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NASA eClips™ Interactive Lessons: A Three-year Study of the Impact of NASA Educational Products on Student Science Literacy

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NASA eClips™, developed by the National Institute of Aerospace (NIA) in partnership with NASA, provides educators with standards-based educational resources that seek to increase student science, technology, engineering, and mathematics (STEM) literacy through the lens of NASA. Over the past four years a new project within NASA eClips™, NASA Spotlite, has been rigorously tested exploring the impacts of students developing and using short videos to understand and address science misconceptions. Foundational partnerships with schools plus online hosting by commercial partner Nearpod enabled the team to broaden its audience. A comparison of three years of NASA Spotlite lesson research supports the findings that student engagement with the lessons significantly impacted their understanding of commonly misunderstood science concepts. In a quasi-experimental study with over 100 students, some overall positive significant changes in student content knowledge were recorded, while major student achievement differences based on lesson delivery format were confirmed. Positive changes in student science literacy resulted through both instructional modes, though less for those experiencing the more traditional lesson delivery via interactive PDFs than those for whom the delivery was via Nearpod. This work illustrates the importance of fidelity of lesson implementation and how choices in the use of instructional technology may impact lesson delivery.

Keywords: Science literacy, NASA, online, STEM, science, technology, implementation, standards-based

INTRODUCTION

"NASA's journeys have propelled technological breakthroughs, pushed the frontiers of scientific research, and expanded our understanding of the universe. These accomplishments, and those to come, share a common genesis: education in science, technology, engineering, and math" (NASA, 2018).

Shortly after NASA began the Space Act decree of 1958, it started capturing the attention of our nation and in so doing, the imagination of our nation's children (NASA History Office, 2019). Throughout the decades, NASA has developed educational programs focused on bringing science to learners of all ages in ways that *only NASA can.* Continuing in that tradition, NASA eClips™, developed by the National Institute of Aerospace (NIA) in partnership with the NASA Science Mission Directorate, provides educators with standards-based educational resources that increase Science-Technology-Engineering-Mathematics (STEM) literacy through the lens of NASA. This study explores the effectiveness of one of the NASA eClips™ resources, lessons designed to use NASA Spotlite student-produced videos. NASA Spotlite is a new project within the NASA eClips™ portfolio of learning experiences that focuses on helping students address science misconceptions.

Student misconceptions and gaps in basic science content are common and significant barriers to learning (McKenna, 2014). Students with gaps in knowledge and misconceptions are unable to scaffold their understanding to a deeper level and will often retain initial misconceptions until they are provided with a more compelling explanation or experience (McKenna, 2014). This is a significant concern for students and has been documented within the Nation's Report Card (2016). The Nation's Report Card communicates elementary and secondary students' achievements in various disciplines based upon the findings of the National Assessment of Educational Progress (NAEP). NAEP is congressionally authorized within the Institute of Education Sciences of the U.S. Department of Education. Students' science achievement levels are consistently low. For example, a representative sample of 110,900 eighth graders participated in the 2015 NAEP science assessment that measures students' knowledge and abilities in the areas of physical science, life science, and Earth and space science. Although scores in science increased slightly from 2011 to 2015, the recent report card indicates that approximately two out of every three eighth graders lack basic scientific knowledge (Zelazo, Blair & Willoughby, 2016).

LITERATURE REVIEW

Classroom teachers are tasked with developing 21st century skills in their students and often turn to the Internet to find educational materials such as videos, activities, and visualizations to incorporate into their lessons (Gold, Ledley, Buhr, Fox, McCaffrey, Niepold, Manduca & Lynds, 2012). NASA has a long history of providing educational resources and educators continue to seek out these resources utilizing sites such as NASA.gov/stem and Science.NASA.gov (NASA History Office, 2020). NASA eClips™ materials are included in NASA's offering of educational resources.

Conceptual Knowledge and Misconceptions

Knowledge of student misconceptions is a critical tool for science teachers (Patil, Chavan & Khandagale, 2019). Demonstrations and student questioning can help teachers probe for and assess their students' prior knowledge to identify misconceptions and establish a baseline for learning. Without this baseline, it is nearly impossible to change student ideas (Reuell, 2013). Students must be given an opportunity to construct or reconstruct an accurate framework for new knowledge (Fairweather, 1999).

While conceptual change requires multiple modalities of learning, many prominent educational researchers, including Robert Marzano (2005), identify a strong relationship between vocabulary and one's ability to comprehend new information (McKenna, 2014). Additionally, students must encounter words in context more than once to learn them. Marzano contends that one of the best ways to learn a new word is to associate an image with it. Imagery-based techniques produced achievement gains 37 percentile points higher than gains produced by techniques that merely focused on having students review word definitions (Marzano, 2005). Marzano also found that the effects of vocabulary instruction are even more powerful when the words selected are those that students encounter when attempting to learn new content. He identified a five-step strategy for teaching new terms and phrases that builds on the opportunity for students to construct their own explanations or descriptions of the targeted term or phrases which led to the Frayer model (Frayer, Frederick, & Klausmeier, 1969). The Frayer model uses a graphic organizer guiding students to use inquiry to learn new concepts and develop vocabulary in science and math (Dunston & Tyminski, 2013). Students demonstrate their understanding and construct meaning by providing examples from their own lives and experiences, increasing the level of critical analysis required and going well beyond traditional vocabulary development (Nesbitt, Baker-Ward & Willoughby, 2013). Frayer models take vocabulary beyond definitions as students develop conceptual knowledge of vocabulary.

The American Association for the Advancement of Science (AAAS) identifies building conceptual knowledge and developing an understanding of scientific concepts and processes as key components of student science literacy (1989; 2011). Three of the basic tenants of scientific literacy have been described by the National Academies (1996) as: 1) knowledge of the substantive content of science, 2) ability to think critically about science and the natural world, and 3) having scientific or technical knowledge. While there is still active debate within the scientific and educational communities about the “definition” of scientific literacy (Braman, Kahan, Peters, Wittlin, & Slovic, 2012), the practical application is most often scientific content knowledge and civic scientific literacy as described and tested, over 20 plus years of research, by Jon Miller of the University of Michigan and Director of the International Center for the Advancement of Scientific Literacy (Miller, 2016). The importance of scientific literacy cannot be understated as the United States continues to show a declining scientifically literate public (Miller, 2016).

Strategies to Remove Misconceptions

NASA eClips™ is a NASA supported project that, “brings together exciting video segments and resources with educational best practices to inspire and educate students to become 21st Century explorers” (nasaeclips.arc.nasa.gov). One of the resources offered by NASA eClips™ is NASA

Spotlite lessons which give teachers a complete lesson containing national standards alignment, time frame for delivery, materials, background, and a student-created video to build awareness of common science misconceptions. For example, the Spotlite Ozone lesson addresses the misconception that there is a “hole in the ozone,” guiding students to the scientifically correct understanding that it’s not truly a hole, but a thinning and decreased concentration of the ozone layer within Earth’s atmosphere. This lesson and all Spotlite lessons adopt three main focus areas: 1) 5E Learning, 2) the Frayer Model for vocabulary building, and 3) the use of student-produced videos addressing the misconceptions. The five phases of the 5E Model (Engage, Explore, Explain, Elaborate, Evaluate) provide a planned sequence of student centered instruction and encourages students to construct their understanding of the science concepts through exploration (Bybee, 2014). The Frayer Model utilizes a graphic organizer which provides students an opportunity to develop and clarify their understanding through comparing and contrasting word characteristics and identifying examples (Greene & Coxhead, 2015). Combining these proven learning enhancement methodologies with student-produced videos addressing science misconceptions represents a novel approach to promoting student science literacy. The need to determine approaches that are successful for increasing student’s science literacy led to two research questions listed below and further described in this paper.

Research Questions

1. What impact do the NASA Spotlites Clouds and Seasons lessons have on student science literacy?
2. What effect does delivery platform have on student performance and educational value?

METHODOLOGY

Our mixed methods research design incorporated both quantitative and qualitative data in a deductive research methodology. Working with primary data, the work focused on experimental findings while incorporating descriptive data where possible and appropriate. Experimental data consisted of student pretest and posttest results and educator survey responses. Descriptive data consisted of self-reports from educators on post experience surveys. The research criteria were adjusted throughout this three-year study based on outcomes reflecting the evolving formative assessment and refinement of the research questions.

Research Focus and Design

The research questions were formulated from prior work with the lessons and vetted through a teacher advisory board. This refined focus factored in the need to assure the fidelity of NASA Spotlite lesson implementation in an effort to increase the scalability of lesson use and positively impact changes in students' science literacy. The research focus, design, and questions are included in Table 1.

Table 1
Research Focus, Design and Research questions

Research Focus	Research Design	Research Questions
Fidelity of model implementation utilizing two digital platforms to: 1) increase the number of students in the study and 2) test the differences in the two technologies of Nearpod, an online learning environment and iPDFs, interactive PDF documents accessed online	Fidelity of implementation with pretest-posttest and non-equivalent groups. Teacher post survey	1. What impact do the NASA Spotlites Clouds and Seasons lessons have on student science literacy? 2. What effect does delivery platform have on student performance and educational value?

Participants

Participants included 23 teachers and 949 of their students. All teachers were currently in the classroom and teaching a science, technology, engineering, or mathematics (STEM) subject area course. The teachers completed the study protocol in two different technology-enhanced learning environments. The first environment, Nearpod, is an instructional platform that allows educators to develop their own multi-media lessons or use those developed by others. The second environment, Interactive Portable Document Format (iPDF), allows educators to share an interactive document with students with embedded links to media, resources, and lesson elements. A total of 12 Nearpod educators teaching grades 5-8 and 11 iPDF teachers teaching grades 4-8 completed the study.

The 23 teachers involved in the study were recruited from two collaborating external partners, Nearpod and a neighboring school district, Portsmouth Public Schools (PPS). Nearpod assisted in recruiting and identifying teachers who were already working in their platform and currently teaching science. PPS teachers were recruited with the help of the Science Supervisor and Science Teacher Specialist. Participants were incentivized with $100 per lesson to complete all aspects of this study, requiring them to follow the lesson plan protocol and deliver the Spotlite lessons through one of two digital tool protocols.

After enrolling a total of 447 students, Nearpod teachers had 296 students in grades 5-8 complete both the pre and post knowledge tests (matched pairs) for the Clouds lesson. After enrolling 402 students, Nearpod teachers had 262 students in grades 5-8 complete both the pre and post knowledge tests (matched pairs) for the Seasons lesson. After enrolling a total of 502 students, the iPDF teachers had 172 students in grades 4-8 complete both the pre and post knowledge tests for the Clouds lesson. After enrolling 502 students, the iPDF teachers had 215 students in grades 4-8 complete both the pre and post knowledge tests for the Seasons lesson. Table 2 summarizes the research participants.

Table 2
Participant Breakdown

Digital platform	# Teachers	# Clouds Students	# Seasons Students
Nearpod	12	447 Enrolled to participate 336 Pre responses 344 Post responses 296 Matched pairs	402 Enrolled to participate 370 Pre responses 338 Post responses 262 Matched pairs
iPDF	11	502 Enrolled to participate 464 Pre responses 374 Post responses 172 Matched pairs	502 Enrolled to participate 452 Pre responses 352 Post responses 215 Matched pairs

Measures

Content knowledge measures were developed in-house and reviewed by content experts. Survey instruments were developed by the external evaluator, Dr. Bradford Davey of Technology for Learning Consortium, Inc. and comprised of items developed specifically for this work and those developed by Romine, Sadler, Presley, and Klostrman (2012) in their Student Interest In Technology and Science (SITS) survey. The measures to investigate the impact of the NASA Spotlite lessons on learners' scientific literacy consisted of a pretest taken by students prior to engaging with the lesson in the classroom and a posttest taken immediately at the end of completing the lesson. The pretest and posttest had a combination of objective items that included multiple choice content knowledge items as well as self-report items about their interests, attitudes, and future behaviors towards STEM and NASA. In addition to the student pretests and posttests, teachers were given a post lesson delivery survey consisting of both quantitative and qualitative items. The interest, attitude, and future behaviors data is not included in the analysis and results of this paper. Table 3 lists the student test content items while Table 4 shows a sampling from the educator survey.

Table 3
Description of Content Knowledge Measures

Description for Student Pre and Posttest Content Knowledge Items
Clouds Content Items • What factor can help balance Earth's temperature? • What can reach Earth's surface and lead to warmer temperatures? • Low level, thick clouds that reflect incoming solar energy are called ______________. • Some clouds act as a blanket and make Earth __________. • Five friends were looking at different clouds in the sky. They wondered how those clouds affected life on Earth. Which statement is correct?
Seasons Content Items • Study the diagram below. It shows the tilt of Earth and how Earth revolves around the sun. The tilt of Earth is responsible for Earth's _______ • When the North Pole is tilted toward the sun, what are the sun's rays doing? • More heat is absorbed when the sun's rays hit Earth ________ than when they hit at an angle. • What is important in determining Earth's seasons? • The picture below shows Earth spinning on its axis. This is called-

Table 4
Sample Items from Teacher Post Intervention Survey

Items
• Please identify each section of the lesson that you completed with your students and the degree of alignment between the lesson plan and your delivery of the lesson.
• How well do you feel the following sections of the lessons supported students' learning?
• How did the NASA Spotlites Lessons compare to other science lessons you do with your students? (more or less difficult, shorter or longer, different style, more or less engaging, relevant/real-world connections, etc.)
• Please rate each area of the NASA Spotlites Lessons.
• How well do you feel the NASA Spotlites Lessons helped your students:

Intervention

Formative assessment of the first two years of this project informed and defined the interventions and content focus for this study.

Teachers of grades 4-8 students were recruited to utilize one of two lesson delivery platforms. Lessons were designed to take students between 45 and 60 minutes to complete and were delivered from start to finish. When the lesson could not be completed in a single classroom period, the lesson was completed the next time the students were together. Twelve teachers delivered the Spotlite lessons via Nearpod. Eleven teachers delivered lessons organized within an interactive PDF (iPDF). While both formats provide digital learning experiences, the iPDF lessons must be downloaded and accessed online to maintain the functionality of hyperlinks, bookmarks, page transitions, and buttons utilized by both groups contain instructions organized into a Teacher Packet and a Student Packet. Instructions in the Teacher Packet include how to use the lessons, descriptions of the different components, tutorials, and links to resources. Students were guided through each step of the lesson in the Student Packet.

The lesson design and flow for both the Nearpod group and iPDF group were the same. The Clouds lesson, for both groups, begins with instructing students to complete the pre survey followed by exploring the essential question, "What role do clouds play in Earth's energy budget?" In both formats, students are prompted to look at images of clouds to describe what they see and probe for prior knowledge. The difference in the experiences are related to the functionality and flexibility of the two platforms. Within the iPDF, students look at static cloud images. Within Nearpod, students can adjust the image for a 360 view.

Teachers had more control over the pacing of the Nearpod learning experience as they are able to "push out" slides to students' devices. While still interactive and collaborative, teachers have less control over their students' pacing within the iPDF platform. Following the 5E learning model, students continue to explore the different concepts, watch a Spotlite student-created video, think-pair-share, draw, diagram, utilize the Frayer vocabulary model, apply what they've learned, and then review and evaluate the concepts. For the purposes of this study, students were then directed to complete the posttest and survey.

RESULTS

Student Science Literacy Findings

Teachers administered both a student pretest and posttest using identical lesson protocols. All pretests and posttests were administered online using the online survey tool Question Pro. Quantitative data were analyzed to determine statistical change and to present findings numerically. Qualitative data were analyzed for themes and meaning to add to the quantitative findings and add explanatory findings to the numerical findings.

While both platform groups demonstrated significant increases in knowledge from the Clouds pretest to the posttest, Nearpod students scored significantly higher on four of the five test items (p <0.01 level). iPDF students scored significantly higher on two of the five items (p <0.01 level).

While both groups showed significant improvements, Nearpod students also had a significantly higher mean posttest scored (79% correct) on Clouds compared to iPDF students (68% correct) (p <0.01), as shown in Table 5 and visually displayed in Figure 1.

Table 5

Clouds Pretest and Posttest Lesson Data

Test Item	Nearpod N=296		iPDF N=172	
	Pre	**Post**	**Pre**	**Post**
Cohort 3 Student Mean Score	61%	**79%*^**	58%	**68%***

*Indicates a significant difference pre to post (p ≤0.01)

^Indicates a significant difference between the Nearpod post mean and the iPDF post mean (p≤0.01)

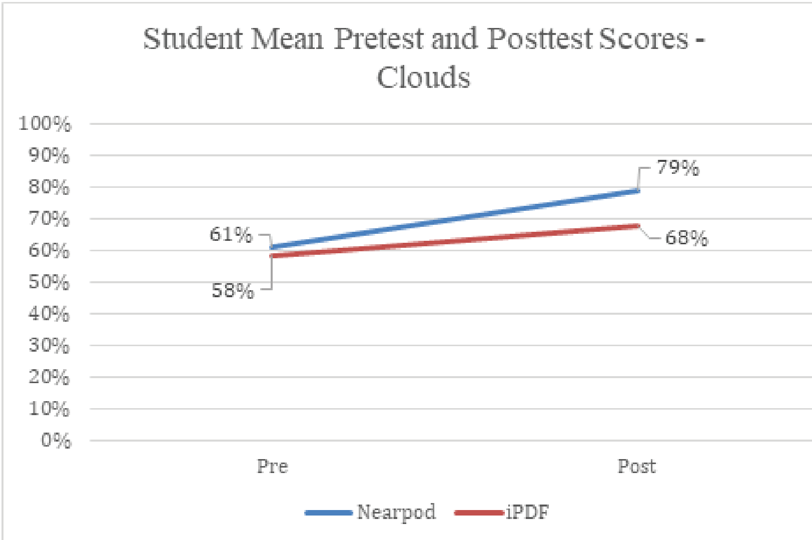

Figure 1. Student pretest and posttest data on Clouds Lesson.

Students from the Nearpod group demonstrated a significant increase in knowledge on the Seasons pretest and posttest and scored significantly higher on four of the five test items (p <0.01). iPDF students scored significantly higher on two of the five items (p <0.05).

Nearpod students also had a higher but not statistically significant mean posttest scored (75% correct) compared to iPDF students (72% correct), as shown in Table 6 and graphically displayed in Figure 2.

Table 6

Seasons Pretest and Posttest Lesson Data

	Nearpod N=262		iPDF N=215	
	Pre	**Post**	**Pre**	**Post**
Cohort 3 Student Mean Score	63%	**75%***	66%	**72%**

*Indicates a significant difference pretest to posttest (p <0.01)

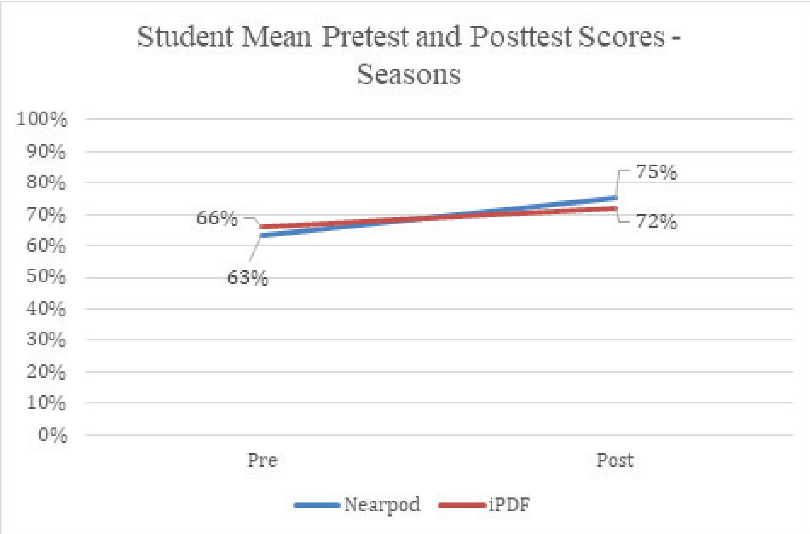

Figure 2. Student pretest and posttest data on Seasons Lesson.

Teacher Feedback

After implementing the lessons, the Nearpod and iPDF teachers were asked about how well they felt the lessons supported student learning in the 5E lesson categories (Engage, Explore, Explain, Elaborate, Extend) within the constructivist model of learning. In all categories, Nearpod teachers rated the lessons highly for supporting student learning (Table 7).

Table 7
How Well the Lessons Supported Student Learning According to Teachers by Platform

	iPDF (N=12)		**Nearpod (N=11)**	
	Well	Very well	Well	Very well
Engage	27%	36%	17%	83%*
Explore	45%	27%	25%	75%*
Explain	55%	27%	33%	67%*
Elaborate	64%	27%	25%	75%*
Extend	45%	36%	25%	75%*

*Indicates a significant difference between Nearpod and iPDF responses ($p<0.01$)

On a post intervention survey, Nearpod and iPDF teachers were asked to rate a number of different areas of the NASA Spotlite lessons used with their students. Nearpod teachers consistently rated the different areas of the lessons higher than the iPDF teachers as indicated by the percentage of "agree" and "strongly agree" responses including being student centered effectively used technology for instruction, provided them a variety of ways to assess student understanding, and provided students an opportunity to demonstrate creative thinking percentages are listed in Table 8.

Table 8
Educator Ratings of Each Area of the NASA Spotlite Lessons

	% Agree and Strongly Agree	
	iPDF (N=11)	**Nearpod (N=12)**
Are student-centered	72%	100%*
Effectively use technology for instruction	54%	100%*
Engage students	54%	100%*
Provide teachers a variety of ways to assess student understanding	72%	100%*
Provide students an opportunity to demonstrate creative thinking	55%	100%*
Provide students an opportunity to work collaboratively with their peers	73%	92%*
Introduce the key concepts in a variety of ways	73%	100%*
Provide students an opportunity to develop their own understanding of key concepts through exploration activities	73%	100%*
Provide opportunities to connect leaning with NASA	64%	100%*
Provide students opportunities to make career connections	55%	83%*
Meet a variety of learning styles	73%	92%*

*Indicates a significant difference between Nearpod and iPDF educator responses (p <0.01)

CONCLUSIONS

The study design and utilization of a 5E constructivist model in the NASA Spotlite lessons yielded significant changes in student science literacy, including understanding processes in the natural world through demonstration of content knowledge mastery and using scientific ways of thinking. Data showed that implementing the lesson to confront misconceptions resulted in improved student achievement and that the use of web-based interactive digital tools supports fidelity of instruction. The method of delivery seems to play a potentially important role in student learning. Nearpod students showed significantly greater gains in content knowledge over their iPDF peers and Nearpod teachers, when comparing teacher research group ratings, also reported finding greater value, ease of use, and more impact delivering the Spotlite lessons.

DISCUSSION

While the study has shown light on some factors influencing student learning guided by NASA Spotlite lessons, there are two questions that remain for further investigation. First, while students showed significant gains in content knowledge, they were still below a level many might consider "mastery." Mastery of a subject suggests a comprehensive understanding beyond what may be assessed from only a multiple-choice test. The use of open-ended response items could provide more data to better assess changes in student understanding. Second, while the choice of technology was deliberate, the significance in student performance suggests that the platform plays a more significant role that we anticipated. Teachers also reported significantly different instructional experiences based on technology utilization. This is an area that should also be explored through a more controlled study, especially in response to the need for increased levels of online instruction for K-12 students.

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