Improving Science Education in International Schools Through Professional Development Targeting Next Generation Science Standards Assessment Design

by

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Abstract

Science education has been the focus of education reform in the United States for decades, as quality science education has been perceived as one of the mechanisms by which the United States can maintain its competitiveness in an increasingly technological and global marketplace. The Next Generation Science Standards, released in 2013, is a set of standards which seeks to develop science literacy utilizing a unique three-dimensional structure. Implementing the standards effectively requires significant professional development for teachers. As of January 2019, 21 U.S. states have adopted the standards for the basis of their K-12 science instruction, and so to have a number of not-for-profit American-curriculum international schools around the world. Not-for-profit American-curriculum international schools operate in a unique space. Situated in countries outside of the United States, the schools typically seek to replicate an American educational environment by employing native English-speaking, western-trained teachers, while delivering an American-style education to expatriate students, a large proportion of which are United States citizens. This study utilizes the Revised Consensus Model of Pedagogical Content Knowledge for science instruction to explore how science teachers in American-curriculum international schools come to understand the NGSS. This action research study's intervention is a professional development activity centered on a tool which guides systematic reflection of practitioner-developed assessments of NGSS performance expectations. Results from the study may serve to improve science instruction in international schools by informing the design of future professional development activities for science instructors in international schools.

Chapter 1

Introduction

The Challenges of Science Education Reform

Science instruction entered the United States' public school curriculum during the 19th century, in part because scientists themselves argued for its value amongst the studies of humanities, which were the primary focus of the time. Thomas Huxley, Herber Spencer, Charles Lyell, Michael Faraday, John Tyndall, and Charles Eliot were notable scientists who were outspoken about bringing science instruction into mainstream classrooms (DeBoer, 1991). In the midst of the transformations brought on by the industrial revolution, scientists argued the discipline's practical application and inductive reasoning processes provided superior intellectual training over the deductive reasoning processes prevalent in education at the time (DeBoer, 1991).

Through much of the early and mid 20th century, science instruction was justified by its relevance to society more so than by the value of logic and skills inherently linked to organized science (National Education Association, 1918; National Society for the Study of Education, 1932; 1947). In the mid and latter parts of the 20th century, as nuclear proliferation continued and the United States and the Soviet Union battled over space, the centrality of science and technology to American geopolitical strength became increasingly apparent (DeBoer, 1991; Johanningmeier, 2010). It was therefore significant when, in 1983, the publication of *A Nation at Risk*: *The Imperative for Educational Reform* (National Commission on Excellence in Education, 1983) cast doubt on American's ability to compete in science and math. Considered to be one of the most significant events in the history of the United States public education system, the 36 page report highlighted science and mathematics education as one of the key avenues through which the United States might continue its competitiveness on the global scene, while simultaneously suggesting a steady deterioration of American academic achievements in science (Klieger & Yakobovitch, 2011). *A Nation At Risk* created a notable public response and has been seen as a catalyst to creating the political will which lead to subsequent decades of education reform movements, including an increased emphasis on improved standards for science education (Neumann, Fischer & Kauertz, 2010; Stevenson & Stigler, 1994).

While *A Nation at Risk* created the political will for large scale reforms, the reforms of subsequent decades frequently materialized as largely content-focused standards, structured to disseminate discrete scientific knowledge to prepare students for international measures of science achievement (DeBoer, 1991). Often, instruction was heavily dependent upon vocabulary and diagram memorization. Laboratory activities, if they existed, were of a ‘cookbook’ variety where students followed precise directions to arrive at predetermined outcomes (Bentley, et al., 2007; Pruitt, 2014).

The Next Generation Science Standards

The Next Generation Science Standards (NGSS), which heavily emphasize conceptual and cross-disciplinary understandings and the development of scientific skills and processes, are a significant departure from previous content-focused standards (Brunsell, Kneser & Niemi, 2014; Pruitt, 2014). First released in 2013, as of January 2019, 19 U.S. states have adopted the NGSS as the basis for their public school curriculum, and another 21 are either contemplating adoption, or have developed their own standards based on the conceptual framework outlined in the National Research Council’s (NRC) *A Framework for K-12 science education: Practices,* *crosscutting concepts, and core ideas* (NSTA, 2019). In developing *A Framework* (National Research Council, 2012), the NRC built upon major ideas from *Science for all Americans* (American Association for the Advancement of Science, 1990) and *Benchmarks for Science Literacy* (1994), the *National Science Education Standards* (National Research Council, 1996), and other research conducted by the American Association for the Advancement of Science (2012).

Like prior reforms, in developing the framework which underlies the NGSS, the NRC acknowledged indications that American students lag behind their international counterparts in science achievement, and are not being well-enough prepared for 21st-century economies. The NRC referenced a 2009 Carnegie Commission on Mathematics and Science Education report in describing its motivation to develop the NGSS:

> ...the nation's capacity to innovate for economic growth and the ability of American workers to thrive in the modern workforce depends on a broad foundation of math and science learning, as do our hopes for preserving a vibrant democracy and the promise of social mobility that lie at the heart of the American dream. (Commission on Mathematics and Science Education, 2009, p. vii)

In developing the new conceptual framework for science instruction, the NRC has interpreted the commission's call for a "broad foundation of math and science learning" to be more than just the memorization of large quantities of scientific information. Rather, the NRC's framework seeks to build a base of scientific knowledge coupled with proficiency of scientific inquiry skills, understanding of science and engineering processes, and an ability to apply scientific concepts across disciplines. So the NGSS, which were developed in accordance with the NRC's conceptual framework, incorporate scientific inquiry and other science processes and skills in a way that previous standards have not (Brunsell, et al., 2014.; Nollmeyer & Bangert, 2015; Pruitt, 2014). With the NGSS, each student Performance Expectation (PE) is three-dimensional, consisting of a discipline-specific core idea, a science or engineering-related practice, and a broader cross-disciplinary crosscutting concept (Pruitt, 2014).

The three-dimensional nature entailed in each NGSS PE challenges teachers to not only have a strong grasp of science content and practices, but also the pedagogical implications for the way the three dimensions are tied together (Bybee, 2014; Krajcik, 2015). For example, using models effectively, using evidence as a basis for argumentation, incorporating engineering design, and constructing explanations of scientific phenomena are new and unique instructional techniques for many teachers (Bybee, 2014; Reiser, 2013). Consequently, science educators have expressed feeling unprepared to fully implement the NGSS. Haag and Megawon (2015) conducted a study to describe U.S. middle and high school teachers' preparedness to teach the NGSS. The mixed-methods study collected data from 710 middle and high school science teachers from 38 states and focused on three aspects of teacher quality related to the NGSS - teacher motivation to teach the NGSS, teacher preparedness to teach the NGSS, and how experience with modeling instruction affected motivation and preparedness to teach the NGSS. They concluded that typically only teachers with significant amounts of professional development (PD) with modeling instruction felt prepared and motivated to teach the standards (Haag &Megowan, 2015). Harris, Sithole, and Kibirige (2017) conducted a similar study sampling teachers from across 16 states, which found only about 50% of teachers considered themselves familiar with the NGSS. Wilde (2018) conducted a smaller study of high school science teachers in California - a state which had adopted the NGSS nearly five years earlier - which revealed that only 41% of teachers considered themselves highly familiar with how the NGSS PE related to student assessment (California Department of Education, 2015).

It should be self-evident that having many teachers unprepared, unmotivated, or even unwilling to use the new methods associated with the NGSS has significant repercussions for their successful implementation, as teachers are the primary mechanism by which any standards are ultimately enacted (Bybee, 2014; Haag & Megowan, 2015; Loveland, 2004). A key contributor to the development of the NGSS, Dr. Rodger Bybee, recognized early in their adoption that teachers themselves might be the NGSS's Achilles Heel lamenting, "...the responsible individuals [teachers] have their ideas about teaching and learning and those ideas do not necessarily align with the NGSS." (Bybee, 2014, p. 218). Even while some educators welcome changes to pedagogy, others may quickly return to traditional teaching methods if not engaged with sustained support and accountability (Lam, Cheng & Choy, 2010). Effectively engaging, preparing, and sustaining teachers in their work to understand the new standards will be essential to the NGSS's success (Bianchini & Kelly, 2003; Bybee, 2014).

Situating the Problem of Science Education Reform in American-curriculum International Schools

The effects of U.S. reform movements in science education extend beyond national boundaries. There are a number of schools around the world which employ U.S. trained educators to simulate home-country educational experiences for the children of American expatriates. Singapore American School (SAS), where I am currently employed, may be the quintessential American international school. Like many such schools, SAS was founded in the mid-1900s by an expatriate parent population seeking an educational experience that would allow their children to easily reassimilate upon return to their home countries. When SAS opened in 1957, just 105 students received instruction in small colonial style bungalows. Over the next several decades, as Singapore gained independence and transformed into a major economic force in Southeast Asia, the number of expatriates in the country also increased. This expansion of expatriates in Singapore likewise allowed SAS to expand its facilities, academic and extracurricular offerings, and recruit quality educators from around the world. SAS now serves more than 3500 non-Singaporean students from at least 56 different nations, and those students enjoy purpose-built facilities on a 36-acre campus situated approximately ten miles north of Singapore's central business district.

SAS has also established a reputation for academic excellence. In 2016, of all schools in the world registered to offer Advanced Placement (AP) courses, SAS was ranked in the 96th percentile for the percentage of students earning a three or higher on the AP exams. In the same year, students at the school ranked, on average, in the 94th percentile or higher worldwide in all subjects evaluated by the Northwest Education Association's (NWEA) Measure of Academic Progress (MAP) assessment. Currently, 40 college-level courses are offered in the high school, and the senior class of 2016 had an average SAT score of 1930, substantially higher than the global average of 1490 ("Academics," n.d.). Despite such success, SAS continues to pursue initiatives aimed at transforming the educational experience offered to better prepare students for a rapidly changing and increasingly technology-driven global economy. One such initiative is the adoption of the NGSS.

As an 8th grade science teacher at SAS, I was excited by the school's adoption of the NGSS during the 2015-2016 school year. I felt the standards were an improvement to those in place previously, and I was eager to work with and help colleagues to implement them. When I enrolled in Arizona State University's (ASU) Ed.D. in Leadership and Innovation program, I did so with the intention to focus my dissertation research on PD practices aimed at improving NGSS implementation.

As I began my own action research cycles for the ASU program, SAS initiated its own regimen of NGSS-focused PD activities. Through the subsequent two years of working with colleagues on action research cycles I found that, increasingly, faculty at SAS were feeling overwhelmed by participating in parallel PD activities around the NGSS in addition to fulfilling other professional responsibilities. Teachers recognized their need for, and wanted, NGSS-related PD but they wanted it to focus on activities which helped them do better the things they were *already* doing, rather than being asked to do *new* things as add ons.

In August of 2018, a series of PD activities focused on evaluating the alignment of internal assessments (i.e. assessments designed by practitioners for use in their own classrooms) with the constructs of the NGSS was initiated. During the activities, a screening tool developed by science consultant Paul Andersen and Lisa Brosnick, president of the Science Teachers Association of New York State (STANYS) was introduced (Andersen & Brosnick, 2018). In the interim, similar PD activities have been implemented in at least 19 international schools in 15 countries. The reception from teachers regarding the PD activities has been positive, but anecdotal (P. Andersen, personal communication, Dec 19, 2018). Scholarly investigation of how these PD activities, centered on systematic reflection of internal assessments, affect teachers' understanding of the NGSS and associated pedagogy are the focus of this study. It is my hope that the results of this study will inform future cycles of action research at SAS as well as NGSS-related PD activities at similar international schools.

Problem of Practice

Science teachers need help implementing the NGSS because the standards integrate science and engineering skills, broader conceptual understandings, and content knowledge in a way previous standards have not (Bybee, 2013, 2014; Brunsell, Kneser & Niemi, 2014.; Nollmeyer & Bangert, 2015; Pruitt, 2014). Many teachers, even those who have been trained in science, lack experience with the sorts of authentic investigations envisioned in the NGSS. (Kang, Donovan & McCarthy, 2018). These teachers need professional development activities which help them to understand the NGSS and the implications of the NGSS on pedagogy and assessment practices (Bybee, 2013, 2014; Haag & Megowan, 2015; Harris, Sithole & Kibirige, 2017).

Purpose of the Study

This study seeks to improve science education in American-curriculum international schools by contributing to the understanding of NGSS focused PD. The study specifically explores how science teachers in international schools come to understand the NGSS through PD targeting NGSS assessment design. The innovation in the study is a PD activity which engages teachers in a systematic reflection of NGSS assessments developed by teachers for use with students in their own classrooms (i.e., internally-designed). Conclusions from the study may be used to inform future PD activities in international schools.

Research Question

How does professional development mediated by the use of a screening tool (3D-PAST) enhance and/or challenge science teachers' understandings of the Next Generation Science Standards (NGSS) in American international schools?

Chapter 2

Conceptual Framework and Research Guiding the Project

This chapter describes the two bodies of knowledge which compose the conceptual framework guiding this investigation and interpretation of collected data. The first body of knowledge is Pedagogical Content Knowledge (PCK). PCK has been embraced by the science education community as an important theoretical framework for researching the professional knowledge of science teachers (Abell, 2007; Chan & Hume, 2019). The Revised Consensus Model (RCM) of PCK for science instruction is presented as a model for considering PCK. Second, given their centrality to this project, I will use the key concepts articulating the NGSS to guide my research. Subsequently, a review of literature situating the study within the unique context of international schools is presented.

Pedagogical Content Knowledge

PCK has been articulated as the unique domain of understanding at the intersection of teachers' content knowledge (CK) and pedagogical knowledge (PK) (Shulman, 1987). In Shulman's (1986) original formulation, CK and PK were mostly distinct and independent knowledge domains influencing PCK (Lederman & Gess-Newman, 1992; Shulman, 1986, 1987). CK is the factual, subject-specific expertise held by a teacher. For example, teachers of science may need to know facts about cell structure and laws of physics, how to operate microscopes or prepare biological specimens. A strong grasp of CK is considered a fundamental trait of effective teachers because teachers need CK to make decisions about instruction, pose challenging questions which elicit students' critical thinking, contextualize facts and topics, engage students with and select appropriate materials for use with students (Anderson &

Freebody, 2012; Ball, Thames & Phelps, 2008, Baumert, et al., 2010; Findel, 2008; Rovengo, 1995). The acquisition of CK is typically a primary focus of teacher preparation and licensure programs (Howell, et. al. 2018; Ward, Tsuda, Dervent & Devrilmez, 2018).

In addition to CK, effective teachers must also have a developed understanding of how to best transform that knowledge into learning experiences for their students (Bybee, 2014; Covay Minor, Desimone, Caines Lee & Hochberg, 2016; Kind, 2009; Shulman, 1987). In contrast to CK, PK refers to teachers' understanding of the ways to create effective learning opportunities for students. PK may include knowledge of classroom management practices, learning processes, student characteristics, and methods of questioning and planning (Lederman & Gess-Newsome, 1992; Voss, Kunter, & Baumert, 2011). While teacher preparation programs may attempt to develop PK outside of actual practice, it is recognized that a teacher's PK is developed throughout the duration of a career and within the specific working environments a teacher experiences (Lederman & Gess-Newsome, 1992).

Differentiating "a content specialist and a pedagogue" (Shulman, 1987, p.8) is the extent to which they have developed an "amalgamation of content and pedagogy" (p. 8) which is able to elicit meaningful learning experiences for students; this amalgamation is the realm of PCK. Shulman (1987) described PCK as knowledge of "ways of which to represent and communicate a subject which makes it most comprehensible for others" (p. 9), and as the distinctive bodies of knowledge for teaching which represent the "blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Schulman, 1987, p. 8). PCK is domain specific. For example, a biology teachers' PCK is different from an English or history teacher's PCK, and even within a subject - such as physics - a teacher's PCK may vary by topic. It is also contextual. As teachers' knowledge of students and environments change, so too does teachers' PCK. This is to say, that as teachers' knowledge of content, students, and teaching context change, the methods they employ to help students learn particular content also changes.

Since its inception, however, various aspects of PCK have been debated. These debates have included whether it is a distinct body of knowledge, the extent to which PCK is a knowledge base, a skill set or both, what components should be included in the knowledge base of PCK, the extent to which PCK is context specific, individual or collective, and the appropriate boundaries within which PCK can be considered (Chan & Hume, 2019; Krepf, Ploger, Scholl & Seifert, 2018). Unsurprisingly, then, the complexity of PCK has been investigated using a variety of models. For example, a study by Kind (2009) found at least nine different models that have been utilized to study teachers generally, or science teachers specifically. However, Kind (2009) notes that much of the variation in models are accounted for in ways subcategories of knowledge within the PCK domain are classified (Kind, 2009). Despite these differences, the concept of PCK as a distinct knowledge domain of teachers has generally been affirmed (Covay, et. al, 2016; Kind, 2009).

Refined Consensus Model of PCK for science instruction.

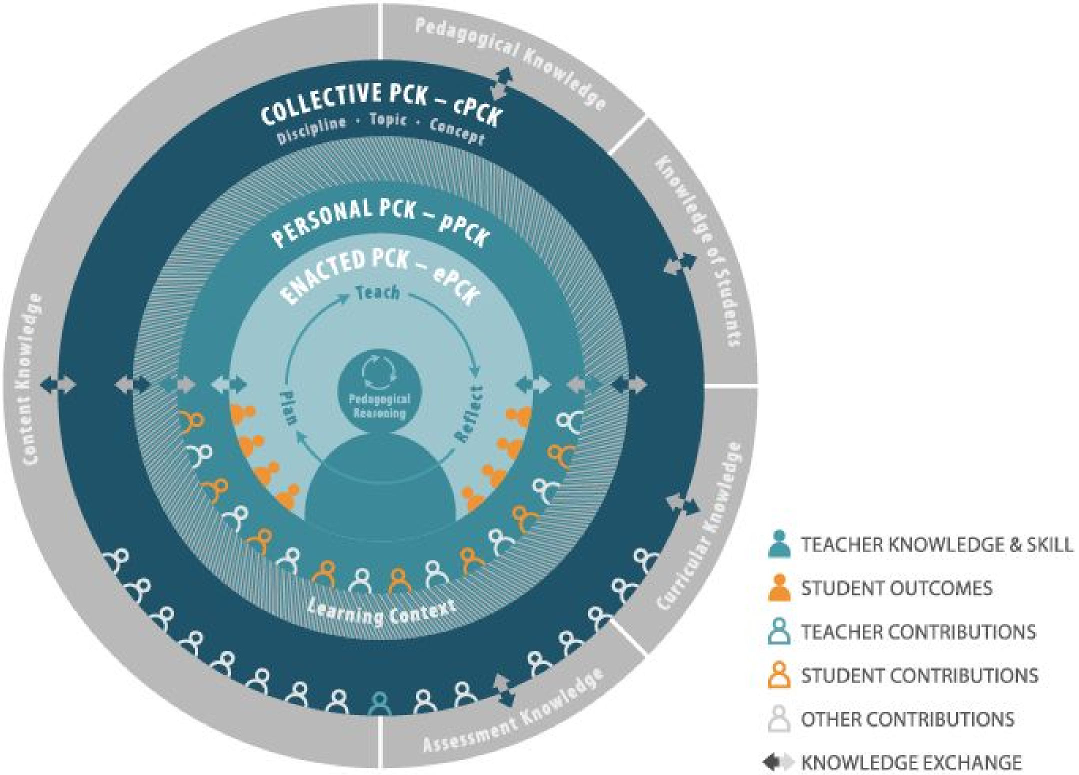
The Refined Consensus Model (RCM) of PCK for science instruction was developed in 2017 from the contributions of more than two dozen researchers in science teacher education with a goal to aid researchers in situating studies of student science learning in relationship to PCK, and to provide a means to situate theories about the development of teacher PCK (Carlson

& Daehler, 2019). The RCM is conceived as a dynamic layering of three distinct realms of science PCK, collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK). ePCK, at the center of the model, is the most specific and context-dependent realm, consisting of the knowledge utilized when a teacher is engaged in the practice of teaching (i.e. planning instruction, carrying out a lesson, etc.). ePCK is drawn from pPCK which is the larger reservoir of pedagogical knowledge and skills possessed by a teacher. pPCK is developed over the course of a career through formal education, teaching experiences, and professional sharing. ePCK and pPCK are influenced by the learning context. The learning context may be considered to include not only classroom environments and student attributes, but also school or district conditions and the broader educational climate. The knowledge developed and shared by the larger science research and education community, which is more generalized and public, is considered cPCK (Carlson & Daehler, 2019). cPCK may include the knowledge present within the field's literature, but also "a continuum of knowledge held by a group that extends what is present in the literature and recognises that the knowledge about science teaching is also developed within school districts, school sites, departments, grade-level teacher teams, and professional learning communities" (p. 89).

Standards and benchmarks like the NGSS occupy the realm of cPCK; they were developed through a collaboration of science and education experts, utilizing ideas drawn from a number of previous studies and science education reform efforts, and they are intended to be generally applicable for all science students (National Research Council, 2012). The RCM describes how, as cPCK, the NGSS may exist outside of and apart from individual educators' knowledge. In being a part of cPCK, standards and benchmarks do not impact classroom learning experiences until there is a knowledge transfer from cPCK to pPCK, and then ultimately to ePCK where teachers' personal repertoire of PCK is enacted to have a direct impact on student learning. This translation of knowledge from the realm of cPCK to ePCK is a persistent problem in education (Hiebert, Gallimore & Sigler, 2002; Hume, Cooper & Borowski, 2019). In defining the boundaries of knowledge transfer, the RCM serves as a tool to investigate this problem (Hume, Cooper & Borowski, 2019). Figure 1 presents a graphical representation of the RCM.

Figure 1.

Representation of the Refined Consensus Model (RCM) of PCK. From: Hume, A., Cooper, R., & Borowski, A. (2019). Repositioning Pedagogical Content Knowledge in Teachers' Knowledge for Teaching Science. p. 83.



Three Dimensional Framework of the Next Generation Science Standards

Given their centrality to this project, the key concepts framing the NGSS also guide this research. The NGSS were designed using the conceptual framework articulated in *A Framework for K-12 Science Education* (2012), developed by the National Research Council Committee on A Conceptual Framework for New K-12 Science Education Standards. According to the framework, science literacy can be described as composed of three dimensions: science and engineering practices (SEP), crosscutting concepts (CCC), and disciplinary core ideas (DCI) (National Research Council, 2012; Pratt, 2013).

Science and Engineering Practices

The first dimension of the conceptual framework consists of common practices used by both scientists and engineers. As related to science, these SEP are used to investigate the natural world, build models of concepts, and develop theories to explain phenomena. As related to engineering, the practices are a key set of activities engineers use to design and build systems (National Research Council, 2012). The SEP dimension consists specifically of eight practices considered essential for both scientists and engineers. These practices are detailed in Table 1.

Table 1.

Science and Engineering Practices Included in the Framework[1]

Practice	Description
Asking questions and defining problems	As it pertains to science, this skill constitutes an ability to formulate questions about natural phenomena that are able to be answered empirically. As it pertains to engineering, it constitutes an ability to define a problem, identify constraints, and criteria for successful solutions.
Developing and using models	Models are used in science to describe natural phenomena that may not be observable with the naked eye. In engineering, models can be used to analyze and test systems.

Planning and carrying out investigations	Science frequently utilizes systematic investigations which require proper identification of independent and dependent variables. Engineers conduct investigations to test their designs.
Analyzing and interpreting data	Scientific investigations produce data that must be utilized using a variety of tools and processes. Engineers analyze data to compare different solution designs.
Using mathematics and computational thinking	Scientists and engineers use mathematics and computations tools for representing physical variables, constructing simulations, and identifying quantitative relationships which allow for predictions in physical systems.
Constructing explanations and designing solutions	Scientists seek to construction logically coherent explanations of natural phenomena, consistent with current scientific understanding and available evidence. Engineers use scientific knowledge and models to propose solutions to problems which balance competing criteria and constraints.
Engaging in argument from evidence	Scientists must defend their reasoning and explanations using a foundation of data. In engineering, data is used to critique various design solutions and select those which are most promising.
Obtaining, evaluating, and communicating information	The advancement of science is dependent upon effective communication of scientific findings and their implications. Likewise, in engineering, the field advances when new understandings are able to be effectively communicated. Effective communication of ideas takes a variety of forms, including oral, written, graphical representations, equations, and extended discussions.

[1] Descriptions summarized from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas*, pgs 50 - 53.

Crosscutting Concepts

Concepts which have application across all disciplines of science constitute the second dimension of the NGSS conceptual framework. These CCC are ideas which provide “organizational frameworks for connecting knowledge from various disciplines into a coherent and scientifically based view of the world" (National Research Council, 2012, p. 83). The conceptual framework incorporates the seven concepts detailed in Table 2.

Table 2.

Crosscutting Concepts[1]

Concept	Description
Patterns	Regularly occurring shapes, structures, or processes.
Cause and Effect	Causal connections between two or more events.
Scale, proportion, and quantity	Variations in size and quantities.
Systems and system models	Closely related, but distinguishable, parts of objects, organisms or entities which have boundaries, resources, flow and feedback.
Energy and matter	Inputs, outputs, and conservation principles of energy and matter.
Structure and function	Complementary aspects of objects, organisms and systems.
Stability and change	Changing and unchanging conditions, systems, or processes. Equilibriums, feedback loops, and cyclical processes.

[1] Descriptions summarized from A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas, pgs 85 - 100.

Disciplinary Core Ideas

DCI constitute the third dimension of the NGSS. DCI are the facts and conceptual understandings associated with the specific disciplines of physical sciences, life sciences, and earth and space sciences, as well as engineering, technology, and applications of science. In the NGSS, DCI are not exhaustive of the knowledge existent within a particular field. Instead, DCI are limited to content knowledge which has broad importance, may be a key organizing principle of a discipline, or serves as an important tool for understanding more complex ideas. DCI may also be ideas which have particular relevance to students due to their connection with societal or personal concerns. DCI should also be ideas which can be made accessible to younger students while being broad enough to allow for progressively deeper investigation and understanding throughout students' K-12 experiences (National Research Council, 2012). DCI most closely correlate to what is considered 'content knowledge' or 'subject matter knowledge' in a traditional understanding of K-12 science curriculum.

Understanding American International Schools

While much of the impetus driving science education reform has been the perceived deficit position of students in American schools in comparison to their other first-world counterparts, there is a subset of schools which straddle a fuzzy line between being 'American' and 'not American' which are also grappling with education reform. These schools, overseas American-curriculum schools, are a subcategory of a group of schools known as international schools. The context of international schools has garnered much less interest from scholars than other areas of education and, though the literature is rapidly increasing, it remains an under-researched field (Hayden & Thompson, 2008; 2013).

A precise definition of what constitutes an international school is debated (Hayden & Thompson, 2013; Heyward, 2002; Joneitz & Harris, 1991; Terwilliger, 1972). Historically, international schools were recognized as those schools established outside of a home country for school-age children of internationally mobile professionals (Fertig & James, 2013). These schools were typically non-profit organizations established by expatriate community members (Hayden & Thompson, 2013). Such schools are likely to follow a national curriculum of a particular expatriate nationality, different from the national curriculum of the country in which they are hosted. For example, a school in Cambodia catering to primarily British expatriates would offer the British National Curriculum, one in Tanzania serving predominantly German expatriates would offer a German curriculum, and so on. Typically, these schools offer instruction either in the language associated with the type of curriculum (i.e. in a French-curriculum school, French would be the primary language of instruction) or in English. While these schools often incorporate multicultural and global perspectives into their instruction, their primary goal is often to approximate - albeit with a more global mindset and more culturally diverse student body - a home-country education in an overseas location (Nagrath, 2011; Tate, 2016; Waterson, 2016). This type of international school has been classified as Type-A by Hayden & Thompson (2013).

The number of international schools, their scope of mission, type of clientele, and nature of their governance has expanded substantially in the last half century (Bunnell, 2014; Hayden, 2011). In addition to the Type-A schools, Hayden & Thompson (2013) have identified two other broad categories of international schools. A second type of international school, Type B, has been identified as those that have formed primarily with the purpose of promoting a particular non-national ideology, rather than in response to a specific market need (Hayden & Thompson, 2013). Unlike the Type A schools which formed to serve primarily a specific expatriate population, these Type B schools are exemplified by schools such as the United World Colleges (UWC) system founded in 1967 around the philosophy of Kurt Hahn. Seventeen UWCs in 15 countries operate with the expressed purpose of bringing together students from diverse backgrounds to “unite people, nations, and cultures for peace and a sustainable future.” (Hayden & Thompson, 2013; “What is UWC?” n.d.). The United Nations International School in New

York, Yokohama International School, and the International School of Geneva are other notable examples of schools established under a similar premise (Fabian, 2016; Walker, 2016). The third type of international school, Type-C international schools, are a more recent development. In contrast to Type-A and Type-B schools, these tend to be aimed primarily at host-country nationals and operate on a more commercial basis than either Type-A or Type-B (Hayden & Thompson, 2013). This group is diverse. It includes satellites of prestigious schools such as the UK's Dulwich College and Harrow School, and Canada's Branksome Hall. It also includes chains of schools such as those operated by GEMS Education, Cognita, and Nord Anglia Education, along with a variety of smaller groups and schools that operate as individual entities (Bunnell, 2016; Hayden & Thompson, 2013; Waterson, 2016).

As there is no single organization which governs international schools, reliable statistics of the field can be difficult to obtain (Hayden & Thompson, 2013). However, estimates of the numbers, types, and demographics of the schools can be gleaned from any of the 15 or more regional organizations with which many of the schools collaborate such as the Near East South Asia (NESA) association, Middle East North Africa (MENA) association, East Asia Regional Council of Overseas Schools (EARCOS), Association of International Schools in Africa (AISA) and the European Council of International Schools (ECIS), as well as from various entities such as International School Services (ISS) and Search Associates which assist the schools in a variety of ways, including in the recruitment of faculty (Ortloff & Escobar-Ortloff, 2001). From 1964 to 1995 the number of international schools grew from around 50 to about 1000 schools around the world (Hayden & Thompson, 1995). In 2015, the International Schools Consultancy Group estimated there were over 7500 schools classifying themselves as 'international', and predicted that by 2025 there would be over 8 million students being served by more than 15,000 international schools worldwide (Brummitt, 2015; Keeling, 2015). Nearly all of this growth, however, has been in the more commercially focused Type-C schools (Waterson, 2016).

In contrast, the growth of Type-A international schools has been significantly less. The state of American-curriculum international schools, in particular, can be estimated using the available information from the U.S. Department of State Office of Overseas Schools which keeps information on such schools in order to aid American diplomatic and expatriate families during relocations ("Office of Overseas Schools," n.d.). It is worth noting that the United States military operates 164 American-curriculum schools in 11 countries under the Department of Defense Education Activity. This school system, known as the Department of Defense Dependent Schools (DoDDS), is most certainly 'international' in several senses of the word, but DoDDS are regularly excluded from discussion of international schools because enrollment in them is highly restricted, available primarily to military families with a few limited exceptions (DODEA, Regulation 1342.13, 2008). Consequently, the schools are not viable options for most civilian expatriates ("About DoDEA," n.d.; Ortloff & Escobar-Ortloff, 2001). Of the non-DoDDS schools, the Office of Overseas schools indicates there about 1100 schools outside of the United States which may serve as viable options for American expatriates. Of those, there are 193 schools that the Department of State has relationships with via either direct or indirect support and are classified by the U.S. Department of State as 'assisted' schools ("Schools Worldwide," n.d.). In order to be an assisted school, these schools must demonstrate that they operate with an American educational philosophy and relevant pedagogical approaches as well as promote international understanding (Mannino, 1992). Accreditation is usually important to these schools, and it is common that they are accredited by stateside regional agencies such as the Western Association of Schools and Colleges (WASC) or the Middle States Association of Colleges and Schools (MSA) (Ortloff & Escobar-Ortloff, 2001)

Though these schools hold assisted status, they typically operate as independent non-profit entities governed by school boards selected from parents of the children attending the schools or some combination of parents and other community members (Gillies, 2001; James & Shephard, 2013; Ortloff & Escobar-Ortloff, 2001). In some cases, schools receive grants or have other assistance agreements with the U.S. Department of State and, in these instances, it is not uncommon for one school board member to be appointed by the U.S. Ambassador to the host country. In most cases, however, the primary funding mechanism for these schools is student tuition which can be upwards of $20,000 per year (Fertig & James, 2013; MacDonald, 2006). For example, for high school students at SAS in South East Asia, families spend approximately $31,000 per year in mandatory fees and tuition, while at Frankfurt International School in Germany, tuition alone can be as much as $27,000 per year ("Tuition and Fees," n.d.; "Tuition and Fees for Academic Year 2018-2019," n.d.).

In any school, the ability of administrators to hire quality teachers is considered a key competency, and this is particularly true in an international school market that is increasingly competitive and where there is an expectation for teachers to be native English speakers and western-trained (Garton, 2000; Marzano, 2007; Nagrath, 2011). To facilitate their missions, these schools typically recruit educators who are trained in their respective home countries and are themselves - or, in the case of teachers seeking their first international post, will become upon hiring - expatriates (Hayden & Thompson, 1995). It is common for schools to use various recruiting fairs, starting in about November and running until about May of each year, to hire teachers who are either seeking transfer from another school or are seeking to secure their first overseas position. There are multiple agencies which assist the schools in recruitment, three of the most influential ones being the Council for International Schools (CIS), International School Services (ISS), and Search Associates. These agencies hold fairs in various locations globally where large numbers of teaching candidates are able to interview with school administrators for faculty positions for the following school year (Hayden, 2006). As of 2019, ISS boasts of assisting more than 50,000 educators find placement in international schools since its inception in 1955 ("About ISS," n.d.). Also indicative of the influence of these organizations, is the strength of their annual recruiting fairs. For example, a single three-day fair held in Thailand by Search Associates in January of 2019 attracted over 500 job-seeking teaching candidates and 140 international schools ("Bangkok-January," n.d.).

To the extent that a majority of the faculty in the Type-A, American-curriculum international schools are native English speakers and western-trained, their professional training bears similarities to their domestic counterparts. Teachers in these schools hold at least appropriate Bachelor's degrees from accredited universities (Nagrath, 2011). They typically have completed teacher preparation courses in their home countries, and hold state teaching credentials or, if not American, a teaching credential from the appropriate authorizing body of their home country, so they have the same formal pre-service educational training as what would be expected of domestic teachers. Likewise, the majority of teachers continue to maintain their domestic credentials using processes and PD activities approved by their domestic accrediting agency. An example of how this is facilitated outside of the United States is found in

EARCOS's arrangements with Buffalo State, State University of New York (SUNY) to offer workshops eligible for graduate-level credits at their annual spring conferences. These credits are commonly used by U.S. educators to meet their state-based certification requirements ("East Asia Regional Council of Overseas Schools," n.d.).

So while pre-service training and the certification maintenance practices of these teachers are typically quite similar to their domestic counterparts, the characteristics of the pool of Type-A international school teachers are distinct in other ways. By and large, these schools have policies to only hire individuals with at least two years of experience in their respective subjects (Nagrath, 2011). It is therefore rare to find a 'rookie' teacher in one of these schools. To some extent this serves to satiate high expectations of the parent communities. These schools tend to serve a parent demographic of educated professionals, there is a corresponding results-driven pressure from parents who hope for their children to enter the best possible universities (Mancuso, et al, 2010). A survey of these schools shows that it is common to find them boasting of college acceptance rates at or approaching 100%, with many schools seeing students accepted into prestigious universities in the U.S. and United Kingdom (various school websites). Additionally, the population of teachers in these schools tend to be more educated than U.S. public school teachers. Compared to 56% of U.S. teachers holding advanced degrees, approximately 70% of teachers in the Type-A American international schools in this study hold advanced degrees (Snyder, 2018; various school websites).

In contrast to their experience in the schooling systems of their home countries, international school educators have also indicated social and professional stressors derived from the unique demographic composition of the school community. In many countries, international schools function as a nucleus of social interaction for the expatriate community. Teachers in these schools attest to more tightly bonded school communities and often describe colleagues as more akin to second-family than just associates. Due to the more tight-knit communities, working in these settings is often described as working “in a fishbowl” or “claustrophobic” (Zilber, 2005). The effect is further complicated in that international schools employing expatriates are keen - mostly for economic reasons - to contract ‘teaching couples’ where both spouses are educators. Consequently, there may be a significantly large number of family connections amongst faculty within any one school. This hiring practice also translates to an increased number of students who are the children of faculty. For example, at SAS, 12% of the researcher’s student assignment of 106 students are the children of either colleagues or supervisors. As a result, educators in these schools are more frequently managing stresses that may come from teaching the children of close friends or colleagues (Zilber, 2005). Another oft-cited stressor is the socioeconomic positioning of the international school teacher in comparison to the larger international school community. While the teachers in these schools earn salaries comparable to, or better than, what they would earn in public schools in the United States, it is usually appreciably less than other members of the expatriate communities they serve, such as members of the corporate world or foreign service who have generous salary and benefits packages (Zilber, 2005). Further, although these schools are billed as American, they are decidedly multinational and multicultural in student composition. The schools in this study, on average, have student bodies representing 49 countries, with only 38% of the students holding passports from North America (Search Associates School Data). Consequently, teachers in these schools need to be capable of managing the particular challenges sometimes associated with interactions between cultures, languages, and learning styles (Haliciouglu, 2015).

Teachers in American international schools also face stressors associated with contractual arrangements different than those they've experienced domestically. Perhaps most significantly, these teachers exist with less job security. The initial contract offered by international schools is typically two years, after which it may be renewed upon mutual agreement between the teacher and school. The feeling of insecurity which might come from short term contracts can be further complicated by the lack of teachers unions which serve to protect educators or act as mediators during professional disputes (Hrycak, 2015). As a group, teachers in the Type-A American curriculum international schools tend to be very qualified and experienced educators, bearing similarities to their U.S. counterparts in education and training, but operating in quite different social and professional contexts.

CHAPTER 3

METHOD

Context of this study

The specific setting for this study's intervention is a group of 15 American-curriculum international schools that have adopted the NGSS as the basis of K-12 science instruction. These schools have, in the past year, initiated PD activities to help teachers with the alignment of their internal assessments with the constructs of the NGSS. These international schools are of the type described by Hayden & Thompson (2013) as 'Type A', primarily serving the expatriate communities in their respective host countries. They are independent, non-profit organizations run by school boards composed largely of students' parents. Every school is accredited by a U.S. based accrediting agency such as the Middle States Association of Schools and College (MSC), the Western Association of Schools and Colleges (WASC), or AdvancED (formerly the Southern Association of Schools and Colleges). Table 3 provides characteristics of the faculty and student bodies of schools engaged with the intervention, using information obtained from the schools' websites and organizations which assist the schools in faculty recruitment.

Table 3.

Faculty and Student Body Characteristics of Schools in the Study

		Teaching Staff		Student Body	
School	Country	Faculty	U.S. Faculty	Students	Nationalities Represented
American International School Vienna	Austria	105	71	780	54
American International School	Bangladesh	72	52	467	45
International School of Beijing	China	204	121	1724	40

Colegio Nueva Granada, Bogota	Columbia	345	130	1760	40
American School in London	England	199	139	1380	70
American School of Guatemala[1]	Guatemala			1618	24
Hong Kong International School	China (Hong Kong)	267	190	2825	15
American International School of Budapest	Hungary	114	73	920	58
American Community School of Amman	Jordan	96	77	746	48
American School Foundation of Monterrey	Mexico	300	98	2400	15
Colegio Roosevelt, Lima	Peru	177	66	1711	46
Singapore American School	Singapore	385	226	3938	56
American School of Barcelona	Spain	113	68	914	56
American School of Dubai	United Arab Emirates	199	166	1840	76
American Community School, Abu Dhabi	United Arab Emirates	135	88	1225	60
Total		2711	1565	24248	

[1] *Faculty information not publicly available.*

Participants

Contingent upon approval of school administrators, this study seeks to include all teachers of science at the American-curriculum international schools identified in Table 3. This group of participants includes subject-specific science teachers at the middle and high school level, and also generalist elementary school teachers who teach science in addition to other subjects; all these teachers have been tasked to utilize the NGSS as the basis for their science instruction. All of the participating teachers have been or will be engaged in school-initiated PD activities involving teachers' use of a tool to evaluate internally-designed assessments during the 2018-2019 academic year. Faculty at the schools are predominantly native English speakers, trained in the United States or other western countries, who provide daily instruction to a diverse student body that is composed predominantly of expatriate students.

Intervention

The intervention in this study is a PD activity which utilizes a tool designed to aid science teachers' alignment of their internally-designed assessments with the constructs of the NGSS. The PD activity involves three parts, taking place sequentially 1.) teachers create an assessment to evaluate students on one or more of the NGSS PE 2.) teachers use the tool to systematically analyze and critique the quality of their assessment 3.) teachers utilize points of critique to revise and rewrite the assessment.

3D-PAST: A tool to systematically analyze NGSS PE assessments

Central to the PD activity which serves as this study's intervention is the use of a three-dimensional performance assessment screening tool (3D-PAST). 3D-PAST is a practitioner developed tool, created by Paul Andersen and Lisa Brosnick. Brosnick is the president of the Science Teachers Association of New York State (STANYS), while Andersen a science education consultant, former Montana state biology teacher, Montana state Teacher of the Year, and YouTube personality whose educational videos have garnered millions of views and earned him recognition by YouTube as a top-ten YouTube Edu Guru ("About Paul Andersen," n.d.). Since 2016, Andersen has been hired by at least 29 international schools to assist with implementation of the NGSS, spending up to two weeks at a time working with faculty at the schools. In the case of Singapore American School, Andersen began working with the school in 2016. During each of the 17-18 and 18-19 academic years, Andersen spent four weeks at the school helping teachers to improve NGSS implementation. In addition to working with specific schools, Andersen has also been a presenter to the larger international school community at both the NESA and EARCOS educator's conferences ("Events: Unlocking the Power of the NGSS," n.d.; "East Asia Regional Council of Overseas Schools," 2017)

During the summer of 2018, Andersen and Brosnick developed 3D-PAST to address challenges they experienced in trying to provide effective feedback to science teachers in workshops they were hosting (P. Andersen, personal communication, February 1, 2019). The tool is available publicly via Andersen's website and is free to use and share via the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License, which allows others to "remix, tweak, and build upon" the work, so long as the original author is credited, and subsequent works are licensed under identical terms ("About the Licenses," n.d;). As of February 2019, 3D-PAST has been introduced and used with at least 19 international schools during the 2018-2019 academic year as a component of those schools' in-house PD programs to help teachers implement the NGSS (P. Andersen, personal communication, February 1, 2019).

The design of 3D-PAST is intended to guide a process of systematic critique of internal assessments that are used in classroom evaluations of student achievement towards NGSS PE. 3D-PAST is in the form of an 11 point checklist (see Appendix A). The first six points address one or more of the three dimensions associated with the NGSS PE - science and engineering practices, disciplinary core ideas, and crosscutting concepts. The remaining five points are intended to address other aspects of science instruction considered by the authors to be best practices in science instruction including the use of grade-appropriate language, graphic organizers, scientifically accurate information, and authentic use of scientific phenomenon to engage students (P. Andersen, personal communication, February 1, 2019). Accompanying the checklist is also a brief set of instructions for its use and an explanation of relevant vocabulary.

To use 3D-PAST, teachers must have first developed a classroom-use assessment targeting student achievement relative to a NGSS PE. Subsequently, teachers either complete the assessment acting as though they are a student, or they critically read through the assessment to develop a deep familiarity with the way in which a student would be expected to interact with it. In instances where multiple teachers are available to collaborate, assessments are exchanged for review. Following this initial review of the assessment, teachers then consider the assessment's alignment with each NGSS construct as indicated by 3D-PAST; teachers are encouraged to refer to NGSS literature, such as NGSS evidence statements (see Appendix B) as necessary for clarification. The final step of the PD activity involves editing or rewriting assessments to reflect new understandings developed during 3D-PAST use.

Timeline of Intervention

The PD activity utilizing 3D-PAST was introduced to teachers at SAS and five other Type-A international schools between August and October of 2018 as part of those schools' in-house PD activities. By May of 2019, 3D-PAST will have been introduced and used in PD activities at the remaining nine schools which compose the intended study group. Table 4 details the dates of intervention at each school.

Table 4

Timeframe of Professional Development Activities Utilizing 3D-PAST

School	Country	Dates of PD Activities
American International School of Budapest	Hungary	August 2018
American International School Vienna	Austria	March 2019
American International School Dhaka	Bangladesh	October 2018 January 2019
International School of Beijing	China	October 2018
Colegio Nueva Granada	Columbia	September 2018 April 2019
American School in London	England	March 2019
American School of Guatemala	Guatemala	September 2018
Hong Kong International School	China (Hong Kong)	February 2019
American International School of Budapest	Hungary	August 2018
American Community School of Amman	Jordan	December 2018 February 2019
American School Foundation of Monterrey	Mexico	March 2019
Colegio Roosevelt, Lima	Peru	September 2018
Singapore American School	Singapore	October 2018 January 2019
American School of Barcelona	Spain	September 2018 March 2019
American School of Dubai	United Arab Emirates	April 2019
American Community School Abu Dhabi	United Arab Emirates	April 2019

Data Collection

This study will utilize a multiple-method data collection process, utilizing both quantitative and qualitative data. Multiple-method approaches seek to overcome limitations of a single data collection method and provide a deeper understanding of an issue than either method may provide on its own (Clark & Creswell, 2010; Cresswell & Clark, 2017; Johnson, Onwuegbuzie & Turner, 2007). The multiple methods of data collection in this proposed study will include a survey instrument followed by a semi-structured interview. Data collection will begin with the distribution of a survey to science teachers in the schools listed in2 3. The number of teachers receiving the survey is expected to be over 500 from across 15 schools. To facilitate distribution of the survey instrument, administrators at each school will be contacted for assistance in soliciting faculty for their participation in the study via an electronically distributed survey instrument. A link to an electronic version of the survey instrument will be included with the participation request. Also included will be a request for faculty to indicate if they would be agreeable to subsequently participate in a semi-structured interview. Upon receipt of the responses to the survey, educators who have indicated willingness to participate in the qualitative data collection will be contacted to arrange for their semi-structured interviews to be completed. Table 5 provides a timeline of data collection and data analysis procedures.

Table 5.

Timeline of Data Collection and Analysis

Time frame	Actions	Procedures
Sept 2018 - May 2019	3D-Past Professional Development Activities at Participating Schools	● Faculty introduced to internal assessment NGSS alignment screening tool (3D-Past) during in-house professional learning activities.
April 2019	Recruit teachers to participate in the survey from schools receiving PD between Sept '18 and Feb '19. (Group 1)	● Contact administrators to aid in the distribution of NFSE:STU ● Distribute NFSE:STU
Late April 2019 Early May 2019	Semi-structured interviews. (Group 1).	● Arrange and conduct semi-structured interviews
May 2019	Recruit teachers to participate in the	● Contact administrators to

	survey from schools receiving PD between March ‘19 - May ‘19 timeframe. (Group 2)	aid in the distribution of NFSE:STU ● Distribute NFSE:STU
Late May 2019 Early June 2019	Qualitative Data Collection (Group 2).	● Arrange and conduct semi-structured interviews

Quantitative Instrument

The survey is a version of the 31-item *New Framework of Science Education Survey of Teacher Understanding* (NFSE-STU) developed by Nollmeyer & Bangert (2017) (see Appendix C). As a measure of teacher understanding of the NGSS, the instrument may be considered a measure of pPCK as envisioned by the Revised Consensus Model. The survey has been modified for context, an opportunity for participants to provide open-responses, and to be administered in a retrospective pretest-posttest manner. The retrospective pretest-posttest administration of surveys has been demonstrated to be an effective method of data collection, particularly when there is likelihood for response-shift bias (Allen, & Nimon, 2007; Bhanji, Gottesman, Grave, Steinert, & Winer, 2012; Chang & Little, 2018; Sibthorp, Paisley, Gookin & Ward, 2007)

Development of the instrument followed procedures well-established in the field. A review of relevant literature was conducted, with emphasis placed on literature published by the NRC (2012). Six constructs were identified which were deemed appropriate for measuring teacher understanding of the NGSS. The constructs mirror those of the NRC’s *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas* (2012) from which the NGSS were derived - science and engineering practices, crosscutting concepts, disciplinary core ideas, and integration of the three dimensions. A fifth construct was also included, best practices in science education, which aligns with aspects of the 3D-PAST tool used in the intervention. The original NFSE-STU also contains a construct relating to connections with the Common Core Curriculum, but it has been removed for this study. Following the development of preliminary survey questions, experts made suggestions for improvement. Response items were then revised and pilot tested. The pilot instrument was subsequently validated using exploratory and confirmatory factor analysis, and internal consistency testing. Review of the analysis lead to the production of the final validated NFSE-STU (G. Nollmeyer, personal communication, January 19, 2019; Nollmeyer & Bangert, 2015; 2017).

Semi-structured interview

The semi-structured interview guide and interview process have been designed to elicit more nuanced information on how teachers perceived the impact of the PD activities and utilization of 3D-PAST on their own pPCK. The interview guide consists of twelve questions, two questions associated with each of the six constructs on the quantitative survey instrument. The full interview guide can be found in Appendix D.

Anticipated results, implications and potential contribution of this research project

In my professional conversations with science teachers at Singapore American School, faculty have indicated that they felt professional development activities with Paul Andersen was valuable, and 3D-PAST was a useful tool for aligning internal assessments and promoting a deeper understanding of the NGSS PE those teachers were tasked with teaching. Additionally, when the entire science-teaching faculty at SAS was surveyed about the impact of the professional development activities, 67.5% of respondents (n=39) indicated they Strongly Agreed (Meade, 2019). If SAS is typical of Type-A American-curriculum international schools, then the sampling suggests similar generally positive results at the other 14 schools. As the aforementioned represent very broad generalizations, the study hopes to identify particular facets of the PD and 3D-PAST use which are most beneficial. In doing so, the study may provide designers of future PD activities in American-curriculum international schools with foci for improvement or concentration, which may ultimately benefit student learning experiences via educators who are more effective at implementing the NGSS.

Further, this study hopes to contribute to the literature concerning PCK in science education by adding understanding of a mechanism through which knowledge is exchanged between the realms of PCK as articulated in the RCM for science instruction. The RCM defines three domains of PCK and acknowledges that there is knowledge exchange which must occur between them, but the RCM does not specify the pathways through which those knowledge exchanges occur or by which they may be "publicly examined, verified, refuted, or modified." (Carlson & Daehler, 2019; Park 2019). In other words, the RCM describes the existence of knowledge exchanges, but not the mechanisms. This is a recognized limitation of the RCM, but an important one. The mechanisms through which the knowledge exchanges take place are important because having "a clear understanding of the factors that can be best leveraged to create changes in PCK and the mechanisms through which they work will advance our understanding of how to design learning opportunities for teachers of science and how to assess teacher PCK in science" (Park, 2019, p 125).

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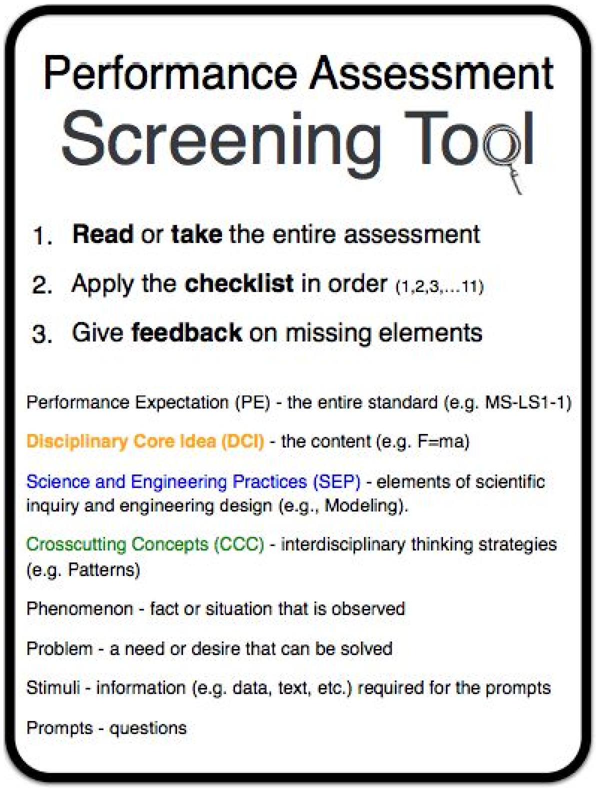
Appendix A: Three Dimensional Performance Assessment Screening Tool (3D-PAST)

The Three-Dimensional Performance Assessment Screening Tool (3D-PAST) is typically distributed to teachers as a two-sided, laminated card, with the images show below printed on either side. Teachers use this tool in conjunction with a pre-made assessment and a detailed description of the relevant Next Generation Science Standard (NGSS) Performance Expectation (PE).

Side 1: Description of the process for using the tool and definitions of key vocabulary.

Side 2: Checklist of key aspects of assessments that are properly aligned with the Next Generation Science Standards three-dimensional performance expectations.



Performance Assessment

Screening Tool

1. **Read** or **take** the entire assessment
2. Apply the **checklist** in order (1,2,3,...11)
3. Give **feedback** on missing elements

Performance Expectation (PE) - the entire standard (e.g. MS-LS1-1)

Disciplinary Core Idea (DCI) - the content (e.g. F=ma)

Science and Engineering Practices (SEP) - elements of scientific inquiry and engineering design (e.g., Modeling).

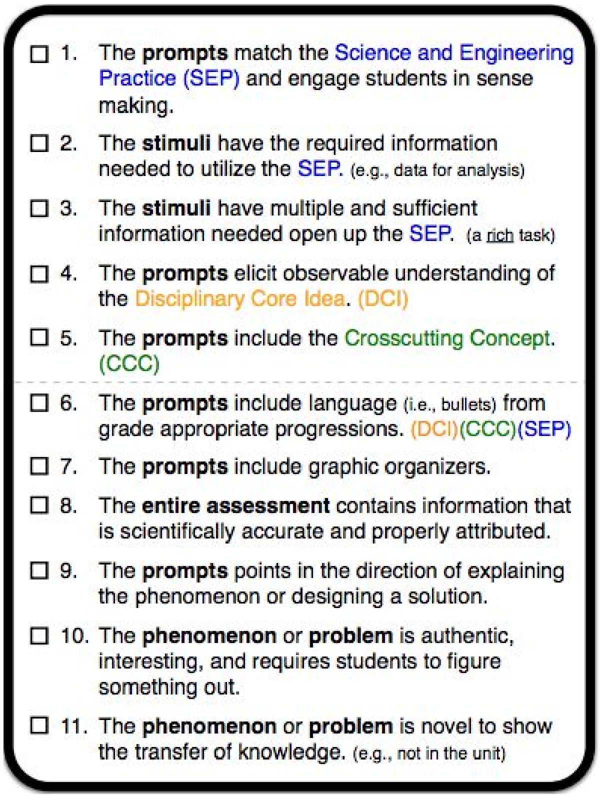
Crosscutting Concepts (CCC) - interdisciplinary thinking strategies (e.g. Patterns)

Phenomenon - fact or situation that is observed

Problem - a need or desire that can be solved

Stimuli - information (e.g. data, text, etc.) required for the prompts

Prompts - questions



☐ 1. The **prompts** match the Science and Engineering Practice (SEP) and engage students in sense making.

☐ 2. The **stimuli** have the required information needed to utilize the SEP. (e.g., data for analysis)

☐ 3. The **stimuli** have multiple and sufficient information needed open up the SEP. (a rich task)

☐ 4. The **prompts** elicit observable understanding of the Disciplinary Core Idea. (DCI)

☐ 5. The **prompts** include the Crosscutting Concept. (CCC)

☐ 6. The **prompts** include language (i.e., bullets) from grade appropriate progressions. (DCI)(CCC)(SEP)

☐ 7. The **prompts** include graphic organizers.

☐ 8. The **entire assessment** contains information that is scientifically accurate and properly attributed.

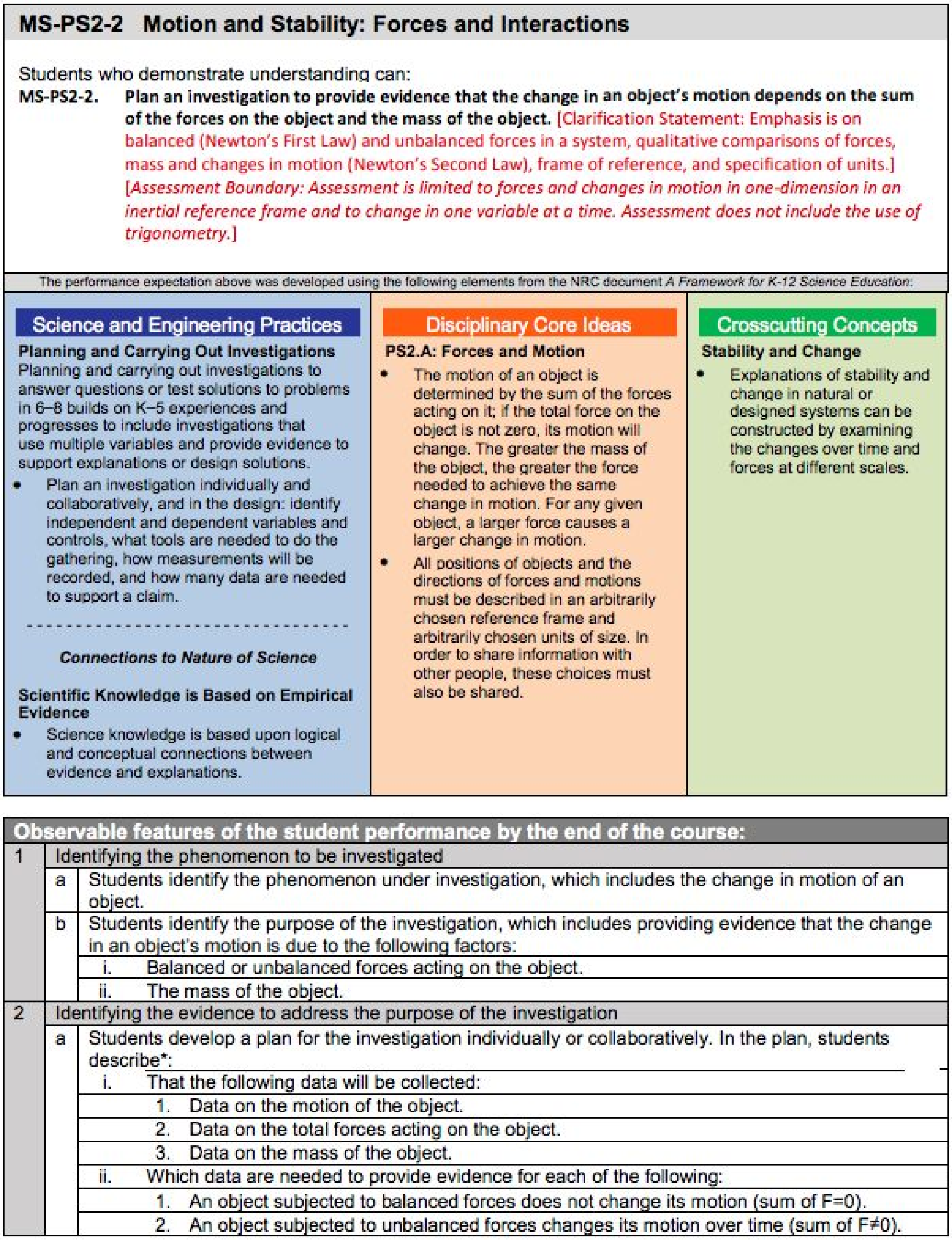
☐ 9. The **prompts** points in the direction of explaining the phenomenon or designing a solution.

☐ 10. The **phenomenon** or **problem** is authentic, interesting, and requires students to figure something out.

☐ 11. The **phenomenon** or **problem** is novel to show the transfer of knowledge. (e.g., not in the unit)

Appendix B: Example of NGSS Performance Expectation Evidence Statements

Associated with each Next Generation Science Standard student Performance Expectation is an evidence statement document which describes each of the three dimensions integrated into the standard, and grade-level appropriate observable features. Below is the evidence statements document for MS-PS2-2, a Physical Science standard for the middle school level.



MS-PS2-2 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-2. **Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.** [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] *[Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.]*

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations.

Disciplinary Core Ideas

PS2.A: Forces and Motion

- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

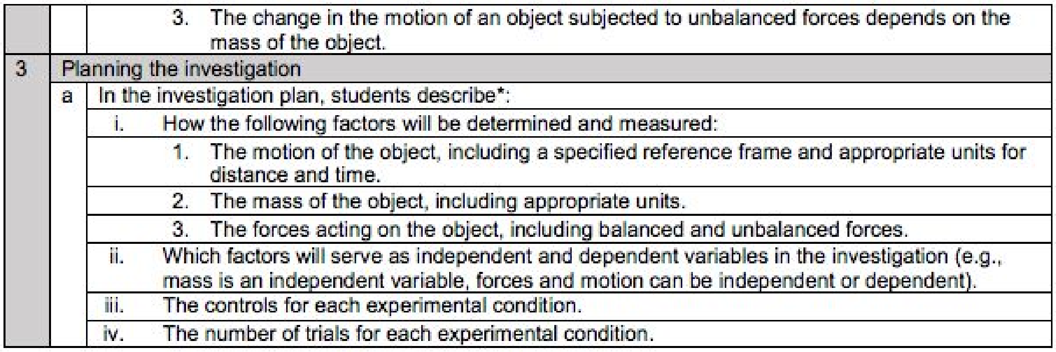
Crosscutting Concepts

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

Observable features of the student performance by the end of the course:

1	Identifying the phenomenon to be investigated	
	a	Students identify the phenomenon under investigation, which includes the change in motion of an object.
	b	Students identify the purpose of the investigation, which includes providing evidence that the change in an object's motion is due to the following factors:
		i. Balanced or unbalanced forces acting on the object.
		ii. The mass of the object.
2	Identifying the evidence to address the purpose of the investigation	
	a	Students develop a plan for the investigation individually or collaboratively. In the plan, students describe*:
		i. That the following data will be collected:
		1. Data on the motion of the object.
		2. Data on the total forces acting on the object.
		3. Data on the mass of the object.
		ii. Which data are needed to provide evidence for each of the following:
		1. An object subjected to balanced forces does not change its motion (sum of F=0).
		2. An object subjected to unbalanced forces changes its motion over time (sum of F≠0).



			3. The change in the motion of an object subjected to unbalanced forces depends on the mass of the object.
3	Planning the investigation		
	a	In the investigation plan, students describe*:	
		i.	How the following factors will be determined and measured:
			1. The motion of the object, including a specified reference frame and appropriate units for distance and time.
			2. The mass of the object, including appropriate units.
			3. The forces acting on the object, including balanced and unbalanced forces.
		ii.	Which factors will serve as independent and dependent variables in the investigation (e.g., mass is an independent variable, forces and motion can be independent or dependent).
		iii.	The controls for each experimental condition.
		iv.	The number of trials for each experimental condition.

Appendix C: Quantitative Survey Instrument

*This instrument will be distributed in electronic form.

New Framework for Science Education: Survey of Teacher Understanding Developed by Nollmeyer & Bangert (2015)													
		Before using 3D-PAST						After using 3D-PAST					
		Level of understanding…						Level of understanding…					
		None	Slight	Fair	Solid	Strong	Advanced	None	Slight	Fair	Solid	Strong	Advanced
Construct 1: Science & Engineering Practices													
1.	When planning and teaching, educators have students participate in practices used by scientists and engineers in the real world.	1	2	3	4	5	6	1	2	3	4	5	6
2.	When planning and teaching, educators have students ask questions about scientific phenomena that can drive exploration.	1	2	3	4	5	6	1	2	3	4	5	6
3.	When planning and teaching, educators have students ask questions to define engineering problems that can drive design.	1	2	3	4	5	6	1	2	3	4	5	6
4.	When planning and teaching, educators have students develop and refine conceptual models to express their understanding about scientific phenomena.	1	2	3	4	5	6	1	2	3	4	5	6
5.	When planning and teaching, educators have students develop models to visualize and refine an engineered design.	1	2	3	4	5	6	1	2	3	4	5	6
6.	When planning and teaching, educators have students plan and carry	1	2	3	4	5	6	1	2	3	4	5	6

	out investigations to gather data about scientific phenomena and engineering problems.												
7.	When planning and teaching, educators have students apply mathematical and computational thinking to investigate scientific questions and engineering problems.	1	2	3	4	5	6	1	2	3	4	5	6
8.	When planning and teaching, educators have students construct evidence-based explanations to describe phenomena that incorporate their understandings about science.	1	2	3	4	5	6	1	2	3	4	5	6
9.	When planning and teaching, educators have students design and refine solutions that meet the needs of an engineering problem.	1	2	3	4	5	6	1	2	3	4	5	6
10.	When planning and teaching, educators have students engage in evidence-based argumentation about scientific explanations and engineered designs.	1	2	3	4	5	6	1	2	3	4	5	6
11.	When planning and teaching educators have students communicate ideas clearly and persuasively through words, images, and other media.	1	2	3	4	5	6	1	2	3	4	5	6
Construct 2: Teaching Disciplinary Core Ideas													
12.	When planning and teaching, educators focus on a few core ideas instead of a large number of topics so that students can achieve greater depth in their understanding.	1	2	3	4	5	6	1	2	3	4	5	6

13.	When planning and teaching, educators recognize that the development of student understandings of disciplinary core ideas is a progression that takes place over years.	1	2	3	4	5	6	1	2	3	4	5	6
14.	When planning and teaching, educators use a learning progression approach by building from prior knowledge and working towards future sophistication.	1	2	3	4	5	6	1	2	3	4	5	6
15.	When planning and teaching, educators include core ideas that have broad importance across multiple disciplines or are key organizing principles within a discipline.	1	2	3	4	5	6	1	2	3	4	5	6
16.	When planning and teaching, educators include core ideas that are important in investigating more complex ideas and solving problems.	1	2	3	4	5	6	1	2	3	4	5	6
17.	When planning and teaching, educators include core ideas that relate to the interests and life experiences of students or societal concerns.	1	2	3	4	5	6	1	2	3	4	5	6
18.	When planning and teaching, educators recognize that the construction of knowledge requires active participation on the part of the students.	1	2	3	4	5	6	1	2	3	4	5	6
Construct 3: Crosscutting Concepts													
19.	When planning and teaching, educators have students consider issues of cause and effect when questioning and discussing scientific phenomena or engineering designs.	1	2	3	4	5	6	1	2	3	4	5	6

20.	When planning and teaching, educators have students develop an understanding that phenomena work differently at different scales.	1	2	3	4	5	6	1	2	3	4	5	6
21.	When planning and teaching, educators have students use systems thinking when investigating scientific phenomena.	1	2	3	4	5	6	1	2	3	4	5	6
22.	When planning and teaching, educators have students consider that since energy and matter are conserved, much can be determined by studying their flow into and out of systems.	1	2	3	4	5	6	1	2	3	4	5	6
23.	When planning and teaching, educators have students investigate phenomena in terms of structure and function as a means of sense-making.	1	2	3	4	5	6	1	2	3	4	5	6
24.	When planning and teaching, educators have students identify what aspects of a system remain stable over time and what aspects undergo patterns of change.	1	2	3	4	5	6	1	2	3	4	5	6
Construct 4: Integration of the Three Dimensions													
25.	When planning and teaching, educators have students explore disciplinary ideas by engaging in practices and making connections through crosscutting concepts.	1	2	3	4	5	6	1	2	3	4	5	6
26.	When planning and teaching, educators intentionally select practices and concepts that best facilitate student sense-making for particular core ideas.	1	2	3	4	5	6	1	2	3	4	5	6

27.	When planning and teaching, educators have students use the crosscutting concepts when engaging in practices about disciplinary core ideas.	1	2	3	4	5	6	1	2	3	4	5	6
Construct 5: Best Practices in Science Education													
28.	When planning and teaching, educators use both teacher-led and student-led strategies to facilitate student understanding of science and engineering content.	1	2	3	4	5	6	1	2	3	4	5	6
29.	When planning and teaching, educators have students engage in sustained investigations accompanied by necessary teacher support.	1	2	3	4	5	6	1	2	3	4	5	6
30.	When planning and teaching, educators teach students how to present their scientific ideas and engineering solutions with clarity through both the written and spoken word.	1	2	3	4	5	6	1	2	3	4	5	6
31.	When planning and teaching, educators teach students how mathematical concepts and skills apply to scientific investigation and engineering design.	1	2	3	4	5	6	1	2	3	4	5	6

Appendix D: Qualitative Survey Instrument

Semi-Structured Interview Protocol
Items in ***bold italics*** are researcher-spoken prompts.

1. Welcome & Introduction

   "Hello, my name is Wyatt Wilcox. First, let me thank you for your time and willingness to participate in this interview about your use of 3D-PAST. I expect this interview to last about 30 minutes.

   This interview will be recorded so that I can recall the information and points that were discussed.

   Is this acceptable to you?"

2. Review of Consent Form & Secondary Verbal Agreement

   *consent form will be distributed and returned electronically, prior to the interview.

   "Thank you for completing the consent form and returning it to me. Do you have any questions about the consent form, and also can you reconfirm verbally that you've given your consent to participate in this research?"

3. Ground Rules

   "I will be asking you a series of questions about your use of 3D-PAST and the way it has affected your understanding of the NGSS. These questions form the framing of the interview, and I encourage you to elaborate on these points, but you are also welcome to talk about things that I haven't asked a direct question about. The point of this interview is to elaborate and extend the quantitative survey that you completed earlier. Your responses will be used to inform the study which I am completing."

4. Participant Introduction
   a. ***Please tell me a little about yourself and your professional context.***
      i. ***What is your school, position, and number of years that you've taught a the school?***
      ii. ***Where is your school in the processes of implementing the NGSS?***

    iii. ***Can you describe your experience with 3D-Past prior to this activity?***

5. 3D-PAST & Construct Questions

    a. Science and Engineering Practices
        i. ***Can you describe your experience with teaching science and engineering practices, prior to using 3D-PAST, as they relate to the NGSS?***
        ii. ***Do you feel that using 3D-PAST to evaluate your NGSS internal assessments changed the way you understood the NGSS or some aspect of what the NGSS requires of you as a teacher with regard to teaching science and engineering practices?***

    b. Teaching Disciplinary Core Ideas
        i. ***Can you describe your experience with teaching the NGSS's disciplinary core ideas, prior to using 3D-PAST, as they relate to the NGSS?***
        ii. ***How do you feel that using 3D-PAST to evaluate your NGSS internal assessments changed the way you understood the NGSS or some aspect of what the NGSS requires of you as a teacher with regard to teaching disciplinary core ideas?***

    c. Crosscutting Concepts
        i. ***Can you describe your experience with teaching the NGSS's crosscutting concepts, prior to using 3D-PAST, as they relate to the NGSS?***
        ii. ***How do you feel that using 3D-PAST to evaluate your NGSS internal assessments changed the way you understood the NGSS or some aspect of what the NGSS requires of you as a teacher?***

    d. Integration of the Three Dimensions
        i. ***Can you describe your experience, prior to using 3D-PAST, with integrating the three dimensions (science and engineering practices, crosscutting concepts, and disciplinary core ideas) as they relate to the NGSS?***
        ii. ***How do you feel that using 3D-PAST to evaluate your NGSS internal assessments changed the way you understood the NGSS or some aspect of what the NGSS requires of you as a teacher?***

    e. Best Practices in Science Education

        i. ***How do you feel that using 3D-PAST to evaluate your NGSS internal assessments changed the way you understood the NGSS or some aspect of what the NGSS requires of you as a teacher with regards to best practices in science education?***

    f. General Questions Related to 3D PAST Usage:
        i. ***Prior to using 3D-PAST, what has been your experience with designing assessments that are aligned to the NGSS?***
        ii. ***Do you feel that 3D-PAST is a useful tool? Would you continue to use it?***
        iii. ***In using 3D-PAST, did you find yourself referring to the detailed NGSS PEs? In what ways were those useful?***

    g. Non-Specific
        i. ***Are there any other points related to using 3D-PAST that you would like to elaborate on?***

6. Closing
    a. ***Those are all of the questions that I have for you. I want to thank you again for your participation in the study and also for your time during this interview today. Your contributions have provided me with useful information.***

       Thank you.