

USING INTERACTIVE SCIENCE NOTEBOOKS

by

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Abstract

The goal of this curriculum design was to improve the effectiveness of incorporating science writing into the curriculum using integrated science notebooks (ISNs). The purpose of applying reflective science writing in the classroom was to improve general writing skills and organization, to help students identifying patterns, to serve as a record of science understanding, and to give students an opportunity to practice and improve problem solving skills. Interactive science notebooks were used to allow concepts to be connected throughout the year through reflecting on questions, building upon academic vocabulary, concept mapping, and referencing. In addition, modeling how scientists problem solve refined their skills in experimentation.

Physics and Earth Science students were presented with the interactive science notebooks (ISNs) the first week of school and they used them throughout the year to record labs and activities, take Cornell notes, record starter/reflection questions, and use the notebooks as a reference. The intention was to search for a correlation between student performance and science comprehension because of ISN use.

Quantitative data on academic improvements were not collected during the introduction and usage of the ISN, however students generally were able to identify connections in their learning to an organized record of scaffolded higher learning opportunities as well as in reflective surveys and writing prompts.

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Introduction

I became interested in introducing Interactive Student Notebooks (ISNs) into my curriculum to address some of the academic issues associated with classes composed of high percentages of Special Education, ESL, gifted students, as well as the regular education students. In addition to the diversity in ability levels, the school I taught at (2007-2011, East High School in Salt Lake City, Utah) was culturally and ethnically diverse. I faced challenges in my first year there balancing the curriculum between students that had privileged backgrounds with typical American experiences and refugee students just arriving to the country with limited English proficiency and experiences that were atypical of an American childhood. There was also a growing Hispanic and a prominent Pacific Islander population.

I chose ISNs as my curriculum redesign project because I was interested in them and felt desperate to improve the range of academic achievement in my students. Using the ISNs appeared to me a way to embrace the students' uniqueness and to connect their experiences (both in and out of the classroom) to the academic content. The writing component of the ISN attracted me because it was versatile in assessment options and utilized a variety of learning styles.

Literature Review

According to the third Trends in International Mathematics and Science Study (TIMSS) (Martin, 2004), science education in the United States was referred to as “unfocused, fragmented, and concerned with facts rather than the concepts that give them meaning.” Although the United States ranked above the international average, we scored low among other developed countries. The TIMSS advocated for improvements in our

science instruction, changing student perception of learning and problem-solving into an *ongoing* process. They also supported focusing on fewer concepts, providing regular feedback, creating opportunities for individual conceptualization, and engaging students in activities requiring higher-order thinking. ISNs have been traditionally used to engage students in recording scientific inquiry and to model how scientists conduct experiments (Campbell, 2003). Using ISNs in the classroom integrated the writing application into science. This enhances thinking and engagement, strengthening skills such as organization and articulation (Williams, 2003).

Effectively using a scientific notebook covers the first five of the eight National Science Standards (Appendix 1). These five include 1) Unifying Concepts and Processes, 2) Science as an Inquiry, 3) Physical Science, 4) Life Science, and 5) Earth Science. The content standards focus on achieving basic scientific tools for effective problem solving as well as key content expectations. The ISN, used with the highly effective techniques below, address these National Science Standards.

*Learning Cycle Approach

-Exploration, Invention, and Application leads to better content achievement, improved thinking skills, and more positive attitudes toward learning science

*Cooperative Learning

-utilized in classroom & laboratory learning increases student achievement, attitudes, and on-task behavior

*Analogies

- results in the development of conceptual understanding by enabling the learner to compare something familiar to something unfamiliar

*Concept Mapping

-student & teacher generated concept maps for teaching science concepts results in improved student achievement and more positive student attitudes

*Systematic Approaches to Problem Solving

-planning solutions to mathematical chemistry & physics problems in a systematic way enables student to more frequently solve the problems correctly

*Real-Life Situations

-situations in science instruction through technology or actual observation increases student interest in science, problem-solving skills, and achievement

*Discrepant Events

-using discrepant events in science instruction results in cognitive conflict that enhances students' conceptual understanding

The ISN provides a structure for the above learning principles to be used and recorded. Using these principles in the science curriculum supports the content-related National Science Standards (Appendix 1). Students must be able to analyze, understand, and solve problems, adapt to fast-paced change, and learn new skills throughout their lives. Our educational system has experienced an “unprecedented” level of reform activity at the state and federal level in the past decade, with marginal improvements in student achievement. One might consider the power of improved teaching rather than the “top-down” reforms (Cawelti, 1995).

Marzano, *et al.* (2001) focus on nine effective strategies that help in developing higher-order thinking. These nine strategies are:

- Identifying similarities and differences
- Summarizing and note taking
- Reinforcing effort and providing recognition
- Homework and practice
- Nonlinguistic representations
- Cooperative learning
- Setting objectives and providing feedback
- Generating and testing hypotheses
- Cues, questions, and advance organizers

These strategies can be implemented and/or observed in the ideal usage of ISNs. A strong reason to utilize ISNs is the personalization and the ownership students develop in their own learning. Students also develop a stronger understanding of how they learn –

metacognition (Marcarelli, 2010). Students can use their unique combination of learning styles to express themselves and their knowledge about the world around them.

Metacognitive thinking is a large component in achieving the goals associated with using ISNs (Marcarelli, 2010). There are four levels of metacognition: tacit, aware, strategic, and reflective use. By providing opportunities for these four types of thinking to take place it is possible to scaffold through to the higher levels of thinking. *Tacit* is the lowest level of metacognition, which involves subconscious thinking. In the next level, *aware*, the student is conscious of their own thoughts and actions. In the *strategic* level the student is more engaged in processing actively and organizing his/her own thinking. The final *reflective* level, the student goes one step further and reflects on how to advance and improve (Marcarelli, 2010).

Teachers are to model to their students the higher levels of metacognition through collaboration as they problem solve and ask questions (Marcarelli, 2010). Students are to practice analyzing and organizing their thinking to become more advanced problem solvers. The ISN is a continuous work in progress, which teaches students science investigation and research is a process. As those new concepts become more developed and understood they become part of the learners' reservoir of knowledge waiting to be connected to more complicated scientific concepts (Marcarilli 2010).

Students demonstrate their improvements by maintaining an ISN. The record of their past investigations will support and initiate their inquiry, provide background information for future predictions, and serve as a reference for experimental designs. They represent an alternative assessment, progress towards achieving science skills, and a reflection of investigations and discussions. Spot-checking these works would not

represent an adequate assessment of that individual. Assessment requires depth and thoroughness. Neatness and quantity do not reflect understanding (Campbell, 2003).

Inquiry is not a linear sequence. Students bring an array of skills and experiences that can be recorded in their notebooks. Teachers are able to follow their growth in their comprehension level by reading their ideas, questions, analyses, and conclusions in their entries. A sense of order develops as they continue to learn from each inquiry (Marcarilli, 2010).

The literacy connections are present through language development as students practice posing questions, making educated predictions, collecting and organizing data, and reflecting on what it all means. There are even connections to English Language Arts standards. A notebook enhances oral and written communication as it provides a non-intimidating place for experimenting and growing as a writer and academic vocabulary development. Integrating science writing into the curriculum shows students that effective writing is an important life skill. Collaboration is an important component to ISNs. Students utilize each other and their personal experiences to develop understanding. Writing with a partner when translating thoughts into words is advised in the beginning stages to develop metacognition (Marcarilli, 2010).

Writing clarifies thinking and it can be viewed that it IS thinking. Analyzing student writing allows us to determine what our students know. They need to demonstrate their learning in writing activities. Students can fake knowing things on more traditional short-answer or multiple-choice assessments even if they don't understand the concepts (Fisher, 2007).

The National Assessment of Educational Progress (NAEP) framework (Fisher, 2007) includes a writing assessment and the organization has noted that writing is “one of the most important skills that young people can acquire and develop throughout their lives.” Of the three types (narrative, informative, and persuasive), informative writing would be the most used in the ISN with the purpose of reporting on observations or analyzing and connecting concepts. Some suggested principles to implement writing into the curriculum are:

- Clear objectives
- Provide genre & format constraints
- Grading with portfolio system/point system/check system
- Short assignments
- Insert writing into the curriculum to accomplish a specific goal
- Grade on content
- Peer collaborations when appropriate

Some higher-level learning techniques to integrate writing into the curriculum include: interactive writing (where the teacher is involved and active while the students are writing), summary writing, Role, Audience, Format, and Topic writing (RAFTs), and read, write, share, and pair (Fisher, 2007).

Composing research papers requires generating ideas and questions. Information is collected, analyzed, and synthesized from many sources and appropriately organized to communicate to the right audience. Notebooks serve science the same way, gathering evidence and assembling ideas to support literacy development (Campbell, 2003).

There are three benefits to using ISNs according to Marcarilli (2010): 1) Competitive preparation for the workforce; 2) Improved communication between student, instructor, parent/guardian; 3) Diversified/differentiating instruction through incorporating multiple learning styles.

How others have implemented ISNs

Varying strategies have been used in implementing ISNs into the curriculum. According to Campbell & Fulton (2003), planning is necessary to cover the logistics of making the science notebook system work in the classroom; for example, the most important choices are deciding on the notebook type, format of entries, choosing content prompts, and making objectives/goals. There is also a recommended structure for each unit that includes: 1) a cycle of introducing material and exploration, the sharing of ideas and collectively brainstorming strategies; 2) recording those strategies and discussing results, making connections to the content (facilitated by the instructor); 3) students' collaboration involving pairing up and sharing their ideas; 4) engaging in individual reflection writing. The support level the teacher must provide depends on the student; however, teacher modeling and student collaboration are effective (Campbell, 2003).

These strategies support a format focusing more on the science content rather than writing standards. The content was collected from peer collaboration during data collection, comparing results, whole class discussions, and assigned reading. Writing standards could be addressed during each step of the process. In addition to reflective writing to communicate scientific thought, technical drawings were useful to visually support findings. It is necessary for guided drawing to take place lest students claim they lack in artistic ability. In guided drawings, distinctions can be made between symbols and quality. The instructor facilitates observation of a common subject and, together with the class, point out details that can be represented in a drawing. Detailed drawings are important components of lab investigations. Digital cameras can be used as well as photojournalism as an optional extension to drawing (Marcarilli, 2010).

Another unit format was proposed by Marcarilli (2010), who suggested two pieces of writing be assigned in each unit. One piece, a self-reflection, is an individualized summary of their best work and the other, an “aha” thesis, demonstrate their level of understanding. The “aha” experience occurs with each unit. It begins with “aha” connections, which is a series of engaging activities that trigger student inquiry. Questions and discussions follow until essential questions or problems is posed and then answered through lab experiments. Reflective summaries are written and added to the “aha” connections. This is where the connections are be made between concepts by using arrows and text.

Cornell note-taking can be used to record input (Marcarilli, 2010). The right-hand side of the notebook is reserved primarily for input (observations, data, and diagrams) and the left-hand side is reserved for output (summaries, analyses, flowcharts, Venn diagrams, homework questions, graphs, data tables, and graphic organizers). The method behind this type of note-taking involves a series of steps including: 1) Recording: which includes the input of information where questions can be answered or where concepts are explained, 2) Reducing: this step requires students to identify cue words or questions to be placed into the left hand column that can be used later to review the notes, 3) Reciting: involves reading the facts from the notes out loud, engaging the students’ auditory as well as linguistic development. The left and right columns can be utilized to self -quiz the student as they are reciting vocabulary words, definitions, or concepts. 4) Reflecting: which includes looking at what was learned and asking questions like: How does this relate to my prior knowledge? How can I apply this information? How would I benefit from knowing this information? 5) Reviewing: this step aids in retention and is

recommended to be done completely and nightly, and the last step 6) Recapitulating: which involves the summarizing of the notes in the students' own words (Zorn, 2007). Using higher level learning techniques such as Cornell note-taking creates a standard of engagement for students that fits perfectly with the goals of using an ISN.

Encouraging inquiry to instigate experimentation can begin with rephrasing yes/no questions into open-ended questions. These open-ended questions are recorded and posted on a "research board" to validate student inquiry and to support experimentation. An effective way to show the practical use of ISN is to interview a scientist on the importance of recording data and how they use notebooks in their fields. It shows a real-life application of the skills developed in using scientific data (Marcarilli, 2010).

There are many formats to choose from when beginning the ISN. Recording the date, time, and a heading for notebook entries is standard. Advanced Via Individualized Determination (AVID) (Molloy, 2003) has developed widely used documents and templates to assist in the organization and inclusion of higher-level learning in the ISN. These templates include: a table of contents, record of assignments, handouts on writing activities/graphic organizers, and a variety of rubrics (Appendix 2).

Signs of progress in using the ISN take place as students become more independent in their experimental design, technical drawings, and data collecting and recording. More attention to detail takes place. Students transition from collecting data and making obvious connections to interpreting their results and asking more questions. Evidence of the integration of science concepts is visible through application. Students use the results from previous activities/discussions/inquiries as support in later

investigations. Assessments can become more formal through a comprehensive project, such as science fair, slideshow, or a big book (Campbell, 2003).

The ISN opens up some unique ways to provide feedback on student work and effective communication for constructive improvement. Feedback has two objectives: 1) informs students where they are in their learning and what they need to do next (cognitive) and 2) instill a feeling of control over their own learning (motivation). Susan Brookhart (2008) shares in her book, *How to Give Effective Feedback to Your Students*, a coversheet for lab reports (Appendix 3). The rubric is structured to give students a quantitative value for their work as well as feedback from the instructor with the purpose of developing understanding and increasing or maintaining motivation.

From a nonacademic view, there are dynamic personal developments that can grow from using an ISN. During middle adolescence (ages 15 to 17), children are developing “coherent plans” and “long-term goals”. At this age they are also growing their capacity to analyze problems and ask deeper questions about moral, ethical, and religious issues. Other skills that are characteristic of this developmental stage include: more stable sense of self, increasing intellectual awareness of the world, reflections gained from time in solitude, and discovery of new talents and abilities in areas such as sports, art, and music. The ISN addresses these developments and allows the students to grow in these areas. Written reflections, collaborating and sharing ideas with peers, problem solving, and designing experiments are some of the activities that lead these young adults into responsible and educated individuals. Although schools are often focused on attendance in AP courses or pass rates in courses such as Physics or Biochemistry they often fail to prepare our students for the next developmental stage like

working effectively with others. Traditionally, large impersonal schools, lecture-based classes, fragmented curricula, tracking, and excessive academic pressure are just a few of the developmentally inappropriate practices in today's high schools (Armstrong, 2006).

From one teacher's testimony (Rossi, 2004) it did not take a significant time consuming commitment to transition over to using ISN with her students. In her opinion, the biggest change was her attitude when going from teacher controlled and structured to student-centered learning. According to her observations, teachers with rigid teaching styles were more likely to quit using the ISN in the classroom. These teachers had a difficult time releasing control of learning over to the students. Another difficulty involved the required effort level from students in learning. Students with lower levels of literacy may not appreciate the effort required and will be challenged by the written reflections. As students build upon their content knowledge, they will be expected to demonstrate their progress, being challenged at every step. The ISN utilizes a lot of writing, which can be misused in education. When it is used as a punishment it relays to the student that writing is not fun (Fisher, 2007).

Grade-conscious students may find the ISN difficult. The way ISN motivates students is intrinsic; the goal is learning rather than the letter grade on the report card. Students feel a sense of achievement when paging through their ISN, which recorded real questions and answers that student have posed throughout the year.

Justification

I was interested in using ISNs for the following reasons. ISNs require students to communicate by applying the scientific method. They show students that science is an ongoing process and encourage design improvements to be made in order to reduce error.

They also serve as a platform for inquiry as more questions can be posed after experimental analysis of results.

Students can keep their ISN throughout their formal education to refer to as a reference and record of content mastery. It serves as a portfolio of individual scientific thought as well as collaborative experimentation. As students transfer mid-semester to a different school or simply to a different teacher within the building, the ISN will provide an excellent summary of skills that the student has that is more informative than a letter grade. For the student, it provides evidence of problem solving skills that can be reviewed for perhaps a lab credit in college or for qualifying for academic scholarships or special honors.

The format can be easily modified and used with different science and non-science disciplines to maintain high expectations allowing more connections with cross curricular/integrated projects. This may show more practical, applicable meaning in the content than disconnected units of subject matter, which will result in more consistent or, better yet, *improving* grades throughout the academic year.

Based on the Utah Secondary Science Core Curriculum (2003), “science instruction should cultivate and build on students’ curiosity and sense of wonder. The science core is based on an integrated set of Intended Learning Outcomes (ILOs) for students that include:

- Use science process and thinking skills.
- Manifest science interests and attitudes.
- Understand important science concepts and principles.
- Communicate effectively using science language and reasoning.

- Demonstrating awareness of the social and historical aspects of science.
- Understand the nature of science

Teachers facilitating the ISN the way it is intended can lead students in achieving these six ISOs (Appendix 4).

The American Association for the Advancement of Science (AAAS) developed a series of benchmarks leading up to the goals stated in Project 2026, called Science for All Americans (SFAA), for science literacy. These benchmarks are divided into grade levels 2, 5, 8, and 12 to pace the expectations of skills in science, mathematics, as well as technology. The intent assumes that curriculum reform be based on a “vision of lasting knowledge and skills we want students to acquire by the time they become adults.” It is also desirable that science literacy does not result only in comprehension of individual disciplines, but understanding the connections and relationships between science, mathematics, and technology in addition to arts, humanities, and vocational subjects. The versatility of the ISN matches the goals of the curriculum reform statements of Project 2026. The benchmarks (Appendix 5) overlapping the goals and functionality of using ISNs are found in:

*Nature of Science: Scientific Inquiry

*Habits of the Mind: Values and Attitudes

*Habits of the Mind: Communication Skills

Design

In the 2010-2011 academic year I taught 2 sections of Limited English Proficiency (LEP) Physics to students in grades 10-12 at East High School in Salt Lake City, Utah. My students were from a variety of cultural backgrounds. Salt Lake City is

one of the main hubs for refugees immigrating to the United States. There are forty-two languages spoken as first languages other than English at East High School. Spanish is the most prominent language spoken as a first language other than English (650 students). Tongan comes in second (40 students). Students who do not speak English as their first language have none or one other student in the entire school that speaks their first language. Over nine hundred students qualify for English as a Second Language (ESL) services; however a little over three hundred students actually receive language accommodations.

During the 2007-2009 academic school years I participated in Brigham Young University's ESL Endorsement program. Professionals from the Salt Lake City School District participated in this training to become more effective in reaching our unique student population. Two of the top techniques during this two-year professional development were 1) implementing teacher stations (which allow students to work in very small groups with the instructor on anything from a tough concept to informal assessment) and 2) developing effective partnerships (through monthly newsletters, home visits, and guest teaching) between teachers and parents to effectively maximize student learning. ISNs were utilized in both of these techniques. During the small group teacher stations, students recorded summaries, observations, inferences, or data in their ISN, but it was also utilized as a reference.

The ISN was also used to develop effective partnerships. When home visits were made or parent-teacher meetings at the school took place, the ISN was shared because it served as a record of the student's engagement and comprehension. When guest teachers

were invited to class or field trips took place the ISN was used to record questions, observations, and reflective thoughts.

The two sections of LEP Physics (as well as three sections of Earth Systems) began the 2010-2011 academic year using ISNs to improve the reflection and comprehension of Physics concepts through a number of different modes. LEP Physics students used two main resource texts: Minds on Physics (Leonard, 2008) created by the University of Massachusetts Physics Education Research Group and Take-Home Physics: 65 High-Impact, Low-Cost Labs (Horton, 2009) from the NSTA Press, some being reformatted or revised to focus on reading comprehension.

ISNs had been used 2010-2011 to organize notes, practice calculations, record and reflect on daily journal questions, develop experimental design sketches, create graphs, analyze data, define academic vocabulary concepts, and reflect on how science concepts connect. Students were to keep the journal well organized by maintaining a table of contents (including numbering pages) as well as labeling every entry with a title and date. The journals were peer graded at the end of each week using a rubric that assessed the content and quality of their responses. The journal was sequential by date and was easy to follow when using the Elmo® visualizer document camera technology to model the organization of the ISN. This technology was also useful when analyzing possible answers for credit and helping students follow along as entries were added.

Students were provided a composition notebook at the beginning of the year. I spent one class period to construct the notebook, attaching AVID resources (Appendix 2), graphic organizer references, standardized rubrics, and discussing how the ISN would be used in the classroom. A 6" x 9" manila envelope with a metal clasp was taped to the

back of the ISN to hold vocabulary cards. Some of the students had used the ISN in previous science or other content area classes.

I kept my own personal ISN for both Earth Systems and LEP Physics. Before each class, I would record the daily journal question, notes or activities. All of the pages were numbered so I could keep track of what was recorded in the table of contents. This benefited me as an instructor to be more prepared by having the structure of what needed to be covered in class. The ISN offered structure while allowing flexibility within the content. My ISNs were available for students to catch up from absences. Students were able to easily record the daily journal questions and the left column (input) notes.

I would ask students regularly to reflect on how the ISN could be used more effectively. They provided general feedback on how the mechanics of using the ISN could be smoother. This qualitative data was used to make immediate modifications to the design of the ISN, such as changes to rubrics.

The academic success of my LEP Physics students was very much influenced by the ISN. LEP students immigrating to the U.S. are not familiar with the school norms that native students innately understand in order to be successful. These students had limited experience in the United States school system and benefit from the structure the ISN provides. Their language proficiency, background knowledge, and cultural norms contributed to challenges that could be addressed using the ISN.

Introducing the ISN was, overall, a positive learning experience for the students. It provided structure within the class that incorporated reflective writing, organizing input, and resulted in a hard copy of their academic progress. Students picked up on the expectations of keeping a high quality ISN within the first few weeks.

Positive Outcomes

Students indicated that using the ISN made it easy to stay organized in the class. Most students identified that the ISN was easier to bring to class compared to the typical textbook. ISN also was beneficial in helping students study for tests. Students also identified that ISN made academic expectations clear and simple to follow, helpful to stay on top when tests and projects were due, made it easier to make up missing work after an absence, and made scientific concepts easier to understand.

I observed students becoming more comfortable and aware of their performance in the science classroom due to expected assessments based on rubrics. The emphasis of writing and collaboration encouraged students to go beyond what was structured into the activities. It became a classroom norm to discuss science concepts and experimental results. Students seemed to rarely forget their journals because it was more manageable to bring to class than the typical thick, heavy textbook. This offers the idea to students that science knowledge is constructed rather than memorized out of a book. Students making up missed work found that task easier as well. The ISN was a more comprehensive system used to demonstrate student understanding for assessment purposes because it served as a sequential profile of student understanding. As we continued to use the ISN, students were more engaged in activities, wanting more time to work on an activity over the weekend when assessment was going to be checked for completion after being shared in class. They showed more pride in their learning. A few of the positive comments referred to their preference of the *way* the journals were utilized in class. One student identified that it was more valuable to be able to express his understanding through his writing than a simple worksheet. I noticed most of the

students that used science journals in previous years had more consistent grades throughout the academic year (and their grades generally ranged between A's and B's).

Negative Outcomes

The most common downside students identified with using the ISN was that if they had forgotten to bring it to class they became disorganized. Another drawback was in the rare case of losing their journal, this was detrimental to their grade. There were a fair share that disliked the reflective journal questions and completing the Cornell notes for the ISN. A few students felt that completing work in their journal did not reflect what they knew and would have rather read from the traditional textbook. Of course there were those students that felt worksheets were simpler to complete than writing assignments.

Losing ISNs was not common, but resulted in student starting all over again without the lost portion as a content reference. Many of my students identified with this issue, but throughout the year and with five classes, only one student actually lost her ISN. I found that although it was "easier" for students to make up missed work after an absence, it was difficult for students to self monitor what was appropriate to copy. Students had a hard time drawing the line between copying notes from class (which was appropriate) and copying reflective work. Organization was difficult when students forgot to bring ISNs to class; papers became out of sequence if students didn't enter them into their ISN right away. Some students complained of being graded lower than what they actually deserved, the absence of worksheets, the monotonous structure, and usage of Cornell notes.

Reflection

A minority of students find academic success no matter the teaching environment and style. The majority of students, however, are affected by environmental issues such as attendance, homework, lateness, resources, and/or behavior that puts them at a disadvantage for academic success. These students rely on the structure of the course as well as the classroom experience.

Next year I would like to improve upon a few aspects of the ISN structure from the first year. During this first year I enjoyed how there was a shift of focus in the students from getting a good grade to the actual learning and discovering through collaboration and individualized reflective writing taking place in the classroom. There is an appreciation of learning that occurs from the student perspective because of its personalized approach in reflective writing. In the next few years I would like to work collaboratively with instructors from other disciplines to create integrated goals to show students how content is applied across the curriculum. I would also like to continue the shift of responsibility and ownership to the students. Since new students will fill the seats every year, a process to transition the students into using the ISN more effectively will be used.

Appendix 1: National Science Standards

1. Unifying Concepts and Processes Standard

Conceptual and procedural schemes unify science disciplines and provide students with powerful ideas to help them understand the natural world. Because of the underlying principles embodied in this standard, the understandings and abilities described here are repeated in the other content standards. Unifying concepts and processes include:

- Systems, order, and organization.
- Evidence, models, and explanation.
- Change, constancy, and measurement.
- Evolution and equilibrium.
- Form and function.

2. Science as Inquiry Standards

In the vision presented by the Standards, inquiry is a step beyond "science as a process," in which students learn skills, such as observation, inference, and experimentation. The new vision includes the "processes of science" and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science. Engaging students in inquiry helps students develop:

- Understanding of scientific concepts.
- An appreciation of "how we know" what we know in science.
- Understanding of the nature of science.
- Skills necessary to become independent inquirers about the natural world.
- The dispositions to use the skills, abilities, and attitudes associated with science.

3. Physical, 4. Life, and 5. Earth Science

The standards for physical science, life science, and earth and space science describe the subject matter of science using three widely accepted divisions of the domain of science. Science subject matter focuses on the science facts, concepts, principles, theories, and models that are important for all students to know, understand, and use.

Physical:

- Structure of atoms
- Structure and properties of matter
- Chemical Reactions
- Motions and forces, Conservation of energy and increase in disorder, Interactions of energy and matter

Life:

- The cell
- Molecular basis of heredity
- Biological evolution
- Interdependence of organisms
- Matter, energy, and organization in living systems
- Behavior of organisms

Earth:

- Energy in the earth system
- Geochemical cycles
- Origin and evolution of the earth system
- Origin and evolution of the universe

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Appendix 2b

Making My Journal Great!

I know that keeping an _____ journal is a big part of earning a good grade in Mrs. Yi's class! I can use this list to make sure I have everything included that I need to earn an A 😊

*Both the _____ and the _____ are written every day.

*The _____ is written in color or is circled to make it _____.

*I wrote the _____ question (except anything in parentheses).

*My answer is at least _____ long.

*My sentences are _____, or they show _____.

*My _____ is neat and easy to read!

*I am here _____!!!

*I do all of the assignments _____ to earn all possible _____.

Appendix 2c

This is my journal: _____
 Block: _____

Journal Peer Grade

Question Number	Sentence Criteria	1 st Sentence	2 nd Sentence	3 rd Sentence
	How many sentences long was this answer?	1	3	5
	How many of the sentences were good?	1	3	5
	How many sentences long was this answer?	1	3	5
	How many of the sentences were good?	1	3	5
	How many sentences long was this answer?	1	3	5
	How many of the sentences were good?	1	3	5
	How many sentences long was this answer?	1	3	5
	How many of the sentences were good?	1	3	5
	How many sentences long was this answer?	1	3	5
	How many of the sentences were good?	1	3	5
Writing	Is the writing neat & easy to read?	No = 0	Most = 3	Yes! = 5
Separation	Did the author write the Date & Circle the question number every day?	No = 0	Most = 3	Yes! = 5
Stamps	Award 10 points for every _____ stamp given	0 Stamps = 0 points	3 Stamps = 30 points	5 Possible Stamps = 50 points

Total Score =/110 points

What did the author do well and should continue to do for future journal grades?

How can the author improve to get more credit?

If you were absent for an excused reason recently and believe you need extra time to complete more of your journal for a better grade your deadline is: _____

I, the author, read the grader's comments (sign here): _____

Appendix 2d

BIG Journal Grade

Name: _____ Block: _____

Question Numbers: 1 to 15 I have _____ out of _____ stamps possible

Question Number																
# of Sentences																

	Beginning	Approaches Standard	Meets Standard	Exceeds Standard	Self	Yi
Neatness	Very hard to read 4	Messy, but readable 6	Neat writing 8	Uses spaces, underlining, other tools to increase readability 10		
Notebook Use	Wastes lots of space 4	Writes on both sides of pages 50% of time 6	Writes on both sides of pages 75% of time 8	Writes on both sides of pages 100% of time 10		
Organization	No pattern of organization 4	In order, number circled, more than half days/dates not written 6	At least 12 days/dates written, questions circled, space left between days 8	Every question number is circled, each day and date is written, space left between days 10		
Questions Completion	50% or fewer questions answered 5	Some questions and some answers present (10-14) 10	All questions copied, at least 12 answered 20	All questions copied, all answers present 30		
Response Quality	Brief answers, 1 sentence average 0-20	Average 2 sentences per answer 30	Thorough answers, each at least 3 sentences 40	Thoughtful, in-depth answers, MOST exceed 3 sentences 50		
Stamps Earned	No Stamps 0-20	Has 50% of possible stamps 30	Has 75% of possible stamps 40	Has 100+ of possible stamps 50		
TOC	Some pages are numbered 0-10	Most pages are numbered, TOC is partially completed 15	All pages are numbered, TOC is partially completed 20	All pages are numbered, TOC is 100% completed 25		

Total Points out of 185 _____

I have graded this journal according to the work I have done, and I believe the grade I assigned myself accurately represents my journal assignment performance.

Signature (-10 points if missing)

Appendix 3

QuickTime™ and a
H.264 decoder
are needed to view this picture.

Appendix 4: Utah Secondary Science Core Curriculum

1. Use Science Process and Thinking Skills

- a. Observe objects, events and patterns and record both qualitative and quantitative information.
- b. Use comparisons to help understand observations and phenomena.
- c. Evaluate, sort, and sequence data according to given criteria.
- d. Select and use appropriate technological instruments to collect and analyze data.
- e. Plan and conduct experiments in which students may:
 - Identify a problem.
 - Formulate research questions and hypotheses.
 - Predict results of investigations based upon prior data.
 - Identify variables and describe the relationships between them.
 - Plan procedures to control independent variables.
 - Collect data on the dependent variable(s).
 - Select the appropriate format (e.g., graph, chart, diagram) and use it to summarize the data obtained.
 - Analyze data, check it for accuracy and construct reasonable conclusions.
 - Prepare written and oral reports of investigations.
- f. Distinguish between factual statements and inferences.
- g. Develop and use classification systems.
- h. Construct models, simulations and metaphors to describe and explain natural phenomena.
- i. Use mathematics as a precise method for showing relationships.
- j. Form alternative hypotheses to explain a problem.

2. Manifest Scientific Attitudes and Interests

- a. Voluntarily read and study books and other materials about science.
- b. Raise questions about objects, events and processes that can be answered through scientific investigation.
- c. Maintain an open and questioning mind toward ideas and alternative points of view.
- d. Accept responsibility for actively helping to resolve social, ethical and ecological problems related to science and technology.
- e. Evaluate scientifically related claims against available evidence.
- f. Reject pseudoscience as a source of scientific knowledge.

3. Demonstrate Understanding of Science Concepts, Principles and Systems

- a. Know and explain science information specified for the subject being studied.
- b. Distinguish between examples and non-examples of concepts that have been taught.
- c. Apply principles and concepts of science to explain various phenomena.
- d. Solve problems by applying science principles and procedures.

4. Communicate Effectively Using Science Language and Reasoning

- a. Provide relevant data to support their inferences and conclusions.
- b. Use precise scientific language in oral and written communication.
- c. Use proper English in oral and written reports.
- d. Use reference sources to obtain information and cite the sources.
- e. Use mathematical language and reasoning to communicate information.

5. Demonstrate Awareness of Social and Historical Aspects of Science

- a. Cite examples of how science affects human life.
- b. Give instances of how technological advances have influenced the progress of science and how science has influenced advances in technology.
- c. Understand the cumulative nature of scientific knowledge.
- d. Recognize contributions to science knowledge that have been made by both women and men.

6. Demonstrate Understanding of the Nature of Science

- a. Science is a way of knowing that is used by many people, not just scientists.
- b. Understand that science investigations use a variety of methods and do not always use the same set of procedures; understand that there is not just one "scientific method."
- c. Science findings are based upon evidence.
- d. Understand that science conclusions are tentative and therefore never final. Understandings based upon these conclusions are subject to revision in light of new evidence.
- e. Understand that scientific conclusions are based on the assumption that natural laws operate today as they did in the past and that they will continue to do so in the future.
- f. Understand the use of the term "theory" in science, and that the scientific community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.
- g. Understand that various disciplines of science are interrelated and share common rules of evidence to explain phenomena in the natural world.
- h. Understand that scientific inquiry is characterized by a common set of values that include logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results and honest and ethical reporting of findings. These values function as criteria in distinguishing between science and non-science.
- i. Understand that science and technology may raise ethical issues for which science, by itself, does not provide solutions

Appendix 5

AAAS Project 2026 Benchmarks

Science Inquiry:

By the end of the 12th grade, students should know that:

-Investigations are conducted for different reasons, including to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare theories.

1B/H1

-Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available). 1B/H2

-Sometimes, scientists can control conditions in order to obtain evidence. When that is not possible, practical, or ethical, they try to observe as wide a range of natural occurrences as possible to discern patterns. 1B/H3*

-There are different traditions in science about what is investigated and how, but they all share a commitment to the use of logical arguments based on empirical evidence. 1B/H4*

-Scientists in any one research group tend to see things alike, so even groups of scientists may have trouble being entirely objective about their methods and findings. For that reason, scientific teams are expected to seek out the possible sources of bias in the design of their investigations and in their data analysis. Checking each other's results and explanations helps, but that is no guarantee against bias. 1B/H5

-In the short run, new ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism. 1B/H6a

-In the long run, theories are judged by the range of observations they explain, how well they explain observations, and how useful they are in making accurate predictions.

1B/H6b*

-New ideas in science are limited by the context in which they are conceived; are often rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly, through contributions from many investigators. 1B/H7

-Scientists' nationality, sex, ethnic origin, age, political convictions, and so on may incline them to look for or emphasize one or another kind of evidence or interpretation.

1B/H8** (SFAA)

-To be useful, a hypothesis should suggest what evidence would support it and what evidence would refute it. A hypothesis that cannot, in principle, be put to the test of evidence may be interesting, but it may not be scientifically useful. 1B/H9** (SFAA)

-Bias attributable to the investigator, the sample, the method, or the instrument may not be completely avoidable in every instance, but scientists want to know the possible sources of bias and how bias is likely to influence evidence. 1B/H10** (SFAA)

-To avoid biased observations, scientific studies sometimes use observers who don't know what the results are "supposed" to be. 1B/H11** (BSL)

Values and Attitudes:

By the end of the 12th grade, students should

- Exhibit traits such as curiosity, honesty, openness, and skepticism when making investigations, and value those traits in others. 12A/H1*
- View science and technology thoughtfully, being neither categorically antagonistic nor uncritically positive. 12A/H2

and students should know that:

- In science, a new theory rarely gains widespread acceptance until its advocates can show that it is borne out by the evidence, is logically consistent with other principles that are not in question, explains more than its rival theories, and has the potential to lead to new knowledge. 12A/H3** (SFAA)
- Scientists value evidence that can be verified, hypotheses that can be tested, and theories that can be used to make predictions. 12A/H4** (SFAA)
- Curiosity motivates scientists to ask questions about the world around them and seek answers to those questions. Being open to new ideas motivates scientists to consider ideas that they had not previously considered. Skepticism motivates scientists to question and test their own ideas and those that others propose. 12A/H5*

Communication Skills:

By the end of the 12th grade, students should be able to:

- Make and interpret scale drawings. 12D/H1
- Choose appropriate summary statistics to describe group differences, always indicating the spread of the data as well as the data's central tendencies. 12D/H3
- Use and correctly interpret relational terms such as if... then..., and, or, sufficient, necessary, some, every, not, correlates with, and causes. 12D/H5
- Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions. 12D/H6
- Use tables, charts, and graphs in making arguments and claims in oral, written, and visual presentations. 12D/H7*
- Use symbolic equations to represent relationships between objects and events. 12D/H8**

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