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A Content Analysis of NGSS Science and Engineering Practices in K-5 Curricula

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Abstract

The Next Generation Science Standards (NGSS) encourage K-12 teachers to facilitate science and engineering instruction that is three-dimensional in nature, motivating students to develop knowledge building practices. The dimensions are based on crosscutting concepts, disciplinary core ideas, and science and engineering practices (SEPs). This study focuses on the eight SEPs, which were developed for students to use science inquiry and engineering design to solve meaningful problems.

These practices move beyond traditional science instruction and into engineering, which involves content that teachers were not asked to cover prior to the implementation of the NGSS. Because of this, teachers have begun to seek out support in free, online curricular materials to meet the demands of the NGSS, despite budget restrictions or support from administration. This means that we must hold high standards to the curriculum that is provided online to teachers. In this study, the research team examined 40 lesson activities from a website that provides teachers with over one thousand free activities. This website was chosen because it is NSF-funded, a collaborative effort from several well-respected universities, and a top hit when searching for "K-12 Engineering Activities" on Google. It is also one of the only sites that provides complete units, as opposed to stand-alone activities, at no cost.

A search was conducted within the website to limit the focus of this research, which included looking at complete units under "Science and Technology" that cover the Engineering Design Standards for grades 3-5. All lesson activities were coded by two of the researchers, using a codebook that was developed with the "practices matrix" in the NGSS. The codebook included themes and subthemes from the matrix with examples of each code. Intercoder agreement statistics were calculated using MAXQDA software and averaged a correlation of 97.3%.

The findings indicate an emphasis on the following SEPs: (1) planning and carrying out investigations (2) developing and using models and (3) analyzing and interpreting data. For planning and carrying out investigations, the coded segments encouraged students to make observations to be used later for analysis. A few segments related to making predictions but none that asked students to plan an investigation or evaluate data collection methods. Another common practice that appeared in engineering-specific units was developing and using models. For this practice, students were asked to build and test prototypes. Students were not asked to develop a design plan, optimize a solution, or refine ideas based on the performance of a prototype. Instead, students would use teacher-directed models to test solutions and communicate design features.

The practices with little to no coded segments - (1) asking questions and defining problems (2) constructing explanations and designing solutions and (3) engaging in argument from evidence - are critical to the success of these standards. Implications of this research should encourage curriculum developers to re-evaluate the ways in which curricula are aligned to the practices listed in the NGSS. Additionally, websites and curricular resources need to specifically identify the claim that their resources are "NGSS-aligned."

Introduction

As of 2017, nineteen states have adopted the Next Generation Science Standards (NGSS) [1] with the main goal being to improve science instruction and encourage student interest in science and technology fields. The NGSS focus on three strands of science learning, (1) disciplinary core ideas, (2) science and engineering practices, and (3) cross cutting concepts. The standards are aimed to focus on big ideas that blend with practices and cross-cutting concepts in order to allow students the opportunity to explore and engage with these ideas in a meaningful and applied way. Students should emerge from the K-12 progression as practitioners of an "effective method of inquiry" [2]. With this in mind, science education is moving toward giving students an experiential learning opportunity rather than just relying on memorization from textbooks.

Although theoretically beneficial, the NGSS represent a conceptual shift from science instruction to interdisciplinary knowledge, particularly that of engineering. The National Research Council [3] reports that, "[f]or science teachers to embrace their role as teachers of science communication and of practices of acquiring, evaluating, and integrating information from multiple sources and multiple forms of presentation, their preparation as teachers will need to be strong in these areas" [4]. Unfortunately, these standards did not provide reformed professional development or curriculum with it leaving many teachers relying on curriculum kits and memorization techniques [5]. Although memorization skills translate well on standardized tests, the deeper learning experiences the NGSS seek to achieve is missed when teachers are not supported with the proper resources. This presents a pedagogical problem since the NGSS rely heavily on teacher knowledge of science and engineering practices and demand a restructure of teaching style [6].

Elementary teachers tend to be well-versed in general knowledge domains rather than focused specifically on science which means a heavier reliance on textbook resources and professional development opportunities [5], [7]. This is compounded by the fact that most elementary teachers are only required to have taken a single science methods course [3]. Therefore, elementary teachers are not well-prepared to teach science specific curriculum [8]. Teacher quality is a vital part of student achievement since there is a positive correlation between a teacher's subject and educational knowledge and their students' achievement level [9]. Moving past memorizing facts would require deeper content knowledge provided either by professional development or degrees and certification in the discipline focusing on content-specific knowledge and skills [10]. For example, instructors with an expertise and training in a science laboratory would utilize lab technique and examples to create deeper learning experiences that encompass the NGSS rather than textbook memorization [9].

Additionally, the NGSS science and engineering practices (SEPs) include both familiar and foreign practices even for teachers who already use scientific inquiry [11]. As explicitly stated in the standards, the SEPs are not teaching methods. Instead they are student expected practices that should be modeled and evoked by their teachers [3]. Since teachers in the NGSS-adopted states may be less able to rely on their science and engineering knowledge, current lessons, and teaching practices, they may seek additional online NGSS-aligned curriculum. This leads to a need to ensure a high-standard of quality for online NGSS-aligned curricula.

Our study focuses on one of the NGSS strands, SEPs. We use vocabulary from NGSS Appendix F [3] to quantify how often SEPs are implemented in a popular online NGSS-aligned curriculum.

Background

Science and Engineering Practices (SEPs)

The SEPs consist of eight individual practices that are interconnected and encourage students to engage in science discourse [3]. Duschl and Bybee [12] describe the SEPs: “These are important ‘doing science’ experiences that develop students’ insights into the nature of science and the dynamics of how scientific knowledge is generated, refined, and justified.” They are [3];

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Some familiar aspects of inquiry include asking questions, planning and carrying out investigations, and analyzing data; whereas developing and using models, constructing explanations, and engaging in argument from evidence may be less familiar to teachers [11]. These new practices represent some of the most important aspects of science learning because they are inherently based in the social context and the scientific community at large. Overall, the SEPs complement one another to create an advanced matrix of scientific language and actions requiring a high level of engagement and understanding from students and teachers [13].

In Burks’s study of preservice teacher, she identifies the SEP, developing and using models, as a high-leverage practice for teacher professional development because of its use of discourse [14]. The SEPs are complex, multifaceted methods that teachers may need to be able to employ iteratively and interchangeably [12]. For this reason, Duschl and Bybee unpack a single SEP, planning and carrying out investigations, to form a 5D model to bridge less familiar and complex SEPs. In addition, SEPs are supposed to become more complex and sophisticated as students progress through K-12 [3].

Purpose of Study

This study reviewed 40 lessons from a reputable and high-trafficked website. This website provides over one thousand free activities and is funded by NSF. The website’s founding partners consist of more than five well-respected institutions and is one of the only websites that provides complete curricular units, as opposed to stand-alone activities, at completely no cost. Thus, this website was chosen as the data source of our SEP analysis.

Methodology

This research study uses a summative approach to qualitative content analysis [15]. This type of analysis involves identifying certain content that will be the focus of the research prior to analysis, in this case, the Science and Engineering Practices. A summative approach moves beyond word counts to include an interpretation of content, which is why we chose this methodology to answer our research question: *Which NGSS science and engineering practices are the focus of free curricular units available online to teachers?*

The focus of this qualitative content analysis research was a website that provides teachers with over one thousand free lessons and activities. This website was chosen because it is NSF-funded, a collaborative effort from several well-respected universities, and a top hit when searching for "K-12 Engineering Activities" on Google. More importantly, this website indicates that it is aligned with NGSS, provides teachers with information on the standards, and also allows teachers to search for lessons aligned to specific standards. It is also one of the only sites that provides complete units, as opposed to stand-alone activities, at no cost.

In order to narrow down the analysis, a search was conducted within the website, which included looking at complete units under "Science and Technology" that cover the Engineering Design Standards for grades 3-5. This resulted in five curricular units at the time of analysis. Two of the five units were removed because they involved specific programs and expensive materials, like LEGO Mindstorms robots. The three remaining units were the focus of the analysis.

Each unit provides teachers with detailed information, including engineering connections, standards, unit schedules, and all corresponding materials. Within the materials provided, there are two different types of daily lesson plans - lessons and hands-on activities. Since the "practices represent what students are expected to do and are not teaching methods," [3] we narrowed in on the hands-on activities, resulting in 40 units of analysis. In addition to the lesson plan, all accompanying materials were reviewed to ensure that practices were not missed. For example, if the worksheet asked the student to collect data or sketch a design solution, the lesson plan itself was coded to acknowledge this practice.

We started this analysis by identifying the eight SEPs provided in Appendix F of the NGSS [3]. From here, we broke down each of the practices and developed a code book that used the NGSS descriptor from the practices matrix as definitions of each code. Three of the authors then completed an initial round of coding before coming together to collaboratively develop a memo, or detailed description, to elaborate on the NGSS descriptor.

The updated codebook was entered into MAXQDA, a qualitative analysis software, which was then used for the primary analysis. MAXQDA's "Intercoder Agreement" feature [16] was used to calculate inter-rater reliability. This analysis involved coding for existence in the document. This means that MAXQDA checked to see if the same codes were used at least once in each hands-on activity. The reason we chose this option, as opposed to coding for segment agreement percentages, was because our goal was to uncover which of the SEPs were being addressed in each lesson. One curricular unit had 28 hands-on activities and the other two units included six hands-on activities each, for a total of 40 hands-on activities that were analyzed. For the first unit, two coders separately analyzed 50% of the unit and averaged an intercoder agreement of 98%. Since there were 12 total lesson activities for the remaining two units, the entire units were analyzed by two coders to ensure an intercoder agreement of 93% (See Table 1).

Table 1. *Intercoder Agreement Calculations for Each Unit*

Unit 1	Intercoder Agreement	Unit 2	Intercoder Agreement	Unit 3	Intercoder Agreement
1	100%	1	95%	1	98%
2	100%	2	98%	2	100%
3	100%	3	93%	3	94%
4	95%	4	95%	4	93%
5	100%	5	95%	5	95%
6	98%	6	98%	6	100%
7	94%				
8	95%				
9	100%				
10	100%				
11	100%				
12	100%				
13	96%				
14	98%				

Findings

Overall, the findings indicate an emphasis on the following SEPs: (1) planning and carrying out investigations (2) developing and using models and (3) analyzing and interpreting data (See Table 2). In the following sections, we will provide detailed information for each of the eight NGSS Science and Engineering Practices. In each section, we will present the number of coded segments with examples. In the discussion section, we will connect our findings back to the related literature in order to present the significance and implications of this research.

Asking Questions and Defining Problems

There were zero coded segments for the first practice, Asking Questions and Defining Problems (See Table 3). As presented in Appendix F of the NGSS,

> Students at any grade level should be able to ask questions of each other about the texts they read, the features of the phenomena they observe, and the conclusions they draw from their models or scientific investigations. For engineering, they should ask questions to define the problem to be solved and to elicit ideas that lead to the constraints and specifications for its solution [17].

This clearly indicates that the goal of this practice, according to the NGSS, is for students to be the one asking the questions. However, we found the hands-on activities to be primarily teacher-directed. Although students were given opportunities to design solutions and present ideas, there was no indication from the lesson materials that these activities would provide students with the opportunity to ask their own questions or spend time defining the problem.

Table 2. *Frequency of Practices*

Practices	**Frequency (N=40)**
Asking Questions and Defining Problems	0
Developing and Using Models	30
Planning and Carrying Out Investigations	34
Analyzing and Interpreting Data	21
Using Mathematics and Computational Thinking	10
Constructing Explanations and Designing Solutions	2
Engaging in Argument from Evidence	2
Obtaining, Evaluating, and Communicating Information	18

Table 3. *Frequency of Asking Questions and Defining Problems*

Practice	**NGSS Descriptor**	**Frequency (N=40)**
Asking Questions and Defining Problems	Ask questions about what would happen if a variable is changed.	0
	Identify scientific (testable) and non-scientific (nontestable) questions.	0
	Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.	0
	Use prior knowledge to describe problems that can be solved.	0
	Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.	0
TOTAL		0

Developing and Using Models

Thirty of the 40 activities asked students to develop and use models (See Table 4). As previously discussed, each practice was coded using the practices matrix. This means that there were six codes for this practice and five of the six appeared throughout the 14 lessons. The only one that did not appear was “Identify limitations of models.”

The code that appeared most often for this practice was “Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.” Examples from lesson activities include, “Give the students 10 minutes to make a drawing of their design using the provided rulers and colored pencils” and “Give teams 10 minutes to build their rockets.” Another common code for this practice was “Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system,” which included tasks such as, “Testing: Have one group at a time come up to the launch area and put on safety glasses.”

Table 4. *Frequency of Developing and Using Models*

Practice	NGSS Descriptor	Frequency (N=40)
Developing and Using Models	Identify limitations of models.	0
	Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events.	6
	Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution.	2
	Develop and/or use models to describe and/or predict phenomena.	4
	Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.	11
	Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.	7
TOTAL		30

Planning and Carrying Out Investigations

Planning and carrying out investigations was a practice identified in 34 of the 40 lesson activities (See Table 5). This practice was broken into five codes with the most common occurrence being “Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.” This was used to describe any time students were asked to take measurements (e.g., length, time) or when students were asked to observe what happened to their model or prototype. An example of this is “Use the meter stick to measure how far the car travels along the tabletop or floor, and record this on the data sheet.” Making predictions was the second most frequent, followed by comparing two different models and evaluating tools for collecting data.

The one part of this practice that was missing from the lesson activities was for students to “Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.” In all of the activities we analyzed, students were guided through an investigation with structured step-by-step directions, which eliminated their chance to plan and conduct the investigation. Furthermore, these experiences did not ask students to collaboratively produce class data or explore the notion of “fair tests.”

Table 5. *Frequency of Planning and Carrying Out Investigations*

Practice	NGSS Descriptor	Frequency (N=40)
Planning and Carrying Out Investigations	Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.	0
	Evaluate appropriate methods and/or tools for collecting data.	2
	Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.	22
	Make predictions about what would happen if a variable changes.	7
	Test two different models of the same proposed object, tool, or process to determine which better meets criteria for success.	3
TOTAL		34

Analyzing and Interpreting Data

The practice of analyzing and interpreting data appeared third most frequently with 21 coded segments throughout the 40 lesson activities (See Table 6). Each of the five descriptors appeared at least twice. The most frequent were "Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation" and "Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings." each appearing 7 times throughout the 40 lessons. An example which asked students to analyze and interpret data was "Have students calculate the total weight their structures supported." An example which asked students to compare and contrast data was "Conclude with a class-wide comparison of each team's results."

Table 6. *Frequency of Analyzing and Interpreting Data*

Practice	NGSS Descriptor	Frequency (N=40)
Analyzing and Interpreting Data	Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships.	3
	Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.	7
	Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.	7
	Analyze data to refine a problem statement or the design of a proposed object, tool, or process.	2
	Use data to evaluate and refine design solutions.	2
TOTAL		21

Using Mathematics and Computational Thinking

The practice of using mathematics and computational thinking appeared throughout 10 of the 40 lessons that we analyzed. The most common asked students to "Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems." An example of this is "Measure the wind speed by counting the number of times the anemometer spins around in a minute (rotational rate). Point out how it helps to keep track of the number of spins by watching the movement of the cup with the markings. Students should take three measurements at their location and calculate the average rotational rate. Record measurements and observations on the worksheet." Students were asked to organize a data set in one lesson activity, which was included in the lesson plan as "After all measurements have been made, direct students to make a bar graph showing their material and the highest temperature or the lowest temperature it reached."

Table 7. *Frequency of Using Mathematics and Computational Thinking*

Practice	NGSS Descriptor	Frequency (N=40)
Using Mathematics and Computational Thinking	Decide if qualitative or quantitative data are best to determine whether a proposed object or tool meets criteria for success.	0
	Organize simple data sets to reveal patterns that suggest relationships.	1
	Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems.	9
	Create and/or use graphs and/or charts generated from simple algorithms to compare alternative solutions to an engineering problem.	0
TOTAL		10

Constructing Explanations and Designing Solutions

Over the 40 lesson activities analyzed, constructing explanations and designing solutions only appeared twice (See Table 8). Students were asked to identify evidence that supports specific points in a lesson that instructed the teacher, "After testing is completed, have the student teams compare their results for which test objects were considered conductors and which were considered insulators. Have them look for patterns and hypothesize theories." In a different lesson activity where students were using potatoes to power an LED clock, they compared the design of clocks that were powered by one potato versus two potatoes, which would allow students to "Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution."

Table 8. *Frequency of Constructing Explanations and Designing Solutions*

Practice	NGSS Descriptor	Frequency (N=40)
Constructing Explanations and Designing Solutions	Construct an explanation of observed relationships (e.g., the distribution of plants in the backyard).	0
	Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.	0
	Identify the evidence that supports particular points in an explanation.	1
	Apply scientific ideas to solve design problems.	0
	Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.	1
TOTAL		2

Engaging in Argument from Evidence

While engaging in argument from evidence appeared twice in the lesson activities (See Table 9), this practice would need to be clearly identified in a lesson plan as argumentation in order for it to occur. In one lesson activity, the students were asked to gather information on energy and then compare and refine a group definition for energy, which was identified as the practice “Compare and refine arguments based on an evaluation of the evidence presented.” In a follow-up lesson activity, students were asked to “Use data to evaluate claims about cause and effect” when they were asked to use the entire class’s research findings to evaluate claims about insulators.

Table 9. *Frequency of Engaging in Argument from Evidence*

Practice	NGSS Descriptor	Frequency (N=40)
Engaging in Argument from Evidence	Compare and refine arguments based on an evaluation of the evidence presented.	1
	Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation.	0
	Respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions.	0
	Construct and/or support an argument with evidence, data, and/or a model.	0
	Use data to evaluate claims about cause and effect.	1
	Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.	0
TOTAL		2

Obtaining, Evaluating, and Communicating Information

Throughout the 40 lesson activities, students were asked to obtain, evaluate, and communicate information throughout 18 activities. This most frequently involved students communicating their ideas in an oral or written format. For example, an executive summary that asked students to write a problem statement, a description of the solution and a funding proposal. Students were also asked to create poster presentations, journal entries, and persuasive letters to principals and parents. Another common practice asked students to "read and comprehend grade appropriate complex texts" which occurred 6 times. One example asked students to read material on the August 2003 blackout. Another example asked students to read through website links in order to explain how a power grid works.

Table 10. *Frequency of Obtaining, Evaluating, and Communicating Information*

Practice	NGSS Descriptor	Frequency (N=40)
Obtaining, Evaluating, and Communicating Information	Read and comprehend grade appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence.	6
	Compare and/or combine across complex texts and/or other reliable media to support the engagement in other scientific and/or engineering practices.	0
	Combine information in written text with that contained in corresponding tables, diagrams, and/or charts to support the engagement in other scientific and/or engineering practices.	0
	Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.	0
	Communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts.	12
TOTAL		18

Discussion

Developing Models vs. Designing Solutions

As outlined by the NGSS, the "eight practices are not separate; they intentionally overlap and interconnect" [3]. While they are designed to unfold sequentially they also lead into each other and as a result, overlap. They were written for students to see the connections and apply skills learned from one practice into the application of another practice. While aspects of these units claimed to focus on solving problems, we found that the curriculum itself encouraged students to develop and use models instead of design solutions.

The NGSS describes developing and using models through the following:

> In engineering, models may be used to analyze a system to see where or under what conditions flaws might develop, or to test possible solutions to a problem. Models can be used to visualize and refine a design, to communicate a design's features to others, and as prototypes for testing design performance [18].

The NRC Framework elaborates on the practice of designing solutions:

> In engineering, the goal is a design rather than an explanation. The process of developing a design is iterative and systematic, as is the process of developing an explanation or a theory in science. Engineers' activities, however, have elements that are distinct from those of scientists. These elements include specifying constraints and criteria for desired qualities of the solution, developing a design plan, producing and testing models or prototypes, selecting among alternative design features to optimize the achievement of

design criteria, and refining design ideas based on the performance of a prototype or simulation [19].

The difference between these two practices is clear and the practice of designing solutions is much more elaborate than developing and using models. We have outlined these two practices specifically to call attention to what we have found in our analysis. While it appeared that specific lesson activities were asking students to design solutions, when looked at more closely, the instructions were asking the students to develop and use models. These lesson activities asked students to follow step-by-step instructions to design a model and then they were asked to collect data on the model. Occasionally, students were able to make design decisions but for the most part, these decisions had no impact on the design of the solution (e.g., decorate the design). Of the 40 lesson activities we analyzed, students were not asked to develop a design plan, optimize a solution, or refine ideas based on the performance of a prototype. Instead, students would use teacher-directed models to test solutions and communicate design features.

Reconsidering Scaffolding

Throughout this content analysis, it became clear that certain practices included more scaffolding than others. Mainly, model development involved teacher-directed instructions and some other practices, like constructing explanations were left more open-ended. For example, one lesson activity asked the teacher to do the following: "After testing is completed, have the student teams compare their results for which test objects were considered conductors and which were considered insulators. Have them look for patterns and hypothesize theories." While teachers may interpret this in different ways and provide scaffolding to their classes, these directions don't imply that this is necessary. On the other hand, when students were asked to build models, they were given very little autonomy on the design of the model. We argue that there should be more of a balance when scaffolding engineering design activities for students of this grade level. Students should be given more opportunities to design a solution, test the solution, redesign it based on test results, and continue through the engineering design process until they have succeeded at meeting the criteria and constraints. At the same time, students do need more scaffolding in other areas, such as "hypothesizing theories."

"NGSS Aligned"

As of November 2017, 19 states and the District of Columbia have adopted the NGSS and are working to implement them across schools and districts [3]. As more states continue to adopt these standards and as teachers within these existing states further integrate the standards, we will see an increase in curricular materials that are "NGSS Aligned." A part of this movement is free lesson plans on the internet, which is appealing to teachers since it is easily accessible and can be used to supplement existing curricula or help teachers with budget restrictions fully implement the NGSS. However, part of the problem is that websites, such as the one analyzed in this research study, make broad claims and label their entire site as being "aligned to NGSS." While there is no doubt that websites like this provide teachers with a wide variety of excellent resources, we are arguing that claims like this are not beneficial to classroom teachers. Instead, websites like this and all curricular material for that matter, should provide a breakdown of how the lesson or unit is aligned to the NGSS. This should include the performance expectations, science and engineering practices, and crosscutting concepts. This will allow teachers to ensure they are fully integrating the NGSS across their curriculum throughout the academic year.

Implications

This qualitative content analysis research study has uncovered that science and engineering integrated lesson activities highlight specific practices and leave others untouched. While this research narrowed in on 40 lesson activities from one website, the findings are important to consider when designing curriculum and working with elementary teachers to embed engineering practices into their science lessons. First, curriculum developers need to ensure that curricular units encompass a wide range of practices. As outlined in the NGSS, students should have opportunities to engage in all eight practices throughout a given grade band, in this case, grades 3-5. This means that within these grades, students need opportunities to engage in the practices of defining problems, designing solutions, and engaging in argument from evidence. As previously discussed, it is also important for curricular materials to specifically outline which practices are intentionally being covered throughout lesson activities since practices are what students are expected to do, not teaching strategies. Additionally, it is important for curriculum developers to provide professional development opportunities that are specifically designed to enhance curricular materials. As the NGSS continue to be implemented, teachers need specific opportunities that explain the 3D nature of the standards and help them to add in the science and engineering practices as well as the crosscutting concepts. Professional development opportunities that are specifically aligned to curricular materials will further encourage the 3D nature of the standards since teachers will be able to use concrete examples in their teaching practices. Future research in this area will move beyond this curricular resource and analyze other units to help inform other stakeholders, such as teacher educators (i.e., PD facilitators, university teacher education programs, etc). Additionally, we would like to continue our analysis for other aspects of the NGSS, such as the crosscutting concepts.

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