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The Impact of Implementing Virtual Science Notebooks on Student Science Achievement in a Primary Classroom

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Abstract

This action research project investigated the impact of implementing virtual science notebooks on primary students' science achievement. Participants included twenty first grade students and their classroom teacher in a suburban, Minnesota school district. Students used iPads to complete virtual notebook pages after whole group instruction and independent learning time. Qualitative data collected included mid-intervention and post-intervention student and co-teacher interviews and researchers field notes and observations. Quantitative data included pre- and post-intervention rubric scores and a tally count of student inquiry. The data collected showed that students were highly engaged with their virtual notebooks and reported feeling more focused. However, there was no change in academic vocabulary and minimal change in student inquiry. The data collected suggests that more explicit instruction is necessary in academic vocabulary, while science notebooks do increase engagement in the science content and notebook entries.

Keywords: science notebooks, primary, virtual, inquiry, vocabulary

Science education in the United States has been through many phases and evolutions. These phases are spurred by the hope to improve and engage students in scientific concepts and develop their understanding of their world (Slavin et al., 2014). When students are engaged in the process of scientific inquiry, they are expanding their knowledge of the world around them and the interconnectedness of nature and human life. Students develop strategies for wondering, investigating, and summarizing (Maerten-Rivera et al., 2010). However, science scores have trended negatively in both state and national standardized tests. While an increase in time for science education was posed by many researchers as a solution to increase student achievement, many districts and state mandates do not allow for individual teachers to adjust set instructional times (Blank, 2013).

For this reason, science and literacy integration is highlighted as a way to increase time with scientific concepts (Cervetti et al., 2012). With this research on the importance of integration across subject areas, many curricula are implementing the use of science notebooks. Science notebooks have been a proven pathway to build academic vocabulary, scientific observation skills, and develop processes for experimentation (Aschbacher & Alonzo, 2006). However, when students are not engaged fully in their science notebooks, they are not developing these critical pieces.

In analyzing district and school data for a suburban school district in Minnesota, we see the same trend in state standardized science test scores. From 2016 to 2019, the percentage of students proficient in science standards dropped from 81.7% to 68.3%. This is a decrease of 13.4% compared to the state average of 6.8%. Reflecting on observations of students in a first-grade class, there is a problem with low student engagement in the scientific process, which we believe is causing low levels of science achievement. While our students do complete science notebooks, they often copy what is displayed for them on the board rather than engaging with their independent thoughts and work. We also observed that the students' questions are generally more surface-level than deep inquiry. Our students with low academic achievement in writing are disproportionately affected by the use of traditional science notebooks, which leads to further disengagement from this population. These students are often unable to express their understanding and mastery of a topic or are unable to revisit work if they could not record their previous observations. This action research seeks to understand if developing a virtual notebook to provide students additional opportunities to express their ideas, make observations and connections, and create visual representations of scientific concepts will increase student engagement and achievement.

Theoretical Framework

The constructivist theory focuses on the idea that students construct their knowledge themselves based on previous knowledge (Bruner, 1966). Within this theory, language is highlighted for its important role in learning. It is stated that children need time to advance their conceptual learning alongside their language learning. Bruner (1966) identifies three modes of representation: enactive, iconic, and symbolic. These stages focus on the way knowledge is stored in memory. The enactive stage is the first stage based entirely on physical actions. Students learn through the cause and effect of physical interactions with their world. After about one year they transition into the iconic stage. The iconic stage identifies that learners store information as sensory images such as visuals in the mind. This can be unconsciously or consciously. Diagrams and illustrations are visual constructs that learners in the iconic stage use along with verbal information. At about seven years old, students move into the symbolic stage of learning. In this stage, information is now stored in language and can be classified and manipulated (Bruner, 1966).

In science education, the constructivist theory states that students build upon their previous knowledge of science concepts to continue developing a conceptual understanding of the world. The use of science notebooks in classrooms provides students the opportunity to represent these self-built constructs through both iconic and symbolic representations (Fitts et al., 2020). Students are simultaneously learning to use symbolic language for abstract concepts as well as building on the work they previously completed to make connections between prior knowledge and new learning. Huerta et al. (2014) indicates that the modes of representation can also be replicated in virtual science notebooks while students are learning and revisiting past ideas. Students can manipulate the images and iconic representations while attaching them to symbolic representations through typed words and recorded explanations.

Review of Literature

Student achievement in the academic area of scientific knowledge is declining in elementary schools (Nations Report Card, 2019). Often those factors are identified as problems with curriculum or decreasing instructional time devoted to science education. However, other factors exist, such as low student achievement in other subjects, language status, and teacher preparedness. This literature review identifies research that examines the decline in science achievement, explores contributing factors, and analyzes interventions to improve student achievement in science.

Exploring Contributing Factors

In exploring where the learning gap in science education begins, Maerten-Rivera et al. (2010) and Huerta et al. (2016) find that students who enter elementary school with low overall academic achievement and specifically low achievement in reading and math are more likely to have low achievement scores in science as well. Students with low reading ability can often struggle to make inferences and recall written information (Maerten-Rivera et al., 2010). In agreement with Maerten-Rivera et al. (2010), Huerta et al. (2016) find that "young struggling readers often acquire lower vocabularies. . . , have less general knowledge, display less cognitive ability, and are often less able to comprehend science texts and generate science-related inferences" (p. 20).

First language is an additional factor found by researchers to affect science achievement. Morgan et al. (2016) report that "the 50th-percentile score of those who are English language learners (ELL) is lower than the 10th-percentile of those who are non-ELL" (p. 18). One cause is that English language learners do not often receive science content, in favor of additional time spent on literacy and math instruction (Maerten-Rivera et al., 2010). This study also found that after controlling for conflicting variables, English language learners would, on average, perform twenty-three points below non-English language learners on science achievement tests (Maerten-Rivera et al., 2010). Von Secker and Lissitz (1999) turn to English language learners' vocabulary acquisition as a contributing factor to low science achievement. They also argue that the current pedagogical shift from teacher-centered instruction to student-centered instruction will not impact student achievement unless basic academic and scientific vocabulary is in place.

Teacher preparedness also contributes to low student achievement in science. Kleickmann et al. (2016), Slavin et al. (2014), and Zangori et al. (2013) agree that (1) Teachers are underprepared in elementary schools to teach inquiry-based science content; and (2) Common science curricula do not meet research-based best practices for elementary classroom instruction. Slavin et al. (2014) state, "Previous descriptive research has supported the observation that when teachers are given science kits, their focus can be on implementing the materials rather than on building deeper understandings among students" (p. 895). Slavin et al. (2014) continue the argument that kit-based curricula are introduced to be easier for teachers to implement than inquiry-based curriculum, despite lower achievement results, specifically kits with pre-set, hands-on activities. Zangori et al. (2013) agree that students do not receive evidence-based explanations with a standard science curriculum. Kleickmann et al. (2016) focus on the issue that elementary school teachers are generalists and often do not feel prepared to deliver content more deeply for inquiry-based learning when it is not a part of the curriculum.

Interventions Aimed to Raise Science Achievement

The interventions laid out in this section aim to address the factors identified by previous research on student science achievement. These interventions include a range of methods, including teacher professional development and adjustments to content and pedagogy.

Teacher Professional Development

Kleickmann et al. (2016) and Slavin et al. (2014) agree that teacher professional development is at the core of increasing teacher content knowledge. Kleickmann et al.

(2016) studied scaffolded professional development opportunities and their impact on teacher preparedness and student achievement. The researchers found that the group with a higher level of scaffolding throughout their professional development experience saw higher student achievement rates than those in the self-study group. This points to the impact of guided professional learning opportunities for teachers of science content.

Slavin et al. (2014) find that an inquiry-based professional development curriculum has a more significant impact on student achievement, as these curricula include science pedagogy and content-specific knowledge.

Science Notebooks

Linking factors surrounding low general academic achievement and science vocabulary, Rappolt-Schlichtmann et al. (2013) find that the implementation of science notebooks provides students with the chance to develop and engage in the scientific process of critical thinking and observation. Ruiz-Primo and Li (2004) agree that science notebooks allow students to participate in authentic methods such as building text and diagrams for a specific scientific purpose and audience. In a science notebook, Rappolt-Schlichtmann et al. (2013) claim "students are expected to learn actively through observation and interaction, rather than direct instruction" (p. 1210). Aschbacher and Alonzo (2006) focused on the insight science notebooks can provide to educators for formative assessment. They found that scores on science notebooks were more indicative of how students would perform on a hands-on experiment than other assessment methods. Aschbacher and Alonzo (2006) also provided that science notebook entries offer a glimpse into current understanding before a summative assessment. Ruiz-Primo and Li (2004) build on the idea of science notebooks as a formative tool for teachers and argue that they also allow students to begin to develop their metacognitive awareness and self-assessment skills.

Rappolt-Schlichtmann et al. (2013) look specifically at implementing virtual science notebooks to increase student science achievement while removing the burden of reading and writing. The researchers implemented their web-based notebooks in a diverse group of fourth-graders. Their sample consisted of six hundred twenty-one students and twenty-two teachers. This study developed a universally designed web-based science notebook that removes irrelevant barriers students face when completing traditional notebooks. These barriers include low reading and writing achievement. The web-based notebooks provided the ability to audio record responses and draw instead of writing. Rappolt-Schlichtmann et al. (2013) found that their web-based notebooks raised students' achievement with low reading and writing proficiency and among students who previously showed low motivation.

In meeting the needs of students in marginalized communities such as English language learners, science notebooks provide an opportunity for rich content instruction and language acquisition. Aschbacher and Alonzo (2006) found that notebooks can measure different facets and nuances of understanding, thus creating a more well-rounded picture than a summative assessment alone. This provides opportunities for students to show knowledge in ways other than needing to read and interpret questions in a second language. Wilmes and Siry (2019) also found that science notebooks gave students the opportunity to have a multimodal interaction with science inquiry instruction "supported students in representing their understandings in diverse ways" (p. 1017). Huerta et al. (2016) studied how science notebooks can help students from linguistically diverse backgrounds grow their academic language while simultaneously growing their knowledge of science concepts. They attest that using science notebooks to teach academic vocabulary specifically showed a positive contribution to student achievement.

Science in Literacy Instruction

Cross-curricular instruction can address the opportunities for students to build achievement in multiple areas simultaneously and with concurrent support for both content areas. Liston and Hennesey (2018) identify that science instruction has complementary skills and elements to literacy instruction. These include but are not limited to "making connections through questioning, exploring, experimentation and reflecting . . . all of which are carried out through exploratory talk, dialogue, reading and writing" (p. 20). Cervetti et al. (2012) also found that students who participated in an integrated literacy and science program showed positive achievement results. Specifically, the implementation of genre-based reading programs, which is gaining significance in education, can help combine literacy and student interest in understanding their world (Cervetti et al., 2012). Aschbacher and Alonzo (2006) agree that an integrated approach can raise achievement in both literacy and science concurrently. They identified that writing opportunities in science instruction could grow both science process skills and general writing ability. Cervetti et al. (2012) also found that scientific inquiry can guide further writing ability and motivation.

Conclusion

The literature review identifies the contributing factors to low science achievement for elementary students and describes some interventions that address those factors and raise student achievement. The interventions included teacher professional development opportunities, science notebook implementation, and cross-curricular instruction specifically focused on integrating science and literacy. There are additional interventions that meet the needs addressed in the research. Based on these findings, my action research will focus on the implementation of virtual science notebooks and the impact on elementary science achievement.

Methodology

The action research design of this study is experimental, seeking evidence of the effects of implementing virtual science notebooks on elementary students' achievement. Action research is defined as research completed with the goal of improving practices within the classroom (Hendricks, 2017). Both quantitative and qualitative data were obtained during this study. The qualitative data obtained included student and instructor interviews along with field notes and daily reflection. Notebook rubrics and a student inquiry checklist provided quantitative data for the study.

Participants

The population for the research was from one first-grade classroom in a large, suburban elementary school in Minnesota. The classroom teacher was also a member of the research population. The sample included 21 students, 11 male and 10 female. The classroom consisted of 73% white students, and 23% percent of students were eligible for English language learning services. No students were receiving special education services at the time of instruction. 35% percent of the students received tier two or tier three intervention services for reading. All students in the study were continuously enrolled during the intervention. After the classroom was identified for the research, all participants provided consent. All students had access to a learning management system through an iPad to complete their virtual notebooks.

Data Collection Tools

Mid-intervention and post-intervention surveys (see Appendix A) were conducted with both students and the classroom teacher. The questions were the same for both interviews, but the opportunity to elaborate or ask a follow-up question was permitted in the interview. The questions were designed to provide insight into the student and teacher perspectives of the intervention. For students, they were asked about their learning progression and their engagement with the intervention. The co-teacher was asked to reflect on their understanding of the intervention's impact on student achievement. Field notes and post-observation reflections (see Appendix B) were used to record observations and identify opportunities for the next class period. Students were observed on their engagement, understanding, and completion of the task. Anecdotal notes also provided setting context, reminders of surprising or unplanned events, and nuances of behavior in relation to the intervention.

A student inquiry checklist (see Appendix C) was used during observation periods to record student questioning. The checklist counted and categorized student questions into content-focused and non-content-focused. Further broken down, the questions were then categorized by: extending, clarifying, process, or technology questions. After an initial baseline observation, the student inquiry checklist provided more robust insight into the impact of the intervention. Scoring rubrics (see Appendix D) were filled out for students both pre-intervention and post-intervention. The rubrics provided numerical scores for each student's product to be compared against each other for evidence of change. The data gathered focuses on inquiry, organization, academic vocabulary, and content knowledge.

Procedure

Before beginning the intervention, student notebook entries from a previous science unit were scored using the scoring rubric to determine a baseline score for each student. There was also an initial observation for baseline data on the student inquiry checklist. Students received instruction on different animal habitats during the intervention, focusing on one habitat each for two days. The co-teacher and the researcher alternated teaching days. Students were expected to study a specific habitat through whole group instruction during the co-teacher instruction days. The students received instruction through read alouds, videos, discussions, and virtual field trips. During this instruction, the researcher collected data on student inquiry using the student inquiry checklist. The researcher also conducted field observations during these lessons. On the days the researcher provided the classroom instruction, students were expected to study their habitat independently through digital books assigned to them. They were then instructed to draw a picture of the habitat in a physical notebook, upload the picture to the digital learning platform Seesaw, and record or type three things they learned from their research about the habitat. Students were encouraged to add labels, use scientific words, make connections across habitats, and document their wonderings. This pattern of two days per habitat was repeated until all seven habitats were discussed.

By the end of the intervention, students had completed sixteen virtual notebook pages. The virtual notebooks were then scored using the same rubric as at the beginning of the intervention. Eighteen days of field observations were completed, along with nine days of completing the student inquiry checklist. Midway through the intervention, four students were asked to participate in individual conferences about their experience during the intervention. The co-teacher was also asked to participate in a semi-structured interview to provide insight into the effectiveness of the intervention. These conferences were then repeated at the conclusion of the intervention with the same participants. The rubrics, student inquiry checklists, and conference notes were compared for changes in scores or responses from the two different time points. The field notes were analyzed for indications of engagement and behaviors not otherwise indicated in the additional data collection tools. These qualitative and quantitative data collection methods created a well-rounded view into the impact of virtual science notebooks in primary classrooms.

Analysis of Data

The purpose of this study was to investigate the impact of virtual science notebooks on primary students' engagement, inquiry, and achievement in science concepts. Both qualitative and quantitative data were gathered while students learned about animal habitats. Students completed virtual science notebooks with voice recordings, pictures, drawings, and text to show their understanding of each of the types of habitats.

Engagement with Technology

The first research question of this study focused on student engagement while using virtual notebooks. One of the ways the research looked at engagement was through the field notes taken by the researcher. These notes contained observations about individual student engagement as well as whole class engagement. Observations were conducted on both days where students were learning from their classroom teacher and on days where they filled out their virtual notebooks. A sample of students was also interviewed about their engagement during a mid-intervention and post-intervention survey. The students were asked open-ended questions, “Tell me how you do or do not like using your iPad to work on science notebooks?” and “Do you feel more focused working on the iPad than when you wrote them in your “real” notebook? Why?”. The co-teacher was also interviewed about her thoughts on student engagement levels both during and after the intervention. She was asked, “Do you see an increase in engagement from traditional science notebooks to virtual notebooks? What type of engagement do you notice or not notice?” These interviews were transcribed, coded, and analyzed for themes and connections to other data collected.

Academic Vocabulary

Another research question in this study was students’ use of academic vocabulary while implementing virtual science notebooks. Along with classroom observations, students had their notebooks, both physical and digital, analyzed for their use of academic vocabulary. Specifically, the research was looking at a change in science-specific vocabulary usage between physical notebooks and virtual notebook implementation. Physical student notebooks from a previous unit were scored on a rubric (see Appendix D) with the target objective, “Students should incorporate the correct scientific names and process vocabulary”. This same rubric was then used after the intervention to evaluate the student's entries in their virtual science notebooks. Student scores were coded under their pseudonyms and compared to their initial scores in each category. Field notes and observations also provided insight into the academic vocabulary usage of students. It was noted when students used scientific names or process words in their inquiry or discussion during class. During the student interviews, they were asked the open-ended question, “Do you ever change a word you have written to be a word that scientists would use? How do you pick the right word?”. The teacher was also asked to discuss their observations of achievement, specifically related to the use of academic vocabulary.

Student Inquiry

Student inquiry was another focus of the research. It questioned the change in types and frequency of student questioning, along with comments of wonder and curiosity in their science notebooks. A tally chart was created to track and monitor student questions during whole group portions of the lessons. Students were observed as a class for their number of questions in each category: extending question, clarifying question, process question, or technology question. Extending and clarifying questions were labeled as content-focused, while process and technology questions were labeled as non-content-focused questions. An example of an extending question was, “What happens if an animal had to live in a different habitat” while a clarifying question example would be simpler, such as, “Do polar bears live in the artic?”. Technology questions focused on students needing support with how to use the technology, for example navigate the app, turn on sound, or take a picture. Process questions included clarifying the directions of the assignment and structure of their independent work time. There was a baseline taken for the first two days of the unit, this was then compared to the data taken during the intervention for changes in types and number of questions. Student inquiry was also a topic in the student and teacher interviews. Students were asked, “How often do you have a question about science that you want to know the answer to? What do you do to answer that question?" while the teacher was simply asked to discuss her observations of student inquiry and potential changes they saw. The scored rubrics also had objectives focused on student inquiry. Students were expected to show observations, understandings, and inquiries in their notebook entries.

Findings

Student Inquiry

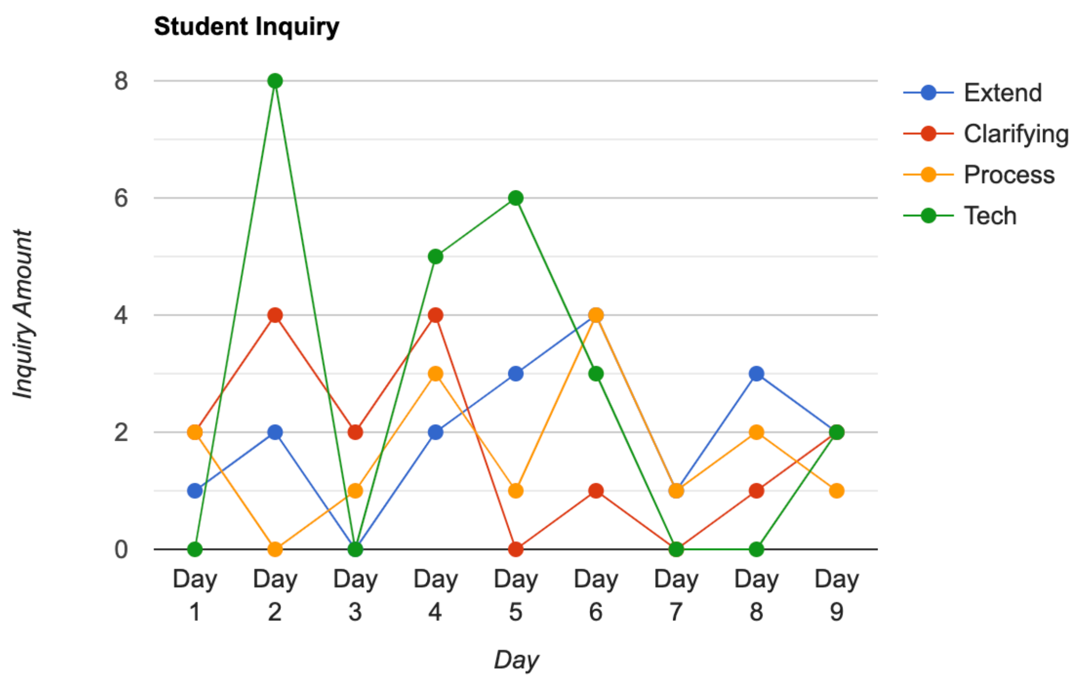
Qualitative data shows student inquiry changes from before the intervention to during the intervention (see Appendix C). Table 1 shows the average amount of question types per class period. This is separated by the baseline week lessons and the lessons during the intervention, along with a column for the change in average. The increases in questions came in the form of extending questions and process questions. There was a decrease in clarifying questions, most likely due to the increase in extending questions. There was no change in the average questions regarding technology. However, observations showed that there was a change in the type of technology questions that were asked. Observations also showed that on whole group learning days, more extending questions and clarifying questions were posed than on days when the independent practice was more prevalent.

Table 1. Average student question type at baseline and during intervention

Type of Question	*Baseline week average*	*Average per observation*	*Change*
Extending Question	*1*	*2.5*	*+1.5*
Clarifying Question	*2.7*	*1.4*	*-1.4*
Process Question	*1*	*1.5*	*+.5*
Technology Question	*2.7*	*2.7*	*0*

Figure 1 below highlights the change over time for student questions. While there was no consistent pattern because the values were often so close to each other, there was a significant spike of technology questions on day two. This is the day that the virtual notebooks were introduced, modeled, and practiced. There is a natural correlation between the days when technology was used heavily and the days in which more questions about technology were asked.

Figure 1. Student inquiry type by day.



Student and Teacher Interviews

Student and co-teacher semi-structured interviews (see Appendix A) were conducted three weeks into the intervention to identify students' and teachers' perceptions of the intervention's impact thus far. When students were asked about their engagement with the technology while completing their work, one student shared, "I feel more focused because there are not papers spread out and lots of tools like a pencil and colored pencils, fewer things." All five of the students interviewed agreed that they felt more focused while working on the iPad than in their physical notebooks. The most common response centered around not using a pencil and recording their answer. Three of the five students enjoyed recording themselves, while two responded that they didn't like recording their voices. However, they both said no when prompted to explain if they would prefer to type their responses. All students interviewed agreed that they did not think about academic vocabulary when adding content to their virtual notebooks, though one student did identify that they would try "different words that had the same meaning to find the shortest one."

During the co-teacher midpoint interview, the teacher mentioned that she saw increased student engagement from the beginning of the unit until now. This increased engagement was particularly noticeable from students questioning. They noted that "students are beginning to ask more questions rather than make statements about what they already knew." The teacher was encouraged that the students were beginning to wonder about the topic and wasn't sure yet if that was carrying over into their notebook entries. She also noticed increased content the students were consuming about their habitats. She cited that the switch to digital learning formats such as e-books and learning videos seemed to keep their attention and engagement longer than traditional print resources. At the midpoint, she felt that the "policing" of student behaviors while using technology was taking away from the learning time of some students in class. She noticed that some students who typically completed their physical notebook entries struggled to stay focused with the iPad and did not complete the virtual notebook entry in the time allotted.

In the post-intervention interviews with students, conducted after the final notebook submission, students again reiterated that they enjoyed using virtual notebooks more than physical ones. Students also stayed similar to their midpoint responses regarding their focus and engagement while completing their work. An additional theme from the interviews focused on students sharing more in their recordings than writing or typing their responses. One student mentioned that they would use a word that scientists use; however, the other four did not notice a change in their academic vocabulary. Responding to the prompt asking students what they do when they have a question they would like answered, the majority of students shared that they would simply ask their teacher. Two students shared that they did not know what to do.

The co-teacher followed-up her comments from the midpoint interview about the type of engagement increase she was seeing. She now noticed a change within their science notebooks instead of just during class discussions. During their recordings, she saw a difference in the students' content knowledge and vocabulary usage. However, she did not observe a change in inquiry responses. After the midpoint concerns about the distraction technology could be, she believed that the initial setup took more time but then became a routine that was just as fast each day as the physical notebook routine. She stated, “While the notebooks took more time to set up than traditional physical notebooks, the students took more opportunities to think about their learning through the virtual resource rather than writing in their notebooks.

Rubric Scores

Table 2. Change in Student Scores from Pre-Intervention to Post-Intervention

Change in Score	*Number of Students (Percent of Class)*
Positive change in score	*14 (64%)*
Negative change in score	*2 (9%)*
No change in score	*6 (27%)*
Positive score change over two points	*3 (14%)*
Negative score change over two points	*1 (5%)*

Table 2 above shows the change in student scores on a rubric (see Appendix D) that was completed for the summative physical student notebooks from a previous unit and was also completed post-intervention for the virtual student notebooks. Only two students received a negative score change and only one student saw a significant negative score change over two points. Most students saw a positive difference in their scores from their physical notebook scores.

Field Note Observations

As the intervention progressed, there were observations of progress in the three areas of questioning, technology engagement, and academic vocabulary (see Appendix B). The field notes provided not only observations of the class as a whole and individual students but also gave context to the data described above.

At the beginning of the intervention, students struggled to phrase their statements into questions. Instead, they focused more on what they already knew about habitats and shared those facts during the discussions. When prompted to ask questions, they focused more on their interests than the lesson's content. As the intervention progressed and students dug deeper into their learning, there was an observed shift from statements to questions in whole group discussions. There was also an observed shift in the types of questions that were asked. At the beginning of the intervention, questions were more basic rather than extending their learning. They were looking for confirmation of what they already knew. As the intervention went on, the questions turned more towards wonderings than questions with a straightforward yes or no answer.

The observations with technology also changed throughout the intervention. Many students were initially very distracted by the iPads and could not stay engaged with their work. They instead were showing their friends how to do certain things, such as emojis or text-to-speech. As the intervention progressed and students learned the routine, most students were much more focused while using their devices than at the beginning of the intervention. One observation of six students showed they were hesitant to record themselves in the notebooks initially. They preferred to type their responses or record further away from the classroom. As they watched their peers record more freely, it was observed that those students became more comfortable with the recordings, and by the end of the unit, every student was recording their voices openly in the classroom. Another observation was that as the intervention went on, the students took less time to complete their notebooks and spent more time engaging with the learning resources. They also developed a preferred way to structure their time, with some students reading the sources then completing the notebook entry and some students choosing to go back and forth between the two.

The field observations of students' academic vocabulary were focused only on discussions during whole group learning. In these discussions, a trend appeared where students who had high levels of interest in the subject matter tended to use scientific vocabulary more frequently than students who were less curious or interested in learning about habitats. As the students discussed habitats more frequently and more in-depth, students began substituting their vocabulary for scientific names. A change in the use of science process words was not observed.

Action Plan

The purpose of this research study was to investigate a possible opportunity to close achievement gaps and enhance science education for first-grade students. After analyzing the data collected in this study, it is evident that students were engaged and responsive to virtual student notebooks. The study also concluded that most students shared more of their knowledge in a recording format than they had previously shared in a written format. It was clear through student interviews and observations that students preferred to use their devices to demonstrate their learning versus physical notebooks. The study also showed that additional interventions must be in place to see increases in student academic vocabulary usage and consistent growth in student inquiry.

While it was observed that the initial setup and routine building procedures for virtual notebooks took time, we also saw the benefits that these virtual notebooks provided. With this in mind, intentional instruction is critical to the continued success of virtual notebook implementation. We saw the benefits of modeling how to access the notebook, navigate to the next page, and how to record and take pictures with their device. Students later in the intervention were able to seamlessly navigate these tasks to allow for more individual learning time. This engagement was also reflected in other pieces of data. The individual student interviews (see Appendix A) and observations of the co-teacher and researcher (see Appendix B) indicated that students felt more focused while completing the science notebooks and were engaged for longer periods of instruction than with the physical notebooks. This is in part because recording their responses through a microphone was simply faster than physically writing their responses. Students had more time during independent work to analyze resources and discuss with their peers.

The data collected also shows a noticeable change in the types of questions students asked throughout the intervention. These changes tended to mirror each other, as one type of question increased in frequency another type of question decreased in frequency. One particular piece of data shows the students moving from one depth of knowledge to another. As students increased their extending questions, it is natural to see a decrease in clarifying questions. Students are moving beyond basic understanding into higher-level thinking, making connections, and questioning beyond the information presented. While deeper inquiry demonstrated within the science notebooks can be attributed to the simplicity and the removal of the writing barrier, the increase in this inquiry does not have enough evidence to support that science notebooks impacted the student's ability to develop these questions. Rather, it simply shows that students are able to express their thinking more clearly through virtual notebooks rather than physical notebooks. It should also be noted that it is common for students to increase their inquiry as they progress through the subject matter. Naturally, students develop a deeper understanding of the content and begin to make connections for further learning opportunities.

Two recommendations for the future include (1) direct and explicit instruction in academic process vocabulary and subject-specific vocabulary and (2) creating opportunities for students to share their knowledge in a variety of formats.

In regard to the first recommendation, our study found that there was no evidence to suggest that students developed a repertoire of academic vocabulary words through this work. We did see an increase in usage over the physical notebooks, but again, we contribute that to their ability to record themselves. There was no significant increase in academic vocabulary usage by students during discussions. Students who already used academic vocabulary continued at the same rate, while no students began using academic process vocabulary or scientific terminology who did not already use it prior to the intervention. These findings suggest that students need more explicit instruction in vocabulary, alongside opportunities to use and develop these terms in their daily repertoire.

The second recommendation comes from our observation of student achievement and rubric score (see Appendix D) growth. Students showed improved growth in their rubric scores from the physical notebooks to the virtual notebooks. Many of the students who showed significant improvement, score changes over two points, were most often students who had lower writing skills than their peers. These students showed a content knowledge level that was higher than their academic writing level. For this reason, it is a recommendation that educators create multiple opportunities and methods for students to demonstrate their learning.

A question that arose from the study had to do with the bridge that can and should exist between physical and virtual notebooks. Where do the benefits of writing and drawing physically, outweigh the benefits of virtual opportunities? More research is needed to compare varying levels of virtual and physical notebook implementation to identify the long-term benefits of both types. This lack of understanding of the deeper implications and limitations of this study led to our recommendation of a variety of methods to demonstrate learning rather than recommending virtual methods only.

Despite no indications of growth in academic vocabulary and impact on the development of deep inquiry, virtual science notebooks did show an impact on student achievement in a primary classroom. Students were able to gain additional learning time, demonstrate their content knowledge in a format that removed the writing barrier, and show increased achievement in scores on an assessment rubric.

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Appendix A

Student and Teacher Semi-Structured Conference
Sherman
Action Research 2021-2022

Semi-structured conferences will be held once in the middle of the intervention and again at the end. Listed below are the topics I hope to cover in each discussion, but the conference will be mainly guided by the responses received.

Topic	Student Questions	Teacher Questions
Engagement	Tell me how you do or do not like using your iPad to work on science notebooks? Do you feel more focused working on the iPad than when you wrote them in your "real" notebook? Why?	Do you see an increase in engagement from traditional science notebooks to virtual notebooks? What type of engagement do you notice or not notice?
Achievement	Are you ready with ideas when you start your notebook page or does a teacher need to help you most times? What makes you ready to start? Do you ever change a word you have written to be a word that scientists would use? How do you pick the right word? How often do you have a question about science that you want to know the answer to? What do you do to answer that question?	During observations or formative assessment, do you notice a change in student achievement along the lines of vocabulary, content knowledge, or inquiry?
Technology	Is it easy to add to your notebook? Why or why not?	What are your feelings about the instructional time needed to set-up virtual notebooks versus the impact on achievement and engagement?

Appendix B

Field Notes
Sherman
Action Research 2021-2022

Date:	**Learning Target:**
Student Notebook Entry:	
Observations:	
Reflection:	
Next Steps:	
Time Spent:	Content Instruction: ____________ minutes Student Notebooks: ____________ minutes Feedback: _____________ minutes
Student Engagement: **0 1 2 3 4 5**	

Appendix C

Student Inquiry Checklist
Sherman
Action Research 2021-2022

Baseline

	Content Focused		Non-Content Focused	
Date	Extending Question	Clarifying Question	Process Question	Technology Question

During Intervention

	Content Focused		Non-Content Focused	
Date	Extending Question	Clarifying Question	Process Question	Technology Question

*Each tally represents one unique question in each category

Appendix D

Science Notebook Rubric
Sherman
Action Research 2021-2022

		Three Points	Two Points	One Points	Zero Points
	Organization Each page should have a title, date, picture/photograph, and description.	Ready for presentation! Each page contains the elements listed in an appealing, easy to read format.	Almost every page has a descriptive title, formatted date, picture or photograph, and description of the content in an easy-to-read format.	Could stand revision by incorporating all elements on each page and/or updating the format.	The notebook is not completed
	Academic Vocabulary Students should incorporate the correct scientific names and process vocabulary.	Students frequently incorporate academic and scientific descriptors to provide in-depth visualization and description of the content.	Students used proper academic vocabulary and other descriptors that match grade-level understanding of content and processes.	Students used proper academic vocabulary occasionally and mainly used other descriptors, but could stand to update more basic terms.	Students did not use proper academic vocabulary.
	Inquiry-Based Students wrote both observations and further inquiry.	Students reflected on the observations/findings and wrote many additional further questions or next steps.	Students reflected on the observations/findings and wrote further questions or next steps.	Students recorded the observations/findings.	Student did not complete the recording.
	Content Knowledge Students have accurate knowledge of the content.	All pages display accurate knowledge of the content.	Almost all pages display accurate knowledge of the content. Two or fewer inaccurate facts.	Most pages display accurate knowledge of the content. Three or fewer inaccurate facts.	There are frequent inaccurate facts in the notebook entries.
	Totals:				