised two research questions:

1. How does formatting affect students’ perception of text?
2. Does the mode of presentation – infographic format vs. plain text – affect students’ retention of information?

They studied seventy-eight out of 350 undergraduate students from DePauw University and University of Minnesota, Twin Cities responded to a Google Form survey with information stimulus in plain-text (words with no graphic design elements) versus an infographic presenting the same narrative as the plain-text using graphic design elements from Canva’s font cues, color contrast, and illustrations to “encourage recall and recognition” (p.14).

Subjects were asked four Likert-scale survey questions and a quiz (four multiple-choice questions and one open-ended question) to measure retention about the information stimuli. The results showed the infographics were more favorable (4 & 5's) and obtained a "similar amount of information" after viewing the plain-text narrative (p.23). They concluded, even with slight differences between in high-levels of retention, infographics still held its retention value and learning engagement with students by using that positive observation and stating the infographic format "does not hinder learners' retention of information" (p.28).

Theoretical articles

Alwadi and Moshen (2023)³ research was supported with Skill Acquisition Theory (SAT) and Cognitive theory of multimedia learning (CTML). Infographics utility are explained through two pedagogical theories of vocabulary acquisition, especially how people learn language through vocabulary. SAT, with cognitive psychology origins, "explains how people can acquire new skills" (p.2). This is applicable to infographics because the authors focuses their study on this learning tool and L2 learning domain, which is the skill to learn a second language. Tier-3 vocabulary has its own L2 learning domain because the language is highly specific to its context, which is very similar to learning a new language. According to Alwad and Moshen, by citing a 2007 study by DeKeyser, state to fully acquire a skill requires three stages: declarative, procedural, and automaticity. With learning a new language, learners "acquire declarative knowledge that is static information" (p.2). Static information is referred to as the language code placed into the learner's memory. The next step requires learners to take what they've learned in the declarative stage and apply it (procedural) with gradual less effort. Finally, learners become communicators as the knowledge is automated and further refining the procedural knowledge. Where infographics fit into SAT starts with the declarative stage of

“including the meaning of a certain word and its correct use” (p.2). During the procedural stage, language learners learn how to communicate by practicing their new vocabulary and concepts stored in long-term memory through infographics. Finally, with constant practice and by continued communication through infographics, “learners can use language for communicative purposes as they practice using these words in different situations” and results in automaticity of word knowledge and production (p.2). But, despite what appears to me a flow of one learning stage to the next, it requires lots of focus and attention. Alwadi and Moshen recognized this and called upon what skill theorists describe to get to automaticity by stating, “L2 learning entails the automatization of lower-order skills to free up space in the human brain” (p.2). Freeing up working memory in our already limited cognitive load is necessary for automatization to work. According to the authors, infographics is “one of the effective tools that help reduce extraneous processing in working memory” (p.2) and leads into another theory called Cognitive theory of multimedia learning (CTML).

They further state that Mayer’s CTML model’s “core principle is that learning from words and pictures is more effective than learning from words alone” (p.3). Figure 1 shows the progression of CTML and the connections a learner uses through visual and verbal memory pathways to acquire and utilize new information. According to Alwadi and Moshen, these two pathways are activated simultaneously, while “learners mentally integrate visual and verbal representations” (as cited in Mayer and Moreno, 1998, p.3). Figure 1 shows the connected nature of how visual and verbal are learned together, but it also shows the limits of each section of memory. Overall, there is a limited capacity to process the data in each section before it succeeds to be placed in long-term memory, which is where the SAT’s automaticity stage may also come into play. CTML has three assumptions on how the human mind works:

1. The verbal and visual memory are dual and separate channels;
2. There is a limited capacity to process information along the two channels;
3. Learners “actively process information from visual and auditory channels” to create something that makes sense and meaningful (p.3).

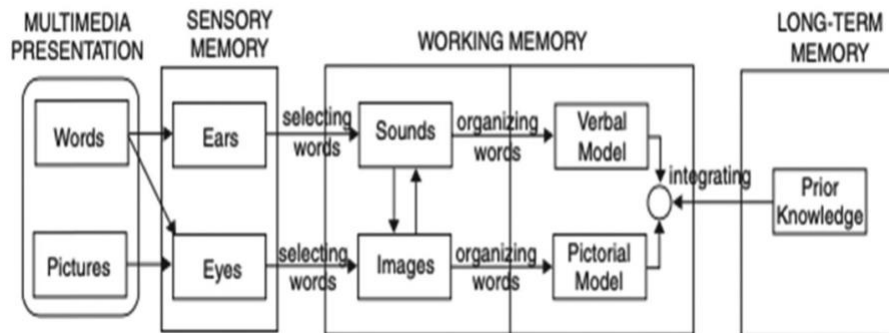


Fig 1: Mayer's Cognitive theory of Multimedia learning (CTML) model. Mayer, R.E. (2005)

To further understand how the human mind works, looking at the biology of the brain, alongside the schema of experiencing verbal and visual language is necessary. It is important to understand the significance of infographics and its connection to student processing of learning through infographics and its long-term acquisition of Tier-3 science vocabulary.

According to an Indiana Department of Education's article (n.d.), “reading is a complex process that occurs in three different by connected areas of the brain” (p.1). The frontal lobe contains the inferior frontal gyrus, which is responsible for processing grammar, speech, and information about the sounds in words. The temporoparietal area is for “processing and storing speech sounds, where phonemes (sounds) are connected to graphemes (letters), and where words and sentences create meanings” (p.1). The occipitotemporal area is responsible for processing visual information. All of this draws on the importance of comprehension and this article's nucleus about reading comprehension using Scarborough's Reading Rope model. According to

this model, a skilled reader is one who develops automaticity by “increasing speed and accuracy in decoding and linguistic comprehension skills” (p.2).

Much like the pathways Mayer refers to, these three areas of the brains that are active during reading follow two pathways: the dorsal (activates during decoding & sounding out) and the ventral (activated when words are read without sounding it out).

Scarborough’s Reading Rope model and Mayer also emphasizes automaticity in the acquisition of learning verbal and visual information.

But, this acquisition toward automaticity is not enough for text comprehension. The learner must also have language comprehension, which requires “in-depth knowledge of morphology, semantics, syntax, background knowledge, verbal reasoning, and literacy knowledge” (p.4). For these factors to come into play, we must think also about five additional components of reading:

1. Phonemic awareness: identifying, thinking about, and manipulate phonemes;
2. Phonics: connecting phonemes and graphemes to reading and spelling;
3. Fluency: reading text accurately, with automaticity, and with expression;
4. Vocabulary: understanding and using words by speaking and writing;
5. Comprehension: understanding what’s read.

To validate the connection of student-created infographics to learning and retaining science Tier-3 vocabulary, understanding the anatomy and function of the brain, along with its theoretical and physical pathways, allows the reader and researcher to maximize the utility of student-created infographics.

CHAPTER THREE

METHODOLOGY

Demographics

Sixty-three, co-ed, 7th grade science students at an international school in South Korea will receive treatment measuring Tier-3 vocabulary student learning and retention by analyzing student-created infographics about any of the units throughout the year. Each class has an equal number of male and female students, with some students possessing a greater science background knowledge to those who hold very little.

Treatment

To measure student-created infographics Tier-3 vocabulary retention quantitatively, the following guidelines were created:

Student-created infographics will be done by hand. Technology will be used for:

- cross-checking any new information
- selecting certain graphs or data from other scientists to back-up their claim, evidence, and reasoning on their infographic
- using their electronic observation notebooks to find evidence they learned through the unit and apply it to their infographic when appropriate
- finding the appropriate vocabulary and its definition in their student vocabulary electronic notebook.

A rubric will be used to measure the level of student learning from their student-created infographics. First, [the rubric](#) will measure the quality and the delivery of information to the reader. Second, [the rubric](#) will measure the level of Tier-3 vocabulary application and indirectly measure the retention level of Tier-3 vocabulary within the student-created infographic. Both rubrics are provided in [Appendix A & B](#).

Students in my classroom have access to daily technology use. Their computers contain Google Slides that hold their observations of lab activities, student artifacts that support their learning growth, and a data diary. A data diary is a meta-cognitive collection of student artifacts on what they are learning in class and thoughts on what they learned. Collectively, this support holds Tier-3 vocabulary learning & prepares them for student-created infographics for Quarter 1.

In between the pre-and post-test, student learning were measured with two formatives, the quality of their observation notebooks, students creating CER posters that require the use of the unit's concepts and vocabulary, and Tier-3 vocabulary retention and learning will be measured on student-created infographics during Quarter 1.

This capstone will be in-treatment, where each student will be compared from the time of their Tier-3 pre-test to their post-test. In-treatment will be stronger than the original attempt of turning this capstone into an out-of-treatment, cohort study, where a different 7th grade group can be measured year-to-year to see indications of student learning and mold the teacher to adapt to each new 7th grade class.

I predicted the collective data would reveal two observations:

1. gaps in Tier-3 vocabulary application and knowledge while explaining its function in the science infographic.

2. well-expressed Tier-3 vocabulary application and knowledge while connecting its correct use in the science infographic.

Instrumentation

If the premise that Tier-3 vocabulary is part of language, and learning language through infographics is credible, then we can accredit the success of this learning is dependent on the quality of the infographic.

To measure Tier-3 vocabulary retention quantitatively in one unit, students were provided a vocabulary pre-test and post-test to measure their background knowledge of the unit's vocabulary. Students were given a pre-test survey and post-test survey with no score attached to it. The pre-test was a Google Form where students click on a dial to rate themselves on a three-point scale of 'No understanding', 'somewhat understand', 'well understood' about the Tier-3 vocabulary relevant to the unit being taught.

Student data was also collected with a 1:1 interview about the infographic they created. This would be a prime opportunity to collect meta-cognitive data on the thought process of how students were able to connect their Tier-3 vocabulary knowledge into something that is graphical and literary.

Quantitative data collection was done by codifying the infographics and an inductive analysis of students' Quarter 1 science infographics. Table One is based off Mertler's example of a coding scheme for inductive analysis (p.174).

Table 1: Inductive Analysis (Mertler, 2025, p.174)

Code	Category Used in the Analysis of Data
CL	Claim
CL Non	No claim present

Tier-3	Correct application of Tier-3 vocabulary
Tier-3 Non	Incorrect application of Tier-3 vocabulary
DataPres	Data present in infographic to connect to Tier-3 vocabulary
DataPres Non	Data is not present in infographic and connected to Tier-3 vocabulary

Research regarding applicable methodologies

For organization and readers of this capstone project, a chart with the methodologies from the authors cited in this literature review is in [Appendix C](#) under ‘Infographic Research Methodologies’.

Alwadi and Moshen’s research methods involved a “quasi-experimental two group pre-post-delayed test design” (p.4) to produce vocabulary learning and retention among college students. Quantitative data was gathered from “two dependent measures of vocabulary knowledge, two written vocabulary tests, and an oral interview” (p.4). Specifically, the authors used 30 words to measure the vocabulary learning and retention. Two written vocabulary tests measured recognition of meaning and grammar. An oral interview was used to measure how language was produced. A questionnaire was provided to collected students’ perceptions of infographics as a learning tool in EFL vocabulary. Information placed into the infographics were selected from the student’s textbooks and used Piktochart website to create them. The two vocabulary test instruments used by the authors were a pretest, immediate post-test, and a delayed post-test. All the written tests were 30 multiple-choice questions and carried the weight of one point per correct answer. The oral interview was used to probe the students on “productive knowledge of the target vocabulary” (p.5). The same 30 words used in the written

tests were given to the subjects and they have 5 answer choice statements, but the scores were not posted with the statements.

- (1) I don't remember having seen this word before... (0 points)
- (2) I have seen this word before, but I don't think I know what it means. (1 point)
- (3) I have seen this word before and I can guess its meaning. (2 points)
- (4) I know this word very well. It means... (3 points)
- (5) I can use this word easily in a number of different ways. (4 points).

Furthermore, the interview collected data on the “participants’ productive knowledge of the form-meaning connection aspect and grammatical function aspect of the target vocabulary” (p.5). Finally, a questionnaire about the treatment ranging from “the participants’ experiences in the experimental group and beliefs toward the use of infographics as a tool for EFL vocabulary learning” (p.5) was provided and was offered immediately after the immediate post-test with a scale of strongly disagree = 1 to strongly agree = 5.

The authors provided a [DOI link](#) to the supplementary materials from their study.

Tavanapour, Chalak, and Tabrizi (2022) conducted a “quantitative quasi-experimental design to examine the influence of animated infographics on vocabulary gain and retention” (p.21). After collecting 60 subjects from the original 90 through a “homogenous test for determining the homogeneity...at the intermediate level” (p.22), a 50 question, multiple-choice vocabulary-based pretest was administered, where each question was one point.

Alrwele (2017) also used similar parameters as Tavanapour et al (2022), and Alwadi & Moshen (2023) to test for student achievement and perceptions of infographics’ impact. An “achievement test” in the form of a scored, 20 multiple-choice, pre- and post-test was provided to the subjects. The test items were based on the curriculum materials. An infographic checklist

was also provided to evaluate the subjects' infographics, a guide to subjects' own work, and a means of peer evaluation.

Data Collection and Analysis Strategies

Data collection was an inductive analysis of student-created science infographics and based on a codification system, which is described in the following section. The student-created infographics were created before and after the unit's second assessment and the data was collected by looking at the infographics, while marking whether or not Tier-3 vocabulary was applied correctly. Additional student data of whether a claim was generated and data was used to support Tier-3 vocabulary was collected to provide further analysis on the action research's focus questions. Instrumentation and research design was pre-vetted to ensure the validity of my study. IRB exemption was asked, granted, and placed in [Appendix J](#).

Alwadi and Moshen (2023) rationalized the connection between “two dependent measures of vocabulary knowledge, two written vocabulary tests, and an oral interview” (p.4) were meant to triangulate “answers to the research question related to vocabulary learning and retention” and the questionnaire gathered “learner's perceptions toward infographics in EFL vocabulary learning supported and augmented the validity of the findings” (p.4). “A vast variety of static infographics” were presented to the student research subjects and allowed to interact with the material. Although the creation of the infographic is described by the authors, I would use this as a method to create a rubric for my student-created infographics for my students. The following parameters, as described by the authors, are in [Appendix B](#) under ‘Parameters of Creating an Infographic’.

Tavanapour, Chalak, and Tabrizi (2022) stated after the animated infographic treatment and control treatment was provided for, an immediate 50 question, multiple-choice vocabulary

post-test was given. To collect data about retention, a delayed post-test, with a rearrangement of the pre-test questions, was given three weeks later. For my Capstone, a comparison between student created science infographics and assessment essays were used in lieu of a control group. A control group could not be arranged because student subjects were not randomly chosen for the treatment.

Alrwele (2017) created a checklist based on observations of exemplar infographics from other studies cited by the author. Infographics were scored on a scale of 0 (features not included in the infographic), 1 (features in the infographic needed improvement), and 2 (the infographic included high-quality features). A 19-item questionnaire to gather perception of infographics was used. It entails “participants’ feelings and thoughts regarding the infographics as teaching and learning tools” (p.107). Items on the questionnaire had positive statements about infographics’ benefits based on intellectual perceptions, life skills, and affective benefits.

CHAPTER FOUR

DATA ANALYSIS

A rubric was used to measure the level of student learning from their student-created infographics. First, the rubric will measure the quality and the delivery of information to the reader. Alwadi and Moshen (2023)'s study of EFL students with L2 acquisition of English provided four phases of creating an infographic. These four phases were used to create a rubric to measure infographic quality. Second, the rubric will measure the level of Tier-3 vocabulary application and indirectly measure the retention level of Tier-3 vocabulary within the student-created infographic. Rubrics for both types of data collection are in the [Appendix A](#) & [B](#).

In between the pre- and post- survey, students will be provided formatives to test for Tier-3 vocabulary comprehension checks. Student work, other than infographics, were gathered to record qualitative data on appropriate use, connections to data, and comprehension with the current unit to explain it using Tier-3 vocabulary. Also, data was collected on student CER work to see how well they mesh the information together in preparation of creating their infographic. The CER also provides a chance to practice before producing their infographic. Ultimately, the infographic will be a summative and will be accompanied by a rubric that measures the quality of the infographic and Tier-3 vocabulary application, [Appendix A](#) and [Appendix B](#), respectively.

For the first comparison with their student-produced science infographics, students were not provided an infographic in a first set of previous summative assessment. Students were provided data tables with quantitative molecular information and photos of the compounds before and after the reaction. They were still allowed to use their paper science notebooks to assist in responding to the questions on the assessment. Quantification of the assessment results

were done by using Mertler's Inductive Analysis through coding the data and shown on [Appendix D](#).

For the second comparison with their student-produced science infographics, students were provided a curriculum-created infographic in the second set of summative assessment. Students were provided data tables with a brief description of the possible disease conditions, medical photos of the conditions, brief list of symptoms, and a brief paragraph of the causes. They were still allowed to use their paper science notebooks to assist in responding to the questions on the assessment. Quantification of these assessment results were also done by using Mertler's Inductive Analysis through coding the data and shown on [Appendix E](#).

For the final comparison, and the focus of this Capstone, students created their individual science infographics. Students were provided their paper science notebooks, electronic vocabulary notebooks, and their supplemental material provided during the unit. Rubrics were provided on the quality and type of data required for their science infographic. Quantification of these assessment results were done by using Mertler's Inductive Analysis through coding the data and shown on [Appendix F](#).

According to Alwadi and Moshen (2023), using infographics resulted in improved "L2 vocabulary learning among participants" (p.6). When the authors applied a delayed post-test for retention, students in their experimental group using infographics to learn L2 "significantly outsourced their counterparts in the control group in terms of vocabulary" (p.7). They explain that the positive results are due to infographic's ability of "visualization that helps the learners store the words in their long-term memory" (p.7).

If the premise that Tier-3 vocabulary is part of language, and learning language through infographics is credible, then we can accredit the success of this learning is dependent on the

quality of the infographic. Hence, the rubric shown in [Appendix A](#) is meant to establish that a high-quality student-created infographic can be responsible for the success of a student's ability to learn and retain Tier-3 vocabulary. From the rubrics, success was quantified by:

1. measuring for curriculum understanding and application on their infographic,
2. measuring Tier-3 application to their science infographic,
3. grading for infographic quality control.

For this action research project, the Tier-3 data will be held in higher esteem, but the two rubrics will be there to provide more dimensions in measuring the success of a student-created science infographic.

Photos of each infographic have been taken for posterity to show future students and a record of exemplar student artifacts to use in deep analysis for this action research project. In Part B, each class is placed under a group. Photos of sampled student artifacts are provided in [Appendix F](#) to correlate to the data table. An asterisk is placed next to certain students in the data tables and referenced to the photos.

For my data, the first step was to count in each infographic condition the categories of how many claims were made, Tier-3 vocabulary used, data present in student artifacts, and when the data was explained using Tier-3 vocabulary. Each condition and the overall number of "yes" and "no" responses for each category were recorded and a grand total of all yes/no observations.

Chi-Squared Test (χ^2) of independence was also performed to examine whether infographic type was associated with claim writing, Tier-3 vocabulary application, applying data to their responses, and explaining their evidence with Tier-3 vocabulary. χ^2 was applied to these dichotomous dependent variables between three or more related groups (conditions) to see if each total were about what we would expect if the infographic condition did not matter (null

hypothesis, H_0) and that it likely isn't just due to random chance and whether to provide evidence to reject the null hypothesis (H_0). The statistical analysis is placed in [Appendix G](#)

Results

After organizing and inductive analysis via a coding schema of qualitative data to gather patterns in student-created science infographics, desegregation of the data tables and graphing each codification is expressed in [Appendix F](#).

Each inductive analysis group data was organized with tallies and graphed to see if any progress was noticed between each group. The tally and graphing are seen in [Appendix H](#).

Analysis of the student-created science infographic data resulted in the following data table and observations across each condition:

Table 2: Improvements in Student Progress across Three Infographic Conditions

Metric	No infographics	Curriculum-based infographics	Student-created science infographics
Claim present	34/63 = 54.0%	42/63 = 66.7%	31/63 = 49.2%
Tier-3 correct	50/63 = 79.4%	47/63 = 74.6%	61/63 = 96.8%
Data present	21/63 = 33.3%	45/63 = 71.4%	46/63 = 73.0%
Evidence explained	23/63 = 36.5%	38/63 = 60.3%	46/63 = 73.0%

From 'No infographics' to 'Curriculum-based infographics':

- Claim present increased by 12.7 percentage points.
- Tier-3 correctly used decreased by 4.8 percentage points.
- Data present in students' explanations and reasoning increased by 38.1 percentage points.
- Evidence explained in students' work increased by 23.8 percentage points.

From Curriculum-based infographics to Student-created science infographics:

- Claim present decreased by 17.5 percentage points.
- Tier-3 correct correctly used increased by 22.2 percentage points.
- Data present in students' explanations and reasoning increased by 1.6 percentage points.
- Evidence explained in students' work increased by 12.7 percentage points.

The strongest improvement is Tier-3 vocabulary's correctly used in the student-created science infographic condition, which rose to 96.8%, compared with 79.4% in the no-infographics condition and 74.6% in the curriculum-based condition.

For the "claim present," the student-created condition is lower than the curriculum-based condition, so that result does not show improvements there. Students improved most in Tier-3 vocabulary use, using data with their Tier-3 vocabulary and evidence explanation, but claim-writing was strongest in the curriculum-based infographic condition.

χ^2 values showed when students synthesized their own science infographics, there is a high correlation between it and using Tier-3 vocabulary in their data and when explaining their evidence. Correlation was borderline / not clearly significant between students' use of the claim and use of infographics in all conditions.

CHAPTER FIVE

CLAIMS, EVIDENCE, AND REASONING

Claims From the Study

Considering my action research questions were directed toward gathering data about how much Tier-3 vocabulary retention occurred, Tier-3 vocabulary knowledge to connect to observations from class data, and how accurately Tier-3 vocabulary was used to explain class concepts, the following claims are:

If students synthesize their own science infographic as an assessment, then their retention and appropriate application of Tier-3 vocabulary increases to 50% when compared to using a curriculum-based infographic and 98% or more when compared to students not presented with an infographic during an assessment.

If students are allowed to reference their collected data from the unit's lessons and apply their learned data literacy skills, then the comparative numbers above are supported and student-created science (SCS) infographics are an essential assessment tool to measure progress in Tier-3 vocabulary retention and application in interpreting their data to create a coherent science infographic. The data showed that successful SCS infographics had a high correlation to Tier-3 vocabulary and appropriate data with Tier-3 vocabulary being used correctly.

Impact of Action Research on the Author

The findings from this data will be shared with administration. The data will be presented as a conversation will be meant to show transparency in my classroom, but to show artifacts that my students are actively learning in my classroom. I also have a feeling when

school leadership sees that 96.8% of students used Tier-3 vocabulary correctly and 73.0% of students used their data with Tier-3 vocabulary correctly and with their evidence, seeing the positive student work leadership can understand, while providing solace that SCS infographics are based in research, it provides encouragement and comfort to them that I am providing a positive learning environment. Further dissemination of this information can be done in workshops and opportunities during a school district's internal professional development workshops or worldwide professional educator workshops. I plan on presenting my action research and the data I gained from Tier-3 vocabulary learning and retention from SCS infographics within the US and worldwide.

During my doctorate, I plan to continue my research on perfecting the student-created science infographic, create a research-based list of standards that reaches across all curriculum standards and models (ex: NGSS, IB, PBL), and publish a comprehensive teacher-friendly target guide on what a high-quality student-created science infographic must look like (ideally at the low-tech end). Currently, with my research, the only expense to the student is access to technology to obtain extra information or fact-check any new data they have not obtained before starting their infographic. Student-created science infographics requires coloring pencils, markers, and wall-sized Post-It notes to produce student artifacts that provide insight into Tier-3 vocabulary learning and retention. These are materials that can be found in any school, so application of this action research at any school setting will not be an issue. The data provides evidence that SCS infographics are an essential assessment tool for the science classroom and further investigation into its universal application would be acceptable.

Value of the Study and Consideration for Future Research

The research cited so far stated that some measure of showing infographics to subjects occurred, but the details of what a good infographic was never explained in-depth. Despite the positive results from the works cited in this literature review, the missing elements are standards in what is considered an acceptable infographic to maximize the information given to the reader, while showing the reader how knowledgeable the infographic creator is. As Dunlap and Lowenthal (2016) put it in their paper, to “investigate popular infographics to learn more about what makes an infographic ‘good’” (p.43).

In Dunlap and Lowenthal’s findings, they based their standards on a quality infographic on three powers of visual literacy: (1) power of vision, (2) power of visuals, and the (3) power of infographics.

The power of vision is based on the premise that human brains are based on, or “evolutionarily wired to” understand images (p.43). This is the power of what visual learners identify as; seeing something to understand it, remember it, and that our brain interprets it.

The power of visuals is to “help improve memory and recall”. According to the authors, “the more visual an instructional or informational message is, the more likely it is to be recognized and recalled” (p.44). This is particularly important when the information is abstract and complicated, along with unfamiliar concepts. A mental model is relayed to the reader, while a mental model is shaped and molded within the creator.

The power of infographics resides in its ability to convey “information and supporting conceptual understanding because people see with their brains” (as cited in Oetting, 2015 and Smiciklas, 2012). Dunlap and Lowenthal also defer to Nelson’s picture superiority theory (human brains are hard-wired for visuals rather than words alone), Pavio’s dual coding theory

(when people view an image, they encode the information with verbal and image code, activate multiple neural pathways to support memory). These two theories, especially the dual coding theory, ties well into Mayer's CTML model of the two pathways (visual and verbal) of processing information into long-term memory.

Since there isn't an established and/or validated instrument to measure a good infographic, the authors based their guidelines on Parrish, Wilson, and Dunlap's aesthetic learning experience framework. Aesthetic learning experience has a blend of Vygotsky's scaffolding into it, where learners are placed in a learning experience that is just beyond the learner's ability to what is achieved by them as easily achievable) and knowing what the final product is. The guideline parameters are listed below:

- **Immediacy:** Infographic designer needs to involve learners directly and instantly with the content and create a sense of urgency or excitement. Clear examples and visual representations of complex ideas are required.
- **Malleability:** Learners need personal meaning and relevance to the infographic's information, as if they were the co-creators of the infographic. Therefore, the infographic "needs enough pliability so learners can influence their own experience of the infographic" (p.47). Also, the infographic should allow the learner to look and learn about the topic in more than one way.
- **Level of being Compelling:** The infographic should make learning from it irresistible by bringing "learners' interest, attention, and admiration" (p.47). The sequence and order within the infographic structure should propel "the learner through the content via a succession of related ideas" (p.48). The need to know what's next must exist.

- Resonance: The ability to kindle “images, emotion, and memories” from the learner or viewer (p.48). Connecting with the learner or reader helps establish storytelling by learning.
- Coherence: There must be “logic, clarity, and consistency” (p.48). A complete message carries information the learner or reader understands and can tell others the infographic’s information.

Gottlieb, Ibrahim, Martin, Yilmaz, and Chan (2022) propose 10 tips to create a high quality electronic infographic for educators. Although the action research I’ll be focusing on is infographics created on paper, these same tips can be applied to student-created infographics to maximize their Tier-3 vocabulary learning and retention.

- Select appropriate content: Infographics serve to take large pieces of information and turn it into bite-size chunks. Choosing the appropriate content and displaying it so others can quickly learn it. On the other hand, highly complex information is not ideal to create infographics from. Infographics “should focus on one to three main points and be presented in a single page” (p.2).
- Define the target audience: Have the end in mind and have the reader in mind. Keeping in mind who the audience is will drive the focus and vocabulary / language will connect to the audience. The reader may want specific design expectations, certain types of data, and the organization of the data.

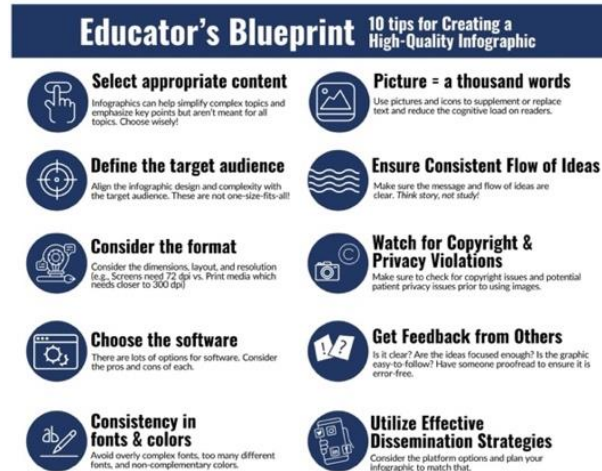


Fig 2: Gottlieb et al's (2022) 10 tips for creating a high-quality infographic educator's blueprint.

- Consider the format: Use dimension, layout, and resolution in the infographic. Learners reading the infographic have a cognitive load to learn the information. The authors propose 16:9 or 4:3 ratios, which are dimensions of televisions, computer monitors, or cell phones in landscape view. The layout should be logical with a clear flow without having “to pause and restart in a new location” (p.2). The resolution would be at 600DPI so the words and figures does not crumble when downloaded or viewed on a reader.
- Select the software: The authors suggest Microsoft, PowerPoint, or Piktochart, but selecting boundaries within the software to not overdesign with the software is important.
- Use consistent font and color schemes: Minimize the number of different fonts and the authors suggest “to prioritize sans serif fonts over serif fonts” (p.3).
- A picture is worth a thousand words: Use the smallest amount of text to highlight key points and graphics over text. The authors bring up cognitive load theory's that the working memory has a limit, much like Mayer's CTML model of limits within certain sections of learning in the mind. Dual-coding theory is also raised by the authors to

explain that pictures and graphics are “encoded as both verbal and visual traces in long-term memory” as opposed to text-only (p.3).

- Ensure consistent flow of ideas: Infographics should contain “a single key message or a select number of takeaways (maximum of three)” (p.4). The authors suggest writing ideas on sticky notes to organize the ideas and create the “story”, sort the sticky notes in a flow of ideas from one to another to reduce the cognitive load. Removing certain ideas is encouraged. Breaking long ideas from the sticky notes into smaller pieces by drawing boundaries, within shapes, or effectively using white space. Humor and metaphors go a long way when used appropriately for the reader in mind.
- Avoid copyright and privacy issues: Creative Commons (CC) is a license that indicates the image is free to use, but within the criteria of the CC license. If photos of actual people are used, then privacy is a must. Obtaining permission and blurring identifying markers is also required.
- Get feedback from others: Peer-reviewing an infographic creation is highly encouraged. A review of concepts, certain visuals that could be useful to portray the information in a cleaner way, or important sources of missing information will help put the ‘info’ in infographics.
- Utilize effective dissemination strategies: Publishing the infographic for public consumption is one of the goals. Social media or a newsletter to maximize the spread of what you want to inform is important.

Eladi, Ş., & Taner, Ç (2021) explain the validity of using infographics in education by stating it holds “an important place in education due to their illustration of the complex information in a compact form” (p.94). In education, infographics interpret the topic through

a story that carries an “introduction, key content, and conclusion sections” (p.94). They also are used to communicate information in various media, starting from paper-pencil and electronic media, to reach learners in different ways.

Bloom’s taxonomy also has inclusion in infographics due to its support of “visual learning skills” because of selecting an education approach that includes visualization of information. Students are intertwined in technology, thus using infographics in education to relay important information in the style of comprehensive information shows that it has a strong function.

On the other hand, Eladi and Taner also indicate caution with the use of infographics in education because it can still have challenges and difficulties for teacher and students in “transferring information in a comprehensible and attractive manner” (p.94). The authors explain that students can have a difficult time transferring large amounts of data into “a purposeful, visual representation” (p.95). There can be conflict in combining too much information and represent it visually without creating misinformation and confusion. Then, there are the time constraints if student-created infographics are given as homework or creating infographics in a certain amount of class time. The authors suggest that a certain amount of productive allotted time or indicating that a certain set of skills are required to be activated to create them. Finally, to maximize the effort of student-created infographics and much like the advice of Gottlieb et al’s (2022) 10 tips of educational infographics, along with Dunlap and Lowenthal (2016), the main function of an infographic for education is to be able to “transfer comprehensible information accurately, but also to transfer it in an attractive way” (p.95). Also, to match the spirit of student-created infographics and Tier-3 vocabulary, combining data with

design is important for the “comprehensibility and attractiveness of infographics” (as cited in Smiciklas, 2012).

In conclusion, recalling from the focused or refined action research questions showed me data that SCS infographics provided an assessment environment for students to correctly use their Tier-3 vocabulary, retain their vocabulary and use it correctly with observations from their class data, and explain science concepts learned from the unit they are learning from, student-created science (SCS) infographics are an essential summative assessment tool for a science classroom.

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APPENDICES

APPENDIX A: QUALITY OF STUDENT-CREATED RUBRIC

Table 3: Adapted from Alwadi and Moshen (2023) four phases of infographic creation

Category	1	2	3	4	Score
Clarity & Planning and Studying	Message is not present or very unclear.	Message is unclear or incomplete or not connected to the main idea of the infographic.	The message is present, but two to three times the message is difficult to understand.	The message of the infographic is clear. It is effective in informing or persuading the audience.	
Logic & Sketching out ideas	Information is disorganized and distracts from the message.	Information is structured in a way that distracts from the message.	Information has a logical flow at time, but it could improve with more clarity and use of Tier-3 vocabulary.	Information is presented in a logical flow that helps the audience understand the significance of the data presented.	
Graphics & Designing	Graphics are not relevant and detract from the message. Graphics are not visually pleasing.	Some graphics are relevant, but others are not, or do not help deliver the message.	Graphics are mostly relevant and help deliver the message. Graphics do not distract from the message.	Graphics are relevant and contribute to the delivery of the message. Graphics are visually pleasing. Data is clear and connects to Tier-3 vocabulary.	
Grammar & Mechanics	Infographic has more than 5 grammatical errors.	Infographic has 3-5 grammatical errors.	Infographic has 1-2 grammatical errors.	Infographic is free of grammatical errors.	
Production & Presentation	Speaker is disorganized and unprepared.	Speaker does not know material well and reads from the page.	Effective speaker with clear communication to the audience.	Product is cleanly written and legible. Confident speaker who knows material and speaks to the audience.	
Total grade				/20	

APPENDIX B: APPLICATION OF TIER-3 VOCABULARY TO INFOGRAPHIC RUBRIC

Table 4: Application of Tier-3 Vocabulary Infographic Rubric

Category	1	2	3	4	Score
Appropriate application of Tier-3 vocabulary	Application of Tier-3 vocabulary is not present	Application of Tier-3 vocabulary is in one or two places	Application of Tier-4 vocabulary is in the claim, evidence, and reasoning. Starting to connect it to data	Application of Tier-3 vocabulary is well-connected to all data and evidence present	
Connection of Tier-3 vocabulary to other vocabulary	Connection of Tier-3 vocabulary and other vocabulary is not present	Connection of Tier-3 vocabulary and other vocabulary is somewhat present and unclear	Connection of Tier-3 vocabulary and other vocabulary is clearly present but requires more clarity	Clear connection of Tier-3 vocabulary and other vocabulary	
Connection for Tier-3 Vocabulary toward data and observations	Connection is not present	Only a few connections are present and/or unclear	Connections are present, but requires a little more clarity on the connections of Tier-3 vocabulary, data, and observations	Connections are clearly present	
Spelling of Tier-3 vocabulary	Vocabulary has more than 5 spelling errors.	Vocabulary has 3-5 spelling errors.	Vocabulary has 1-2 spelling errors.	Vocabulary is free of spelling errors.	
Sentence structure in application of Tier-3 vocabulary	Sentence structure is disorganized not well-written, and evidence of no connections to Tier-3 vocabulary.	Sentence structure has a mix of organized and non-organized thought. Tier-3 vocabulary is barely present.	Sentence structure has errors that needs further correcting and requires fixable help. Tier-3 is used appropriately, but at times, is used erroneously.	Sentence structure has no error marks and can be understood when read. Tier-3 is used correctly with no mistakes and connects to data and/or science observations.	
Total grade				/20	

APPENDIX C

INFOGRAPHIC RESEARCH METHODOLOGIES

Table 5: Infographic Research Methodologies

Referenced author	Demographics of applied methodology	Infographic parameter measured	Length of applied methodology	Rationale of methodology
Alwadi and Moshen	40 female, undergraduate, third year university students in their 1 st semester of English language classes.	Two groups: One control group of 20 measured with “traditional classroom methodology” (p.5). One experimental group of 20 measured with infographics. Infographics were used as study materials to present new vocabulary to the experimental group.	10 weeks	“Investigate the effects of infographics on EFL vocabulary learning and retention among learners at the college level” (p.4).
Tavanapour, Chalak, & Tabrizi	Ninety 18-22 year-old, male and female EFL students from Abadan Medical University, Iran. 60 students were selected from the 90 who scored a std. dev. Above and below the average. Participants were randomly and evenly divided into experimental, animated infographic and control groups.	An animated, slideshow, infographic was created using Storyline software (a PowerPoint type software). Templates are included in the software and cartoon characters.	13 sessions, where one session is 60 minutes.	“Does an animated infographic significantly affect the vocabulary gain and retention of Iranian intermediate EFL students” (p.21)?
Alrwele	165 21 to 23-year old undergraduate female students enrolled in an English language program at Imam Muhammed Ibn Saud Islamic University preparing to become EFL teachers through a course called EDU 306: Principles of Curriculum.	Subjects were informed to bring their smart devices. Subjects also used Piktochart to create their infographics. Subjects wrote a preliminary paper that “sketched out the visual data presentation” (p.108) Subjects worked in teams of two or three.	9 sessions, where each session was 2 hours.	“1. Does the use of infographics result in significant differences ($\alpha \leq 0.05$) in students’ academic achievement versus curriculum without infographics? 2. What are the perceptions of the participants regarding the impact of infographics?” (p.106)

APPENDIX D: ESSAY ASSESSMENT INDUCTIVE ANALYSIS

Code	Category Used in the Analysis of Data
CL	Claim
CL Non	No claim present
Tier-3	Correct application of Tier-3 vocabulary
Tier-3 Non	Incorrect application of Tier-3 vocabulary
DataPres	Data present in infographic to connect to Tier-3 vocabulary
DataPres Non	Data is not present in infographic and connected to Tier-3 vocabulary
EvidExpl	Data is explained and connects to Tier-3 vocabulary
EvidExpl Non	Data is not explained and not connected to Tier-3 vocabulary

Table 6: Essay assessment inductive analysis contingency count

Group 1 Essay assessment inductive analysis count ('0' = not present; '1' = present)

Code	Category Used in the Analysis of Data	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6*	Student 7*	Student 8	Student 9
CL / CL Non	Claim / No claim present	0	0	1	1	1	1	1	1	1
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	0	0	1	1	1	1	1	0	1
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	0	0	1	0	1	1	1	1	0
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	0	0	1	0	1	1	1	1	0
Code	Category Used in the Analysis of Data	Student 10	Student 11	Student 12*	Student 13*	Student 14	Student 15			
CL / CL Non	Claim / No claim present	1	0	1	1	0	0			
Tier-3 / Tier-3 Non	Correct application of Tier-3 Vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	1	0			
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 Vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	1	0	0	0	0	0			
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 Vocabulary / Data is not explained and not connected to Tier-3 vocabulary	1	0	0	0	0	0			

Group 2 Essay assessment inductive analysis count ('0' = not present; '1' = present)

Code	Category Used in the Analysis of Data	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6	Student 7*	Student 8*	Student 9
CL / CL Non	Claim / No claim present	1	0	1	0	1	0	0	1	1
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	1	1	0	0	1
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	1	0	0	0	0	0	0	0	0
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	1	0	0	0	0	0	0	0	0
Code	Category Used in the Analysis of Data	Student 10	Student 11	Student 12*	Student 13*	Student 14	Student 15	Student 16	Student 17	
CL / CL Non	Claim / No claim present	1	0	1	0	1	1	1	0	
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	1	1	1	1	
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	1	1	1	0	0	0	0	1	
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	1	1	1	0	0	0	0	1	

Group 3 Essay assessment inductive analysis count ('0' = not present; '1' = present)

Code	Category Used in the Analysis of Data	Student 1	Student 2*	Student 3*	Student 4	Student 5	Student 6	Student 7	Student 8	Student 9
CL / CL Non	Claim / No claim present	0	0	1	1	1	1	0	0	1
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	1	1	1	1	1
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary /	0	0	0	0	1	1	0	0	1

	Data not present in infographic and not connected to Tier-3 vocabulary									
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	0	0	0	0	1	1	0	0	1
Code	Category Used in the Analysis of Data	Student 10	Student 11	Student 12	Student 13*	Student 14*	Student 15			
CL / CL Non	Claim / No claim present	0	0	0	0	0	0			
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	0	1	0	1	0	1			
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	0	0	0	0	0	1			
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	0	0	0	0	0	1			

Group 4 Essay assessment inductive analysis count ('0' = not present; '1' = present)

Code	Category Used in the Analysis of Data	Student 1*	Student 2*	Student 3	Student 4	Student 5	Student 6	Student 7	Student 8	Student 9
CL / CL Non	Claim / No claim present	0	1	1	0	0	1	1	0	1
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	0	1	1	0	0	1
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	0	0	0	0	0	0	0	0	1
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	0	0	0	0	0	0	0	0	1
Code	Category Used in the Analysis of Data	Student 10	Student 11	Student 12	Student 13	Student 14	Student 15*	Student 16*		
CL / CL Non	Claim / No claim present	1	1	1	0	1	0	0		
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary /	1	1	1	0	1	1	1		

	Incorrect application of Tier-3 vocabulary							
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	1	1	1	0	1	1	0
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	1	1	1	0	1	1	0

APPENDIX E: CURRICULUM-PROVIDED INFOGRAPHIC INDUCTIVE ANALYSIS BY
GROUPS

Code	Category Used in the Analysis of Data
CL	Claim
CL Non	No claim present
Tier-3	Correct application of Tier-3 vocabulary
Tier-3 Non	Incorrect application of Tier-3 vocabulary
DataPres	Data present in infographic to connect to Tier-3 vocabulary
DataPres Non	Data is not present in infographic and connected to Tier-3 vocabulary
EvidExpl	Data is explained and connects to Tier-3 vocabulary
EvidExpl Non	Data is not explained and not connected to Tier-3 vocabulary

Table 7: Curriculum-provided inductive analysis contingency count

Group 1 Curriculum-provided Infographic Inductive Analysis ('0' = not present; '1' = present)

Code	Category Used in the Analysis of Data	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6*	Student 7*	Student 8	Student 9
CL / CL Non	Claim / No claim present	1	1	1	1	1	1	0	0	0
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	0	1	1	1	1	0	0	0
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	1	0	1	0	1	0	0	0	0
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	1	0	1	0	1	0	0	0	0
Code	Category Used in the Analysis of Data	Student 10	Student 11	Student 12*	Student 13*	Student 14	Student 15			
CL / CL Non	Claim / No claim present	1	0	1	1	0	0			
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	0	1	1	1	1	0			
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not	0	0	0	1	1	1			

	connected to Tier-3 vocabulary						
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	0	0	0	1	1	1

Group 2 Curriculum-provided Infographic Inductive Analysis ('0' = not present; '1' = present)

Code	Category Used in the Analysis of Data	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6	Student 7*	Student 8*	Student 9
CL / CL Non	Claim / No claim present	0	1	1	0	0	1	0	1	1
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	0	1	1	1	1	1	0	1	1
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	0	0	0	1	1	1	1	1	0
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	0	0	0	1	1	1	1	1	0
Code	Category Used in the Analysis of Data	Student 10	Student 11	Student 12*	Student 13*	Student 14	Student 15	Student 16	Student 17	
CL / CL Non	Claim / No claim present	0	0	1	1	1	1	1	1	
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	1	0	1	1	
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	1	1	1	1	1	0	1	1	
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	1	1	1	1	1	0	1	1	

Group 3 Curriculum-provided Infographic Inductive Analysis ('0' = not present; '1' = present)

Code	Category Used in the Analysis of Data	Student 1	Student 2*	Student 3*	Student 4	Student 5	Student 6	Student 7	Student 8	Student 9
CL	Claim	0	1	1	1	1	1	0	0	0
Tier-3	Correct application of Tier-3 vocabulary	1	1	1	0	1	1	0	1	1

DataPres	Data present in infographic to connect to Tier-3 vocabulary	1	1	1	1	1	1	1	1	1
EvidExpl	Data is explained and connects to Tier-3 vocabulary	0	1	1	0	1	1	0	1	0
Code	Category Used in the Analysis of Data	Student 10	Student 11	Student 12	Student 13*	Student 14*	Student 15			
CL / CL Non	Claim / No claim present	0	1	1	0	0	1			
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	0	1	1	1	0	1			
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	1	1	1	1	1	1			
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	0	1	1	0	1	1			

Group 4 Curriculum-provided Infographic Inductive Analysis ('0' = not present; '1' = present)

Code	Category Used in the Analysis of Data	Student 1*	Student 2*	Student 3	Student 4	Student 5	Student 6	Student 7	Student 8	Student 9
CL / CL Non	Claim / No claim present	1	1	1	1	0	1	1	0	1
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	1	1	0	0	1
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	1	1	1	1	1	0	0	0	1
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	1	1	1	1	1	0	0	0	1
Code	Category Used in the Analysis of Data	Student 10	Student 11	Student 12	Student 13	Student 14	Student 15*	Student 16*		
CL / CL Non	Claim / No claim present	1	1	1	1	1	0	1		
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	0	1	1	1		

DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	1	1	1	1	1	0	1
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	0	1	1	1	1	0	1

APPENDIX F: STUDENT-CREATED SCIENCE (SCS) INFOGRAPHIC INDUCTIVE
ANALYSIS BY GROUPS

Code	Category Used in the Analysis of Data
CL	Claim
CL Non	No claim present
Tier-3	Correct application of Tier-3 vocabulary
Tier-3 Non	Incorrect application of Tier-3 vocabulary
DataPres	Data present in infographic to connect to Tier-3 vocabulary
DataPres Non	Data is not present in infographic and connected to Tier-3 vocabulary
EvidExpl	Data is explained and connects to Tier-3 vocabulary
EvidExpl Non	Data is not explained and not connected to Tier-3 vocabulary

Table 8: Student-created Science (SCS) infographic inductive analysis contingency count

Group 1 SCS infographic inductive analysis count ('0' = not present; '1' = present)

Code	Category Used in the Analysis of Data	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6*	Student 7*	Student 8	Student 9
CL / CL Non	Claim / No claim present	0	0	1	0	1	1	1	1	1
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	0	1	1	0	1
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	0	0	1	0	1	1	1	0	1
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	0	0	1	0	1	1	1	0	1
Code	Category Used in the Analysis of Data	Student 10	Student 11	Student 12*	Student 13*	Student 14	Student 15			
CL / CL Non	Claim / No claim present	1	0	1	1	1	0			
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	1	0			
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not	1	1	1	1	0	0			

	connected to Tier-3 vocabulary						
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	1	1	1	1	0	0

Group 2 SCS infographic inductive analysis count ('0' = not present; '1' = present)

Code	Category Used in the Analysis of Data	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6	Student 7*	Student 8*	Student 9
CL / CL Non	Claim / No claim present	0	1	1	1	0	0	0	1	1
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	1	1	1	1	1
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	1	1	0	1	1	1	1	1	0
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	1	1	0	1	1	1	1	1	0
Code	Category Used in the Analysis of Data	Student 10	Student 11	Student 12*	Student 13*	Student 14	Student 15	Student 16	Student 17	
CL / CL Non	Claim / No claim present	0	0	1	1	0	0	0	0	
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	1	1	1	1	
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	1	1	1	1	1	0	1	1	
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	1	1	1	1	1	0	1	1	

Group 3 SCS infographic inductive analysis count ('0' = not present; '1' = present)

Code	Category Used in the Analysis of Data	Student 1	Student 2*	Student 3*	Student 4	Student 5	Student 6	Student 7	Student 8	Student 9
CL / CL Non	Claim / No claim present	0	0	1	1	0	0	0	1	1
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	1	1	1	1	1
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	0	1	1	1	1	1	1	1	1
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	0	1	1	1	1	1	1	1	1
Code	Category Used in the Analysis of Data	Student 10	Student 11	Student 12	Student 13*	Student 14*	Student 15			
CL / CL Non	Claim / No claim present	1	0	0	0	0	0			
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	1	1			
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	1	1	1	0	1	1			
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	1	1	1	0	1	1			

Group 4 SCS infographic inductive analysis count ('0' = not present; '1' = present)

Code	Category Used in the Analysis of Data	Student 1*	Student 2*	Student 3	Student 4	Student 5	Student 6	Student 7	Student 8	Student 9
CL / CL Non	Claim / No claim present	0	1	1	0	0	1	1	1	1
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	1	1	1	1	1
DataPres /	Data present in infographic and connected to Tier-3 vocabulary	1	1	0	1	0	1	0	0	1

DataPres Non	/									
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	1	1	0	1	0	1	0	0	1
Code	Category Used in the Analysis of Data	Student 10	Student 11	Student 12	Student 13	Student 14	Student 15*	Student 16*		
CL / CL Non	Claim / No claim present	1	1	1	0	0	0	0		
Tier-3 / Tier-3 Non	Correct application of Tier-3 vocabulary / Incorrect application of Tier-3 vocabulary	1	1	1	1	1	1	1		
DataPres / DataPres Non	Data present in infographic and connected to Tier-3 vocabulary / Data not present in infographic and not connected to Tier-3 vocabulary	1	0	1	0	1	1	1		
EvidExpl / Evid Expl Non	Data is explained and connects to Tier-3 vocabulary / Data is not explained and not connected to Tier-3 vocabulary	1	0	1	0	1	1	1		

APPENDIX G: CHI-SQUARED TEST OF INDEPENDENCE

Step 1: Create a full paired data matrix for each where each row is one student and each column is one condition or metric, where 0 = the metric is absent & 1 = the metric is present.

Table 9: Chi-Squared (χ^2) data matrices

<u>No Claim metric / Claim</u>							
Student	No infographic	Curriculum infographic	Student-created infographic	Student	No infographic	Curriculum infographic	Student-created infographic
1	0	1	0	47	0	1	0
2	0	1	1	48	0	1	0
3	1	1	0	49	1	1	1
4	1	1	0	50	1	1	1
5	1	1	1	51	0	1	0
6	1	1	1	52	0	0	0
7	1	0	1	53	1	1	1
8	1	0	1	54	1	1	1
9	1	0	1	55	0	0	1
10	1	1	0	56	1	1	1
11	0	0	1	57	1	1	1
12	1	1	1	58	1	1	1
13	1	1	1	59	1	1	1
14	0	0	1	60	0	1	0
15	0	0	0	61	1	1	0
16	1	0	0	62	0	0	0
17	0	1	1	63	0	1	1
18	1	1	1				
19	0	0	1				
20	1	0	0				
21	0	1	0				
22	0	0	0				
23	1	1	0				
24	1	1	0				
25	1	0	0				
26	0	0	0				
27	1	1	1				
28	0	1	1				
29	1	1	0				
30	1	1	0				
31	1	1	0				
32	0	1	0				
33	0	0	0				
34	0	1	0				
35	1	1	1				
36	1	1	1				
37	1	1	0				
38	1	1	0				
39	0	0	0				
40	0	0	1				
41	1	0	1				
42	0	0	1				
43	0	1	0				
44	0	1	0				
45	0	0	0				
46	0	0	0				

No Tier-3 Vocabulary Application / Tier-3 Vocabulary Application

Student	No infographic	Curriculum infographic	Student-created infographic	Student	No infographic	Curriculum infographic	Student-created infographic
1	0	1	1	47	0	1	1
2	0	0	1	48	0	1	1
3	1	1	1	49	1	1	1
4	1	1	1	50	1	1	1
5	1	1	0	51	0	1	1
6	1	1	1	52	0	1	1
7	1	0	1	53	1	1	1
8	1	0	0	54	1	0	1
9	1	0	1	55	0	0	1
10	1	0	1	56	1	1	1
11	0	1	1	57	1	1	1
12	1	1	1	58	1	1	1
13	1	1	1	59	1	1	1
14	0	1	1	60	0	0	1
15	0	0	0	61	1	1	1
16	1	0	1	62	0	1	1
17	0	1	1	63	0	1	1
18	1	1	1				
19	0	1	1				
20	1	1	1				
21	0	1	1				
22	0	0	1				
23	1	1	1				
24	1	1	1				
25	1	1	1				
26	0	1	1				
27	1	1	1				
28	0	1	1				
29	1	1	1				
30	1	0	1				
31	1	1	1				
32	0	1	1				
33	0	1	1				
34	0	1	1				
35	1	1	1				
36	1	0	1				
37	1	1	1				
38	1	1	1				
39	0	0	1				
40	0	1	1				
41	1	1	1				
42	0	0	1				
43	0	1	1				
44	0	1	1				
45	0	1	1				
46	0	0	1				

No Data connected to Tier-3 Vocabulary / Data connected to Tier-3 Vocabulary

Student	No infographic	Curriculum infographic	Student-created infographic	Student	No infographic	Curriculum infographic	Student-created infographic
1	0	1	0	47	1	1	1
2	0	0	0	48	0	1	1
3	1	1	1	49	0	1	1
4	0	0	0	50	0	1	0
5	1	1	1	51	0	1	1
6	1	0	1	52	0	1	0
7	1	0	1	53	0	0	1
8	1	0	0	54	0	0	0
9	0	0	1	55	0	0	0
10	1	0	1	56	1	1	1
11	0	0	1	57	1	1	1
12	0	0	1	58	1	1	0
13	0	1	1	59	1	1	1
14	0	1	0	60	0	1	0
15	0	1	0	61	1	1	1
16	1	0	1	62	1	0	1
17	0	0	1	63	0	1	1
18	0	0	0				
19	0	1	1				
20	0	1	1				
21	0	1	1				
22	0	1	1				
23	0	1	1				
24	0	0	0				
25	1	1	1				
26	1	1	1				
27	1	1	1				
28	0	1	1				
29	0	1	1				
30	0	0	0				
31	0	1	1				
32	1	1	1				
33	0	0	0				
34	0	1	1				
35	0	1	1				
36	0	1	1				
37	1	1	1				
38	1	1	1				
39	0	1	1				
40	0	1	1				
41	1	1	1				
42	0	1	1				
43	0	1	1				
44	0	1	1				
45	0	1	0				
46	0	1	1				

No Evidence explained & connected to Tier-3 / Evidence explained & connected to Tier-3 Vocabulary

Student	No infographic	Curriculum infographic	Student-created infographic	Student	No infographic	Curriculum infographic	Student-created infographic
1	0	1	0	47	1	1	1
2	0	0	0	48	0	1	1
3	1	1	1	49	0	1	1
4	0	0	0	50	0	1	0
5	1	1	1	51	0	1	1
6	1	0	1	52	0	1	0
7	1	0	1	53	0	0	1
8	1	0	0	54	0	0	0
9	0	0	1	55	0	0	0
10	1	0	1	56	1	1	1
11	0	0	1	57	1	0	1
12	0	0	1	58	1	1	0
13	0	1	1	59	1	1	1
14	0	1	0	60	0	1	0
15	0	1	0	61	1	1	1
16	1	0	1	62	1	0	1
17	0	0	1	63	0	1	1
18	0	0	0				
19	0	1	1				
20	0	1	1				
21	0	1	1				
22	0	1	1				
23	0	1	1				
24	0	0	0				
25	1	1	1				
26	1	1	1				
27	1	1	1				
28	0	1	1				
29	0	1	1				
30	0	0	0				
31	0	1	1				
32	1	1	1				
33	0	0	0				
34	0	1	1				
35	0	1	1				
36	0	0	1				
37	1	1	1				
38	1	1	1				
39	0	0	1				
40	0	1	1				
41	1	0	1				
42	0	0	1				
43	0	1	1				
44	0	1	1				
45	0	0	0				
46	0	1	1				

Step 2: Create a total count contingency table for each condition: no infographic, curriculum-based infographic, and student-created science (SCS) infographic.

Table 10: Chi-Squared Total Count Contingency

Condition	Claim Yes	Claim No	Total
No infographic	34	29	63
Curriculum infographic	42	21	63
SCS infographic	31	32	63
Total	107	82	189

Condition	Tier-3 vocabulary Yes	Tier-3 vocabulary No	Total
No infographic	50	13	63
Curriculum infographic	47	16	63
SCS infographic	61	2	63
Total	158	31	189

Condition	Data Presented with Tier-3 vocabulary Yes	Data Present with Tier-3 vocabulary No	Total
No infographic	21	42	63
Curriculum infographic	45	18	63
SCS infographic	46	17	63
Total	112	77	189

Condition	Evidence explained with Tier-3 vocabulary Yes	Evidence explained with Tier-3 vocabulary No	Total
No infographic	23	40	63
Curriculum infographic	38	25	63
SCS infographic	46	17	63
Total	107	82	189

Step 3: Reference the Chi-Squared formula to calculate the variables.

$$X^2 = \sum [(O - E)^2 / E]$$

Where:

- O = observed counts;
- E = expected counts.

Step 4: Calculate the expected counts (E), where r = rows, c = columns, N = sample size

$$E = [(r \text{ total})(c \text{ total})] / N$$

Example: “SCS infographic for Tier-3 vocabulary Yes”

$$E = [(63)(158)] / 189 = 52.7$$

Table 11: Expected values from rows and columns of contingency

Condition	Claim Yes E	Claim No E	Tier-3 vocabulary Yes	Tier-3 vocabulary No	Data with Tier-3 vocab Yes	Data with Tier-3 vocab No	Evidence explained Yes	Evidence explained No
No infographic	35.7	27.3	52.7	10.3	37.3	25.7	35.7	27.3
Curriculum-based infographic	35.7	27.3	52.7	10.3	37.3	25.7	35.7	27.3
SCS infographic	35.7	27.3	52.7	10.3	37.3	25.7	35.7	27.3

Step 5: Compute the Chi-Square

Condition	For ‘Claim’	For ‘Tier-3 vocabulary’	For ‘Data’	For ‘Evidence’
No infographic	$[(34 - 35.7)^2] / 35.7 = 0.081$ $[(29 - 27.3)^2] / 27.3 = 0.11$	$[(50 - 52.7)^2] / 52.7 = 0.14$ $[(13 - 10.3)^2] / 10.3 = 0.71$	$[(21 - 37.3)^2] / 37.3 = 7.12$ $[(42 - 25.7)^2] / 25.7 = 10.3$	$[(23 - 35.7)^2] / 35.7 = 4.52$ $[(40 - 27.3)^2] / 27.3 = 5.91$
Curriculum-based infographic	$[(42 - 35.7)^2] / 35.7 = 1.11$ $[(21 - 27.3)^2] / 27.3 = 1.45$	$[(47 - 52.7)^2] / 52.7 = 0.62$ $[(16 - 10.3)^2] / 10.3 = 3.15$	$[(45 - 37.3)^2] / 37.3 = 1.58$ $[(18 - 25.7)^2] / 25.7 = 2.31$	$[(38 - 35.7)^2] / 35.7 = 0.15$ $[(25 - 27.3)^2] / 27.3 = 0.19$
SCS infographic	$[(31 - 35.7)^2] / 35.7 = 0.62$ $[(32 - 27.3)^2] / 27.3 = 0.81$	$[(61 - 52.7)^2] / 52.7 = 1.30$ $[(2 - 10.3)^2] / 10.3 = 6.69$	$[(46 - 37.3)^2] / 37.3 = 2.03$ $[(17 - 25.7)^2] / 25.7 = 2.95$	$[(46 - 35.7)^2] / 35.7 = 2.97$ $[(17 - 27.3)^2] / 27.3 = 3.89$
X^2	4.181	12.61	26.29	17.63

Step 6: Calculate degrees of freedom (df), according to the Chi-Squared Test, by using the total contingency table from Step 1.

$$df = (r - 1)(c - 1) = (3 - 1)(2 - 1) = 2$$

Step 7: Use critical values of chi-square distribution. At $df = 2$, at a significance level (σ) of 0.05, the critical value is 5.991. This critical value is found on any chi-square distribution table.

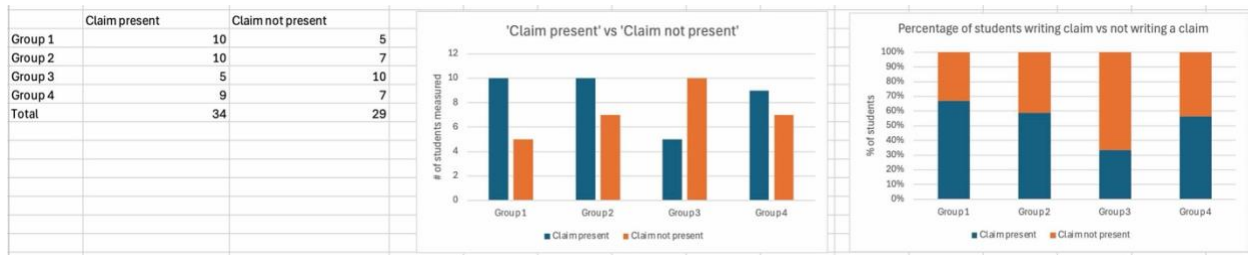
Table 12: Calculated Chi-Squared values

	For 'Claim'	For 'Tier-3 vocabulary'	For 'Data'	For 'Evidence'
χ^2	4.181	12.61	26.29	17.63

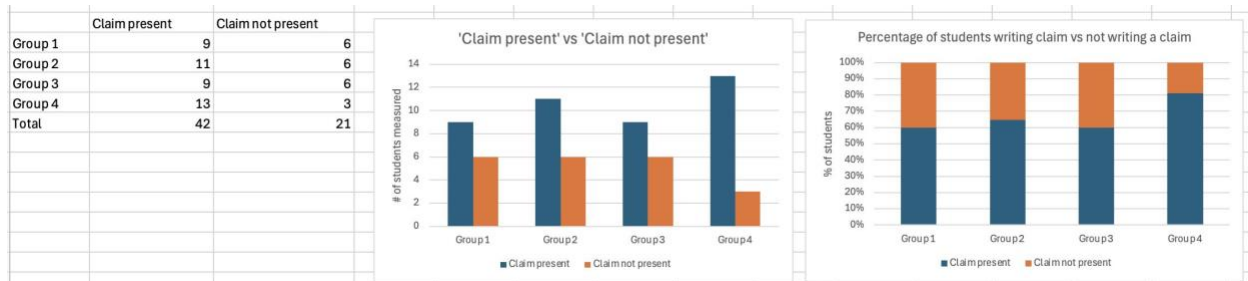
APPENDIX H: INDUCTIVE ANALYSIS GROUPS TALLIED AND GRAPHED

Comparison of students' presence of writing a claim:

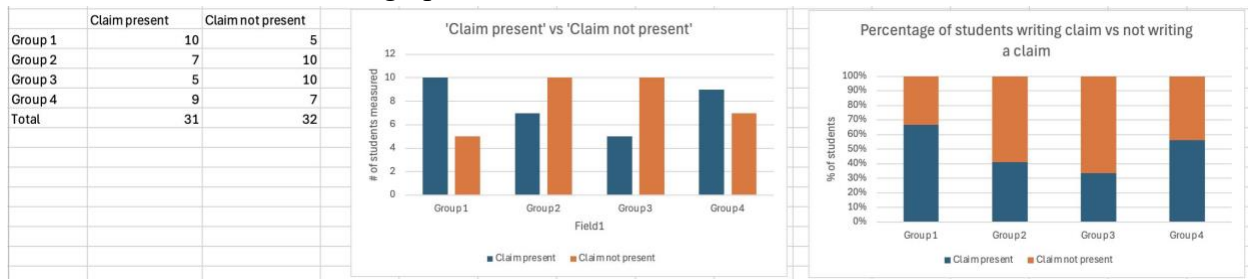
No infographic



Curriculum-based Infographic

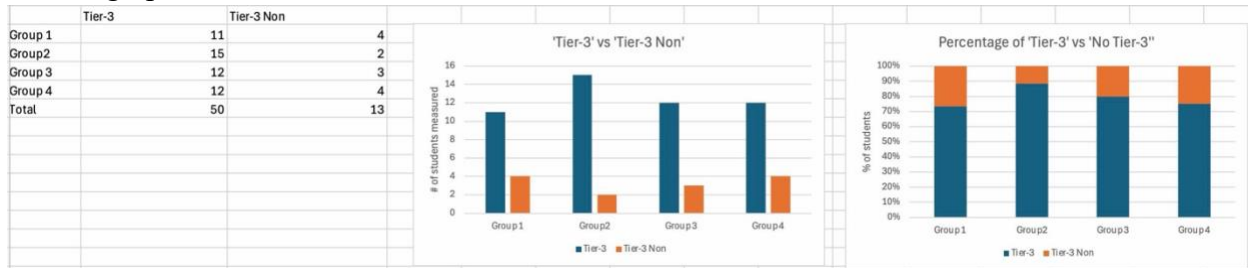


Student-Created Science Infographic

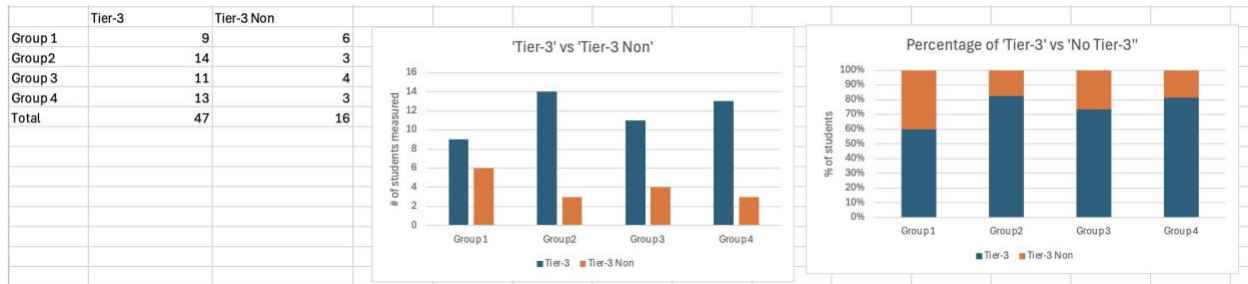


Comparison of the presence of student using Tier-3 Vocabulary:

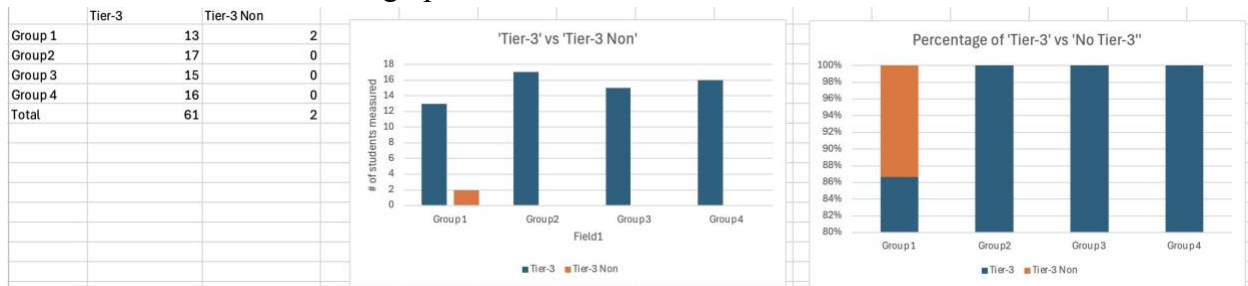
No infographic



Curriculum-based Infographic

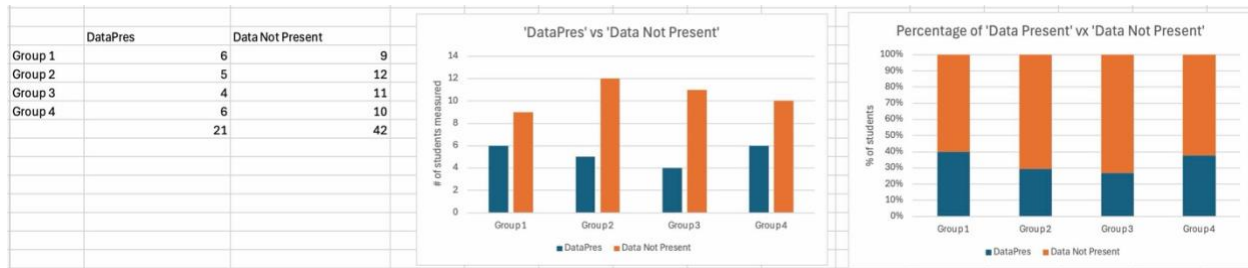


Student-Created Science Infographic

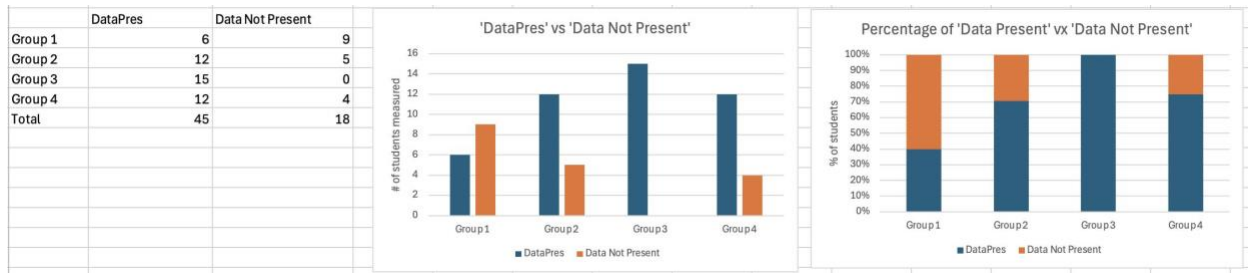


Comparison of the presence of students using Data with Tier-3 Vocabulary:

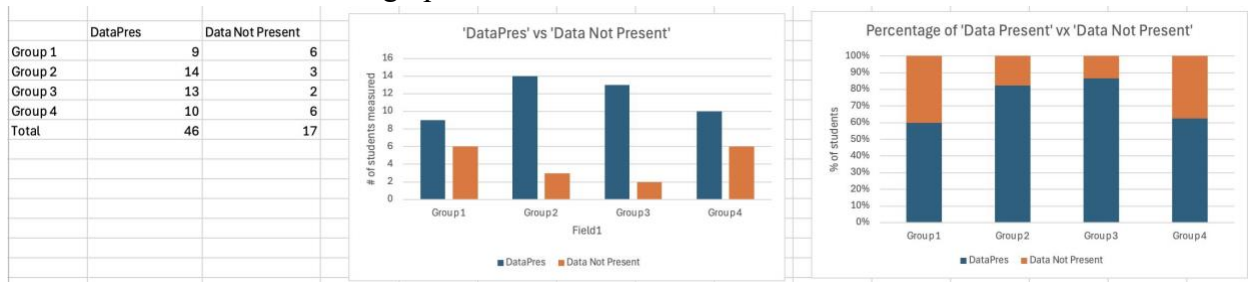
No infographic



Curriculum-based Infographic

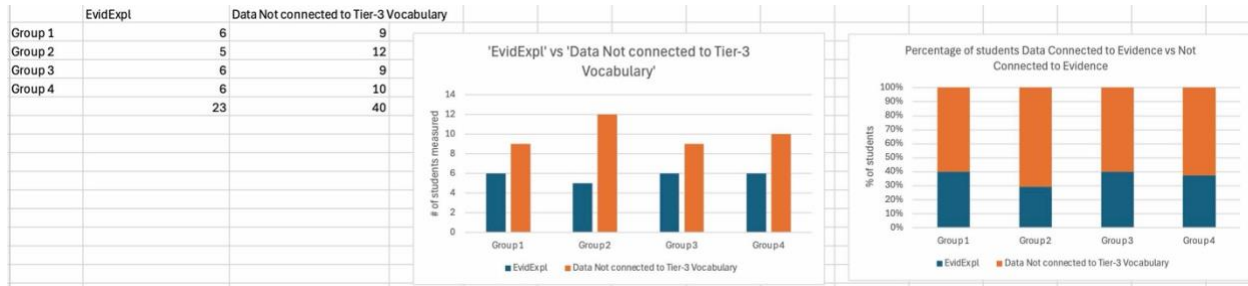


Student-Created Science Infographic

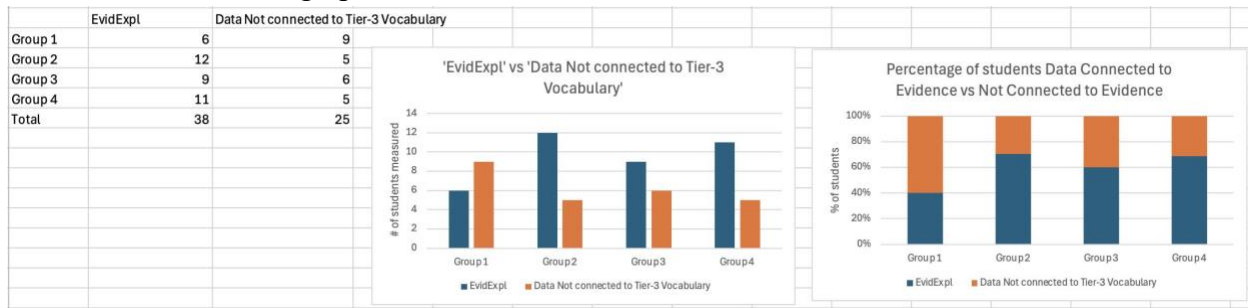


Comparison of the presence of students' explaining their data using Tier-3 Vocabulary:

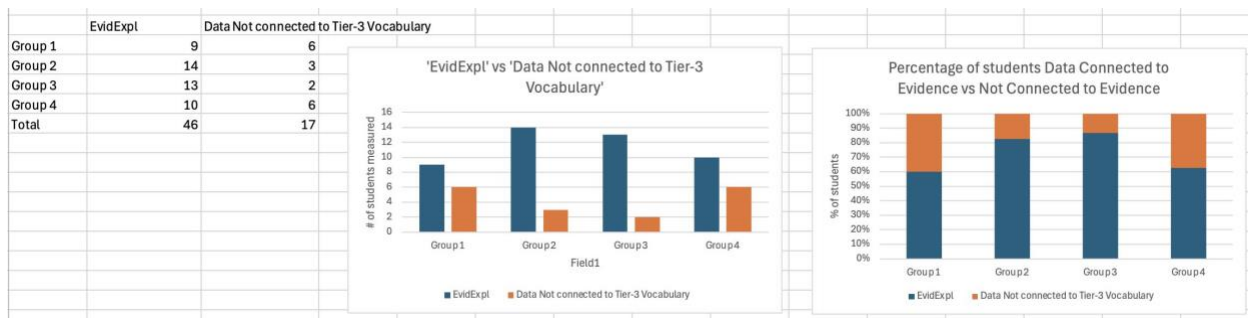
No infographic



Curriculum-based Infographic



Student-Created Science Infographic



APPENDIX I: STUDENT ARTIFACTS OF STUDENT-CREATED SCIENCE (SCS)
INFOGRAPHIC

What is happening with bath bombs when new gas bubbles are made?

Jesha Yun

1. What happened?



2. Density & Flammability



3. What is the Gas being produced by the chemical reaction?

CCl₄ CO₂ CCl₄

[illegible][illegible]

Group 2 Students 13 & 12, respectively

[illegible][illegible][illegible]

Group 4 Students 15 & 16, respectively

APPENDIX J: IRB EXEMPTION



Mister Michael Lee <mleebluerams@gmail.com>

IRB Exemption Status Request

Szott, Brenna <brenna.szott@montana.edu>
To: "mleebluerams@gmail.com" <mleebluerams@gmail.com>

Tue, Oct 21, 2025 at 11:51 PM

Hi Michael,

Thank you for clarifying — that's very helpful. Since you'll be using existing student data and the results will only be shared at the Capstone Symposium and for your own instructional improvement, this project aligns with classroom-based Quality Improvement rather than human subjects research.

Because it does not meet the definition of research under 45 CFR 46 (i.e., it's not designed to contribute to generalizable knowledge), it does not require IRB review or an exemption submission.

You may include this email in your Capstone appendix as documentation of that determination.

Please let me know if your plans change — for example, if you decide to publish or present your findings beyond the symposium — and we can revisit whether IRB review would then be required.

[Quoted text hidden]