Next Generation Science Standards and edTPA: Evidence of Science and Engineering Practices

Erica M. Brownstein*
The Ohio State University, United States

Larry Horvath
San Francisco State University, United States

*Both authors contributed equally to this paper.

Abstract

Science teacher educators in the United States are currently preparing future science teachers to effectively implement the *Next Generation Science Standards* (NGSS) and, in thirteen states, to successfully pass a content-specific high stakes teacher performance assessment, the edTPA. Science education and teacher performance assessment experts have developed a crosswalk designed to highlight specific tasks within the secondary science edTPA; in these tasks, pre-service science teachers are prompted to plan, teach and assess their students as they engage in learning science explicitly aligned with the NGSS. The researchers in this study used qualitative methods to analyze archived actual pre-service science teacher edTPA portfolio artifacts to test the efficacy of this crosswalk. Evidence of student engagement in the NGSS scientific practices was found, confirming some components, and modifications of the NGSS and edTPA Crosswalk are suggested based on the results.

Keywords: NGSS; edTPA; alignment; crosswalk; science and engineering practices

Please address all correspondence to: Erica M. Brownstein, The Ohio State University, 1945 North High Street, Columbus, OH 43210, Brownstein.2@osu.edu

Introduction

Ensuring that future science teachers have the knowledge and skills to implement the *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013a) is one of many challenges facing science teacher educators today. “Achieving the goals of the NGSS will take a long-term systematic effort that requires significant changes in instruction, curriculum, assessment, teacher preparation and professional development, accompanied by extensive financial, administrative, and public support” (National Science Teachers Association, 2013, p. 3). In addition to the charge from the National Science Teachers Association (NSTA), educator preparation programs are increasingly being challenged by legislators, external entities, and accreditors to meet higher requirements and to increase accountability (CAEP Board of Directors, 2013; Crowe, 2011; Darling-Hammond, 2010; Greenberg, McKee, & Walsh, 2013; US Department of Education, 2009). High quality, nationally available assessments that reflect expectations for the job and meet rigorous standards for reliability and validity are just one component of the variegated pattern of accountability. Alignment with standards is necessary for both effective assessment elements

(Webb, Herman, & Webb, 2007) and effective teacher evaluation systems (Heneman & Milanowski, 2003). In January 2015, a crosswalk with a supporting evidence document was developed to display the intersection between a nationally available teacher performance assessment, the edTPA, and the science and engineering practices in the NGSS. (Brownstein, Stansbury, Whittaker, & Horvath, 2015). The initial NGSS and edTPA Crosswalk describes the extent to which edTPA explicitly prompts or provides opportunities for candidates to demonstrate teaching that reveals, supports, or develops NGSS practices.

We asked the following question: does edTPA commentary provide evidence of NGSS scientific and engineering practices? For our inquiry, we analyzed edTPA planning, instruction, and assessment practice commentaries written by preservice science teachers for evidence of NGSS scientific and engineering practices. These commentaries are candidate reflections in response to edTPA prompts. An evidence-based understanding of the content linkages between NGSS scientific and engineering practices and edTPA commentaries may help prospective teachers prepare to implement the NGSS in K-12 settings. If science teacher educators understand which NGSS science and engineering practices are evidenced in the written commentaries, this understanding can be used to inform preservice science teacher curricular decisions. For example, the crosswalk may indicate specific NGSS topical areas that need to be addressed at another point in the preparation program or during a new teacher's induction years. For clarity, we will provide a brief explanation of the science and engineering practices in the NGSS (NGSS Lead States, 2013b), edTPA's design, and the initial NGSS and edTPA Crosswalk (Brownstein et al., 2015). Subsequent sections of the article describe the qualitative, constant comparative methodology; the results of the commentary content linkage analysis; a discussion of the interpreted results in relation to existing literature; and the implications for science teacher educators and the teacher education profession.

Literature Review

The Next Generation Science Standards (NGSS)

The NGSS (NGSS Lead States, 2013a) are the current K-12 national performance-based science standards recommended for adoption by individual states. Developed with input from states and various stakeholders, including scientists, science educators, and education researchers, these standards build on the foundational work of the Framework for K-12 Science Education for the teaching and learning of science in the United States (NGSS Lead States, 2013a). Under the NGSS, students are expected to develop an integrated understanding of science that incorporates knowledge of specific scientific phenomena and the use of science and engineering practices to develop this knowledge (Carpenter, Iveland, Moon, & Bianchini, 2015). Students are also required to make connections, strengthening their knowledge through the use of crosscutting concepts such as cause and effect, structure and function, and energy and matter (Duschl, 2012). To fully realize the promise of the NGSS, a fundamental shift in how students engage in learning science is required (Duschl, 2012; National Research Council, 2011; Penuel, Harris, & DeBarger, 2015; Roseman, Fortus, Krajcik, & Reiser, 2015).

According to the National Science Teachers Association (2013),

> One of the most significant shifts of the NGSS is the recommendation that students engage in science learning at the nexus of three dimensions: science and engineering practices,

> crosscutting concepts, and disciplinary core ideas. Because many current state and district standards address these dimensions separately, it will take a considerable effort to embrace this new vision in the implementation of the NGSS, including instruction, curriculum, assessment, and teacher preparation and professional development (p. 2).

Additionally, the NGSS were developed to demonstrate proficiency in science by establishing performance expectations and assessment recommendations (NGSS Lead States, 2013c). In essence, the NGSS challenges science educators to design and implement curricula with attention to "how science and engineering is practiced in the real world" (NGSS Lead States, 2013c, p. 1). It is imperative that science teacher educators develop mechanisms to support both pre-service and in-service teachers in engaging K-12 students in the science and engineering practices as a required component of the NGSS (National Research Council, 2011; Penuel et al., 2015; Wilson, 2013).

The NGSS identifies eight science and engineering practices, which we refer to collectively as practices. The NGSS practices (NGSS Lead States, 2013b) are as follows:

1. Asking questions and identifying problems
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 and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

In NGSS Appendix F, each practice includes specific grade band competencies. In the example below, analyzing and interpreting data is identified in 9-12th grade classrooms through evidence of the following competencies:

- "Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
- Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.
- Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.
- Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success" (NGSS Lead States, 2013b p. 9)

As stated in Appendix F of the *Next Generation Science Standards*, "The eight practices are not separate; they intentionally overlap and interconnect. . . Just as it is important for students to carry out each of the individual practices, it is important for them to see the connections among the eight practices" (NGSS Lead States, 2013b, p. 3)[1]. Recognizing the overlap and the interconnectedness of the science and engineering practices within effective science teaching, the developers of the science edTPA handbooks (with input from one of the authors) strategically chose to incorporate multiple practices into the requirement for completing and passing this nationally available teacher performance assessment (Stanford Center for Assessment, 2014).

edTPA

Developed by experienced educators and the Stanford Center for Assessment, Learning and Equity (SCALE), edTPA is a nationally recognized high stakes performance assessment designed to assess preservice teachers' readiness to teach; it has been evaluated to be valid and reliable (Pecheone, Shear, Whittaker, & Darling-Hammond, 2013; Sato, 2014; Stillman, Ragusa, & Whittaker, 2015). Through its widespread adoption, edTPA supports the professionalization of teaching by creating a recognized standard for clinical preparation that mirrors standards for other professional fields such as engineering, medicine, or accounting (Darling-Hammond, 2010). edTPA assesses developing pedagogical content knowledge (PCK) with explicit attention to student context, and consists of three interrelated tasks: planning, instruction, and assessment (Pecheone et al., 2013; Stillman et al., 2015). Completed during student teaching, edTPA requires the teaching-credential candidate to produce a portfolio with evidence-based reflective commentaries focused on three to five consecutive hours of teaching. To complete a secondary science edTPA, preservice science teachers must, from prompts, produce a set of reflective commentaries that describe their instructional context as they address, analyze and justify three specific aspects of their teaching: planning of the learning segment, engaging students in learning, and assessing student learning. The required supporting evidence is composed of video clips of classroom interactions during the learning segment, student work samples from the assessment analysis, instructional materials, and lesson plans. Once submitted, an edTPA portfolio is scored across 15 rubrics by a trained and calibrated scorer who has validated teaching experience and expertise in the grade level and content area of the subject edTPA (Adkins, Spesia, & Snakenborg, 2015; Pecheone et al., 2013).

The secondary and middle school science edTPA handbooks were written by SCALE with input from science educators and assessment experts (Stanford Center for Assessment, 2014). The edTPA secondary school science design team intentionally integrated some NGSS science and engineering practices into the rubrics and prompts to support pre-service teacher candidates in engaging their students in learning science with specific attention to the NGSS (Pecheone et al., 2013; Stillman et al., 2015). The crosscutting concepts and disciplinary core ideas may also be evidenced in edTPA portfolios as components of the school/classroom curriculum. By necessity, the implementation of the cross-cutting concepts and disciplinary core ideas will vary widely from one teaching context to the next (by grade level and course).

Next Generation Science Standards (NGSS) and edTPA Crosswalk

"For a system to work . . . its elements must be aligned. . . (I)f classroom teaching and learning activities are to help students attain the standards, they too must be aligned with the standards" (Herman & Webb, 2007, p. 3). Therefore, understanding how a nationally implemented preservice teacher assessment (edTPA) is linked to the NGSS may help guide science educators

[1] For a complete description of the eight science and engineering practices, see *NGSS* Appendix F (NGSS Lead States, 2013b).

in their preservice preparation programs. A crosswalk differs from an alignment chart. Alignment indicates a straight line between the assessment and the standards (Baker, 2004). In this case, edTPA is designed to evaluate authentic teaching practices and not NGSS practices. Therefore, true alignment is not an attainable or an appropriate goal. Instead, a crosswalk can be used to describe the intersections between the assessment and the standards. These linkages may be used to inform science educators of how edTPA can support the integration of NGSS practices within a K-12 experience.

The NGSS and edTPA Crosswalk (Brownstein et al., 2015) was developed using an expert review methodology and inter-rater agreement (Webb et al., 2007). Two science teacher educators and two assessment and evaluation experts engaged in a content validation process to judge the extent to which the rubrics and/or prompts provide opportunities for candidates to demonstrate the NGSS practices (Beck, 2007; Martone & Sireci, 2009). These potential edTPA/NGSS content linkages were found in five of the eight scientific practices (see Appendix A). A complete version of the crosswalk includes the edTPA rubrics and/or the prompt language with potential content linkage to the NGSS practice (see https://secure.aacte.org).

Methodology

Sample

In this research, content linkage requires more than an analysis of the assessment against the standards. It is not only evidenced through an analysis of the edTPA prompts and rubrics but also cross-checked with actual preservice teachers' edTPA commentary to provide a detailed and accurate picture of the intersections with the NGSS science and engineering practices. We analyzed the commentaries from nationally scored secondary science edTPA portfolios for all preservice science teacher candidates who completed a single subject credential program at a large western public urban university in the spring of 2014. The ten credential candidates, six women and four men, ranged in age from to 25 to 48, and all possessed a bachelor's degree in a science content area prior to beginning the program. Three of the ten candidates entered the program immediately after completing their baccalaureate degree. Year-long clinical placements were in a large urban area at nine high schools and one middle school. Candidates were placed in an urban setting for 90 hours of clinical experience in the fall term and student teaching in the spring semester. Although all schools were urban, there were wide variations in their demographics, including small to large student populations, low to moderate socioeconomic status, diverse social cultures, and academic climate. By the time they submitted their edTPA portfolios, the preservice science teachers had completed ten weeks of the student teaching experience in the same classroom where they completed their initial clinical experience in the fall term. The submitted portfolios included biology, chemistry, and physics (see Table 1).

Candidates had also completed one and a half semesters of required credential coursework while being enrolled in a two semester credential program. For spring 2014, the state mandated that each credential candidate must pass the edTPA with a score of 41 as a requirement for successful program completion and the award of a valid preliminary single subject science credential (California Commission on Teacher Credentialing, 2014).

Table 1 Science disc. for each portfolio

edTPA Portfolio	Portfolio Discipline	Grade Level
Port. #1	Physics	High School
Port. #2	Biology	Middle School
Port. #3	Biology	High School
Port. #4	Chemistry	High School
Port. #5	Biology	High School
Port. #6	Chemistry	High School
Port. #7	Biology	High School
Port. #8	Biology	High School
Port. #9	Biology	High School
Port. #10	Biology	High School

Data Collection

All edTPA portfolios were submitted to be scored, and then archived, through the electronic platform, Taskstream. The researchers obtained the required permissions and the 10 edTPA portfolios were released by the program's edTPA coordinator.

After data analysis was complete, scores and summarized demographic data were available to the researchers. Results ranged from 39 to 52 (out of 75, based on 15 rubrics, each with a five-point scale), where each score was reported as a total across all fifteen rubrics. The campus from which the portfolios were drawn was in the process of transitioning from the Performance Assessment for California Teachers (PACT) (Pecheone & Chung, 2006) to edTPA.

The portfolio submitted by candidates includes responses to prompts in each of the three tasks (planning, instruction, and assessment) as well as supporting evidence of lesson plans, videos of lessons, and example student work (Pecheone et al., 2013). For this research, we analyzed candidate commentary from the three tasks. Because candidates submit lesson plans in a format of their own choosing, the lesson plans may not necessarily speak to what is understood by the prospective teacher nor consistently reflect what occurs in the classroom (Beck, 2007). Additionally, the official scorers use submitted lesson plans and videos as supporting evidence for candidate commentaries. Therefore, we chose not to code submitted lesson plans. Candidates document their teaching during the learning segment by submitting up to two video clips that span no more than 20 minutes. The submitted clips are selected by candidates to use as evidence of their ability to analyze, through prompted written commentaries, how they have engaged their students in learning. When the edTPA is scored for consequential purposes, video recordings provide supporting evidence for how the candidate engages with K-12 students. The submitted examples of student work are selected by the candidate to demonstrate the range of student work and are used to support their reflective commentaries. In this study, we focused on the candidate's ability to apply NGSS practices as evidenced in his or her writing about and reflecting on his/her teaching. Therefore, in choosing to use candidate commentaries to guide our inquiry, we acknowledge that the identification of evidence for any of the eight practices is limited to what candidates write about or analyze in their teaching rather than what they might actually enact as identified by an objective expert observer.

Coding Scheme and Reliability

Our study followed the protocols for qualitative research outlined in Merriam (2009) and Denzin and Lincoln (2011). Inductive qualitative content methods were used for all data analyses (Denzin & Lincoln, 2011; Merriam, 2009). The categories for coding were drawn from the descriptions for each of the eight scientific and engineering practices found in Appendix F of the NGSS (2013b). For each category (science and engineering practice), the grade 6-8 competencies were used for the middle school portfolio, and the grade 9-12 competencies were used for the high school portfolios. For the remainder of the paper, we will refer to each category as one of the eight science and engineering practices. For each specific science and engineering practice, narrative passages from the candidates' reflective commentaries were coded.

Capturing both manifest and latent meaning of the content (Cho & Lee, 2014), coding indicated if the preservice teacher planned to engage students in that practice, actually did engage students in that practice, or reflected on missed opportunities to support student engagement in that practice. We utilized a qualitative content analysis by applying a deductive version of the constant comparative method to obtain accurate evidence in all eight coded practices (Cho & Lee, 2014; Fram, 2013). The outcomes were intact text with indexing themes (Gläser & Laudel, 2013). Data analysis is limited to the NGSS practices categories and understanding themes, or links, from those categories (Graneheim & Lundman, 2004).

For coding of the commentaries to the practices, Glaser and Strauss' constant comparison methodology, comparing and contrasting consistent coding instances within the data (1967) while constantly checking for inter-coder agreement between the researchers (Schilling, 2006). Descriptions from the practices matrix in NGSS Appendix F were used to determine if the commentary reflected the quality of that particular practice. For a passage to be coded as evidence of a practice, the commentary needed to address the breadth, depth, and challenge of one bullet point within the grade band of the practice matrix. It was not sufficient to reference a practice without an elaboration of the application of said practice and an integration of the learning of science. Examples of commentary-edTPA coded content linkages are included in Table 2. In each example, the students or prospective teachers are actively engaged (either in the classroom or through writing) in an NGSS practice. In a coded portfolio, the student teacher may be working to make sense of the practice and to understand how it plays out in the classroom. For example, portfolio #8 in Table 2 has a passage coded as analyzing and interpreting data. The central concept is, "How are new species formed?" (portfolio #8, planning commentary). During this portion of the lesson, students are using the science practice to learn the science. In contrast, in portfolio #1, students keep a log of their work building a musical instrument and "use physics vocabulary from the waves unit to explain the scientific phenomena behind music and building a musical instrument" (portfolio #1, planning commentary). However, in the commentary, there was little evidence of physics in the logs. Therefore, while there were components of the lesson where the learning of science was integrated with a science practice, this particular component, the log, was not coded as an example of a P-12 student engaging in a practice.

Table 2 Example commentary for NGSS practices

	Commentary Example #1	**Words from NGSS practices matrices**
NGSS 4	Portfolio #8: Assessment Commentary As a class they did very well analyzing and organizing data to make a hypothetical phylogenetic tree. 84% of the class is at Level 4, meaning the tree is complete and incorporates the data in a logical way. All students attempted to make a tree. I think it really helped them that we practiced drawing trees several times with different data. They could see how the organization of the tree could change depending on what kind of data was used. Additionally, they saw me do an example on the board and some of their classmates' work projected through the doc cam. I didn't see much innovation with the trees, although I tried to impress upon them that evolutionary trees might look very different from each other and still say the same thing	Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations (NGSS Lead States, 2013b, p. 9).
NGSS 7	Portfolio #5: Assessment Commentary Students seemed comfortable picking a clan that was fittest- almost all were able to do this- but many students struggled with using evidence to back up their argument. . . . Student B only talked about what it waslike for the hand clan to collect beans (easier due to having an opposable thumb) but didn't use any evidence to back up his claim that this clan was most successful.	Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence (NGSS Lead States, 2013b, p. 13).

To ensure consistency of coding using the NGSS practices matrix, we examined all three tasks in the ten portfolios for each practice separately. For the four science and engineering practices with potential content linkages as shown in Appendix A, we validated our level of coding consistency using two portfolios until our coding matched. We then independently coded the remaining eight portfolios and discussed our rate of agreement for each code incident to ensure the validity of our codes and to confirm inter coder reliability (Boeije, 2002; Webb et al., 2007). For the remaining four science and engineering practices, we used the process described above to independently code two full portfolios as well as to check and discuss our rate of agreement for each practice. We continued to code a portfolio until we reached a level of agreement above 90% for all three tasks within a single portfolio. We then divided the remaining portfolios and independently finished coding each of the four remaining practices. After we repeated our process for all eight practices, we chose random portfolios under each practice for a final reliability check and found 90% or greater agreement (Webb et al., 2007; Westbrook, 1994). At the completion of the process described above, each portfolio had been analyzed for coding a minimum of eight times and a maximum of 32 times.

Results

The 184 pages of portfolio commentaries provided rich data with which to identify evidence of specific science and engineering practices embedded in the teaching of science content. Table 3 presents the tabulation of the coded instances of each practice within each portfolio. The frequency of coded instances was classified into four levels: no linkages, minimal linkages, moderate linkages, and substantive linkages. Results with minimal linkages were re-examined to determine if a higher-level classification was warranted due to extensive breadth and depth. No portfolio levels were changed.

Table 3 NGSS practice frequency within each portfolio

edTPA Portfolio	**NGSS Practices**							
	1. Asking Qs & defining problems	***2. Developing & using models***	***3. Planning & carrying out investigations***	***4. Analyzing & interp. data***	***5. Using math & comp. thinking***	***6. Constructing explanations & designing solutions***	***7. Engaging in argument. from evidence***	***8. Obtaining, evaluating & commun. info.***
Port. #1	↓	↓	↔	↑	↑	↑	∅	↑
Port. #2	∅	∅	↑	↑	↓	↑	↑	↔
Port. #3	∅	↑	↓	↑	↔	↑	↑	↑
Port. #4	↓	∅	↓	↑	↑	↑	↔	↑
Port. #5	∅	↑	↑	↑	↔	↔	↑	↑
Port. #6	∅	↑	↑	↑	↑	↑	↔	↑
Port. #7	∅	∅	↓	∅	∅	↑	↓	↑
Port. #8	∅	↑	↑	↑	↔	↑	↑	↑
Port. #9	∅	↑	∅	↑	∅	↑	↑	↑
Port. #10	∅	↑	∅	↑	↑	↑	↑	↑

Portfolio Commentary Coding Definition Key

Symbol	**Code**	**Number of instances**
∅	None	0
↓	Minimal	1 – 3
↔	Moderate	4 – 7
↑	Substantive	7 or more

We then examined the levels of occurrence for each of the practices across the ten portfolios. If a practice was deemed to be substantive, it not only needed to have sufficient representation of the practice but also the practice had to be demonstrated consistently across the ten portfolios. We found consistent and strong content linkages for three of the five practices originally identified as linked in the crosswalk (see Table 4). The remaining two identified practices were identified as having inconsistent content linkages. The three practices noted in the crosswalk as not being linked had weak or inconsistent evidence.

Table 4 NGSS science and engineering practice level of content linkage to edTPA portfolio evidence

NGSS Science and Engineering Practice	Level of Linkage
1. Asking questions and defining problems	Weak
2. Developing and using models	Inconsistent
3. Planning and carrying out investigations	Inconsistent
4. Analyzing and interpreting data	Strong
5. Using mathematics and computational thinking	Inconsistent
6. Constructing explanations and describing solutions	Strong
7. Engaging in argumentation from evidence	Inconsistent
8. Obtaining, evaluating and communicating information	Strong

Discussion

To confirm content linkage, an assessment (edTPA) must consistently show evidence of a connection to the particular standard (i.e., science and engineering practice) (Porter, 2002). Although we are pleased to confirm strong content linkages between edTPA commentaries and three of the NGSS practices, we need to address the two practices originally identified as linked but with inconsistent content linkages demonstrated by the candidate commentary evidence: planning and carrying out investigations and engaging students in scientific argumentation. This does not mean that edTPA does not prompt candidates to plan for or to engage students in these practices but that candidates did not provide consistent evidence of actually doing so.

One originally identified linked practice with inconsistent evidence was planning and carrying out investigations. This practice is well established as an integral component of best practices in science teaching (DeBoer, 2004; Dewey, 1910, 1916), although it is yet to be widely applied in science classrooms (Duschl & Bybee, 2014). The NGSS practice of planning and carrying out investigations states, “Students should design investigations that generate data to provide evidence to support claims they make about phenomena. Data aren’t evidence until used in the process of supporting a claim. Students should use reasoning and scientific ideas, principles, and theories to show why data can be considered evidence” (NGSS Lead States, 2013b, p. 7). Coding the commentaries required that they clearly demonstrated specific criteria in the NGSS practices matrices. One of the planning and carrying out investigations 9-12 criteria is as follows:

> “Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision

of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly" (NGSS Lead States, 2013b, p. 7).

To be coded, the commentary would need to include each component. In the context of the edTPA guidelines, which require three to five hours of continuous instruction, it may be unrealistic to expect candidates that teach in a variety of middle and secondary content areas to devote significant, substantive attention to planning and carrying out full investigations in addition to the other edTPA requirements. While we recognize that participation in, and the effective implementation of, all eight practices is essential to fully address the NGSS (NGSS Lead States, 2013a), the student teaching context and scope required by edTPA necessarily limits what can reasonably be required of a candidate in building a portfolio. However, we suggest that when viewed over the ten to fifteen weeks of student teaching typically experienced by preservice science teachers during their clinical work, it is possible to create opportunities for the candidates to practice and refine engagement with their students in planning and carrying out investigations outside of edTPA.

A second practice identified in the original crosswalk with inconsistent evidence was engaging students in scientific argumentation. This practice is not common in classrooms and has been identified as a key/core practice that will require significant attention and reflective planning to successfully engage science students (Berland & Reiser, 2011; Driver, Newton, & Osborne, 2000). Given specific attention to argumentation in prompts and rubrics in edTPA (see Appendix A), we expected to see evidence of argumentation. However, as reported in the results, we found the coded instances for the practice of engaging in argument from evidence to be an inconsistent pattern of content linkage, with most occurring in the biology portfolios; we also identified a gap in the planning commentaries. The cause behind this lack of candidate demonstration of this NGSS practice is unclear: do edTPA prompts need to be more explicit, do candidates not understand the practice itself, do candidates not engage in this practice during student teaching, or does only particular science content lends more to the scientific argumentation practice? To better ascertain the cause of this limitation, we recommend examining the planning commentary prompts as well as the planning rubric in the science edTPA handbooks with an eye to bolstering credential candidates' attention to argumentation in planning, which could lead to more substantive attention in both instruction and assessment. Additionally, with changes in the prompts and rubrics, a future study could better determine the source of the inconsistent results.

For practices not identified as linked in the crosswalk, results varied. For example, we found weak content linkage for the practice of asking questions and defining problems. This result is consistent with the original crosswalk and may be due to the high level of performance expectations within the NGSS practices matrix: "Asking questions and defining problems in 9-12 . . . [is] formulating, refining, and evaluating empirically testable questions and design problems using models and simulations" (NGSS Lead States, 2013b, p. 4).

However, we did find evidence of inconsistent content linkage for both the practice of developing and using models and the practice of using mathematics and computational thinking. For the practice of developing and using models, we recognize that model-based reasoning is a long standing core practice in science and in the teaching of science (DeBoer, 1991; Finlay, 1962; Halloun & Hestenes, 1984; Kuhn, 1970; Moore, 1968; National Research Council, 1996;

Passmore, Stewart, & Cartier, 2009; Rutherford & Ahlgren, 1990; Svoboda & Passmore, 2013), so we are not surprised to find evidence of the practice. However, the lack of specific prompts or rubric criteria may have contributed to the inconsistent evidence. For the inconsistent linkages in the practice of mathematics and computational thinking, there were a relatively high total number of coded instances (Miles & Huberman, 1994). Although evidence of the practice of using mathematics and computational thinking was found across eight of the ten portfolios, nearly two thirds of the identified instances of the practice were in the three physical science portfolios. Additionally, the literature describes the NGSS mathematical reasoning practice as emphasizing deep student thinking rather than algorithmic thinking (Mayes & Koballa Jr, 2012; Tekkumru-Kisa, Stein, & Schunn, 2015). While the content linkages were coded, it was not clear if the items represented engagement in the practice as deep student thinking or meaning making. Therefore, it is our observation that the content linkage of edTPA to the mathematics and computational thinking practice is unclear.

Implications

Our literature review, crosswalk including rubrics and prompts for opportunities to demonstrate NGSS practices, and research findings on content linkage between edTPA secondary science portfolios and the NGSS have multiple implications. While our study is limited to a single setting, these results provide examples of novice teachers' understanding the application of NGSS practices. One indication for the educator preparation community is to consider the advantages of using crosswalks to empower professional educators to examine and utilize the content linkages between edTPA and standards as well as to inform educators in preservice teacher curricular decision making. According to the National Research Council, "the assessments required for teacher licensure and the course work needed for subject-area certification need to reflect the types of learning and assessment tasks that teachers will be expected to develop for students" (National Research Council, 2011, p. 83). In this vein, crosswalks may be useful to verify content linkages between edTPA and the Council for the Accreditation of Educator Preparation (CAEP) Specialty Professional Associations (SPA) content-specific standards for preparing educators, K-12 content standards, and state teaching standards.

According to Herman and Webb (2007), "For the system to work, however, its elements must be aligned" (p. 3). Crosswalk development requires a rigorous protocol that includes validation of identified content linkages through analysis of candidate portfolios. In this paper, a protocol that integrated a qualitative deductive version of the constant comparative methodology (Cho & Lee, 2014; Fram, 2013) with assessment alignment procedures (Martone & Sireci, 2009) was developed and followed. Our methodology is unique in contrast with traditional methods for evaluating alignment between standards and assessment in that we analyzed for content linkages and not complete alignment (see Table 5). Based on this research, an updated crosswalk has been developed (see Appendix B) and posted on the AACTE edTPA secure website (Brownstein et al., 2015). Additionally, an interesting question to pursue may be to examine the curriculum taught in the edTPA portfolio for disciplinary core ideas and crosscutting themes, but that is beyond the focus of this project. While these are essential components of NGSS, a study of the implementation of these two NGSS dimensions is better suited to an examination of the curriculum and observations in K-12 classrooms over an extended period of time.

Table 5 edTPA to NGSS practice content linkage: Proposed to evidence-based

NGSS Science / Engineering Practice	Originally identified content linkage to edTPA	Final evaluation of content linkage based on candidate evidence
1. Asking questions and defining problems	No	No
2. Developing and using models	No	No
3. Planning and carrying out investigations	Yes	No
4. Analyzing and interpreting data	Yes	Yes
5. Using mathematics and computational thinking	No	No
6. Constructing explanations and describing solutions	Yes	Yes
7. Engaging in argumentation from evidence	No	No*
8. Obtaining, evaluating and communicating information	Yes	Yes

*****Recommended changing rubric and prompts to more clearly address NGSS practice

The development and analyses of crosswalks between standards and assessments has the potential to support thoughtful, faculty inquiry (question-oriented) approaches to the implementation of edTPA in teacher preparation programs. Peck, Gallucci, and Sloan (2010) write about the potential pitfalls of a ‘compliance’ approach to implementing edTPA and the potential benefits of a faculty inquiry (question-oriented) approach. A compliance approach focuses on the outcomes and accountability mandates for candidate completion and passing of edTPA and can possibly narrow the program goals for both the teacher educators and the candidates (Peck et al., 2010). Conley and Gardner (2015) build on their work and describe a faculty inquiry approach: “In this case, edTPA was positioned as a vehicle for generative thought among the teacher educators and the teacher candidates” (p. 5). As educators, we can use the knowledge of the intersections between edTPA and the NGSS practices to support and build the needed changes in the teaching of science through the use of a science education faculty driven inquiry approach.

For science educator preparation programs, edTPA provides only partial evidence of science credential candidates’ implementation of the NGSS practices. If we wish to better prepare our future science teachers to engage K-12 students in the NGSS practices, we will need assessments that can provide evidence for the remaining four practices. An assessment that fills in the NGSS gaps in edTPA should be developed for use by educators throughout the US and territories. Peterson and Bruster do note that edTPA also strongly supports reflective practice (2014). There is a potential that preservice science teachers completing the science edTPA may not be just demonstrating an understanding of single specific NGSS science and engineering practices, but through reflective responses prompted by edTPA in the context of their actual practice, preservice science teachers may be increasing their understanding and ability to implement a suite of NGSS science and engineering practices. Still, if we wish to better prepare future science teachers to engage k-12 students in the full 3-dimensional nature of the NGSS, we will need more comprehensive PCK centered assessments that also focus on the cross cutting concepts and specific Disciplinary Core Ideas. Assessments that fill in the NGSS gaps in edTPA should be developed and shared by science educators both in the US and internationally.

Additionally, science teacher educators' need to advocate for a disciplinary-specific faculty inquiry approach to the implementation of edTPA. Because all learning is a "process of active construction" (Cochran-Smith & Villegas, 2015, p. 10), it is possible for science teacher educators to support greater understanding of the NGSS practices through active formative preparation, enabling the summative creation of a strong, reflective science edTPA portfolio. We agree with Stroupe (2015) that there need to be "more studies to better understand . . . how to help novice educators use their science learning experiences to design similar opportunities for students." (p. 1038). The work in this paper contributes to the research needed to prepare candidates for the changes necessary to engage students in science as required by the NGSS (National Science Teachers Association, 2013). Capitalizing on opportunities to engage preservice teachers in critical reflective practice around the suite of edTPA linked practices, both in the program coursework as well as in clinical practice, becomes imperative for success on the edTPA and their readiness to engage students in learning science through inquiry-based practices that reflect how science and engineering are done in the real world (National Science Teachers Association, 2013). Refining the crosswalk to better fit the identified content linkages between the NGSS and edTPA, strengthening the prompts for argumentation in the science edTPA handbook, and taking a faculty inquiry approach to edTPA implementation will support the preparation of highly qualified science teachers who are ready to meet the challenges of implementing the NGSS.

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Appendix A

[Original] *Next Generation Science Standards* (NGSS) and edTPA Crosswalk

This crosswalk is a representation of where the NGSS are demonstrated in the edTPA rubrics and prompts. See original for alignment analysis.

	edTPA Rubric	**NGSS Practices**							
		1. *Asking Qs & defining problems*	2. *Developing & using models*	3. *Planning & carrying out investigations*	4. *Analyzing & interpreting data*	5. *Using math & computational thinking*	6. *Constructing explanations & descriptions solutions*	7. *Engaging in argumentation from evidence*	8. Obtaining, eval., & communicating information
Task 1: Planning	*1. Planning for Content Understandings*			√			√	√	√
	2. Planning to Support Varied Student Needs								
	3. Using Knowledge of Students to Inform Planning								
	4. Identifying and Supporting Language Demands								
	5. Planning Assessments to Monitor and Support Student Learning								
Task 2:	*6. Demonstrating a Positive and Engaging Learning Environment*								
	7. Engaging Students in Learning				√		√	√	√
	8. Deepening Student Learning While Teaching						√		√
	9. Subject Specific Pedagogy: Science				√				
	10. Analyzing Teaching								
Task 3: Assmt.	*11. Analyzing Student Work*								
	12. Providing Feedback to Guide Learning								
	13. Supporting Students' Use of Feedback								
	14. Evidence of Language Use to Support Content Understandings						√		
	15. Using Assessment to Inform Instruction							√	

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Appendix B

[SUGGESTED UPDATE] *Next Generation Science Standards* (NGSS) and edTPA Crosswalk

This crosswalk is a representation of where the NGSS are demonstrated in the edTPA rubrics and prompts as well as evidenced in candidate planning, instruction, and assessment commentaries. See original document for alignment analysis of edTPA rubrics and prompts.

	edTPA Rubric	**NGSS Practices**							
		1. *Asking Qs & defining problems*	2. *Developing & using models*	3. *Planning & carrying out investigations*	4. *Analyzing & interpreting data*	5. *Using math & computational thinking*	6. *Constructing explanations & descriptions solutions*	7. *Engaging in argumentation from evidence**	8. Obtaining, evaluating, & communicating information
Task 1: Planning	*1. Planning for Content Understandings*						√	√*	√
	2. Planning to Support Varied Student Needs								
	3. Using Knowledge of Students to Inform Planning								
	4. Identifying and Supporting Language Demands								
	5. Planning Assessments to Monitor and Support Student Learning								
Task 2:	*6. Demonstrating a Positive and Engaging Learning Environment*								
	7. Engaging Students in Learning				√		√	√*	√
	8. Deepening Student Learning While Teaching						√		√
	9. Subject Specific Pedagogy: Science				√				
	10. Analyzing Teaching								
Task 3: Assmt.	*11. Analyzing Student Work*								
	12. Providing Feedback to Guide Learning								
	13. Supporting Students' Use of Feedback								
	14. Evidence of Language Use to Support Content Understandings						√		
	15. Using Assessment to Inform Instruction							√*	

*Recommended to be included if there is a reexamination of rubrics and prompts for increased language from NGSS practice: Engaging in argumentation from evidence. Modified version retrieved from https://secure.aacte.org