Pedagogical Content Knowledge Institutional Landscape Analysis

GOAL ONE: CRITICAL IDEAS INVENTORY

Because pedagogical content knowledge **(PCK)** is **topic-specific**, a first step is to identify which critical ideas of the discipline are addressed within the Teacher Educator Programs **(TEP)**. Known as the "Disciplinary Core Ideas" in the NGSS and "Content Domains" in CCSSM, these are the critical ideas that teacher candidates will be responsible for teaching. Identifying the extent to which the curriculum TE candidates experience in a program helps prepare the teacher candidates to address these critical ideas is an important consideration for preparing the *Next Generation* of STEM teachers. The purpose of this analysis is to help TEPs assess the extent to which they are preparing teachers in relation to the disciplinary content knowledge.

Table 1. Inventory of Critical Ideas Addressed in the TEP

Science Critical Ideas	**Courses/Experiences in which PSTs are exposed to these critical ideas**
Example: LS2: Ecosystems: Interactions, Energy, and Dynamics LS2.B: Cycles of Matter and Energy Transfer in Ecosystems ● Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment.	***Example:*** SCED 203 Matter & Energy in Life Systems ● Students learn about conservation of energy…. SCED 480 - Science Methods and Curriculum for the Elementary School ● Students participate in a model lesson about the water cycle ● Students develop and teach a unit on life cycles for 3rd grade (not all students)
NGSS: Life Science DCIs	**Courses/Experiences in which PSTs are exposed to these critical ideas**
● ***LS1: From Molecules to Organisms: Structures and Processes*** ○ **LS1.A: Structure and Function** ○ **LS1.B: Growth and Development of Organisms** ○ **LS1.C: Organization for Matter and Energy Flow in Organisms** ○ **LS1.D: Information Processing**	
● ***LS2: Ecosystems Interactions, Energy, and Dynamics*** ○ **LS2.A: Interdependent Relationships in Ecosystems**	

○ **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** ○ **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** ○ **LS2.D: Social Interactions and Group Behavior**	
● ***LS3: Heredity: Inheritance and Variation of Traits*** ○ **LS3.A: Inheritance of Traits** ○ **LS3.B: Variation of Traits**	
● ***LS4: Biological Evolution: Unity and Diversity*** ○ **LS4.A: Evidence of Common Ancestry and Diversity** ○ **LS4.B: Natural Selection** ○ **LS4.C: Adaptation** ○ **LS4.D: Biodiversity and Humans**	
NGSS: Earth and Space Science DCIs	**Courses/Experiences in which PSTs are exposed to these critical ideas**
● ***ESS1: Earth's Place in the Universe*** ○ **ESS1.A: The Universe and the Stars** ○ **ESS1.B: Earth and the Solar System** ○ **ESS1.C: The History of Planet Earth**	
● ***ESS2: Earth's Systems*** ○ **ESS2.A: Earth Materials and Systems** ○ **ESS2.B: Plate Tectonics and Large-Scale System Interactions** ○ **ESS2.C: The Roles of Water in Earth's Surface Processes** ○ **ESS2.D: Weather and Climate** ○ **ESS2.E: Biogeology**	
● ***ESS3: Earth and Human Activity*** ○ **ESS3.A: Natural Resources** ○ **ESS3.B: Natural Hazards** ○ **ESS3.C: Human Impacts on Earth Systems** ○ **ES32.D: Global Climate Change**	

NGSS: Physical Science DCIs	**Courses/Experiences in which PSTs are exposed to these critical ideas**
● ***PS1: Matter and Its Interactions*** ○ **PS1.A: Structure and Properties of Matter** ○ **PS1.B: Chemical Reactions** ○ **PS1.C: Nuclear Processes**	
● ***PS2: Motion and Stability: Forces and Interactions*** ○ **PS2.A: Forces and Motion** ○ **PS2.B: Types of Interactions** ○ **PS2.C: Stability and Instability in Physical Systems**	
● ***PS3: Energy*** ○ **PS3.A: Definitions of Energy** ○ **PS3.B: Conservation of Energy and Energy Transfer** ○ **PS3.C: Relationship Between Energy and Forces** ○ **PS3.D: Energy in Chemical Processes and Everyday Life**	
● ***PS4: Waves and Their Applications in Technologies for Information Transfer*** ○ **PS4.A: Wave Properties** ○ **PS4.B: Electromagnetic Radiation** ○ **PS4.C: Information Technologies and Instrumentation**	
NGSS: Engineering, Technology, and the Application of Science DCIs	**Courses/Experiences in which PSTs are exposed to these critical ideas**
● ***ETS1: Engineering Design*** ○ **ETS1.A: Defining and Delimiting an Engineering Problem** ○ **ETS1.B: Developing Possible Solutions** ○ **ETS1.C: Optimizing the Design Solution**	
Mathematics Critical Ideas: (Note that PSTs should also be able to articulate differences and connections among these conceptual categories (e.g. the relationships between the function standards	**Courses/Experiences in which PSTs are exposed to these critical ideas**

and the algebra standards)	
● *Counting & Cardinality* ○ **Know number names and count sequence** ○ **Count to tell the number of objects** ○ **Compare numbers**	
● *Operations & Algebraic Thinking* ○ **Understand addition as putting together and adding to, and understand subtraction as taking apart and taking from** ○ **Represent and solve problems involving addition and subtraction** ○ **Understand and apply properties of operations and the relationship between addition and subtraction** ○ **Add and subtract within 20** ○ **Work with addition and subtraction equations** ○ **Work with equal groups of objects to gain foundations for multiplication** ○ **Represent and solve problems involving multiplication and division** ○ **Understand properties of multiplication and the relationship between multiplication and division** ○ **Multiply and divide within 100** ○ **Solve problems involving the four operations, and identify and explain patterns in arithmetic** ○ **Use the four operations with whole numbers to solve problems** ○ **Gain familiarity with factors and multiples** ○ **Generate and analyze patterns** ○ **Write and interpret numerical expressions** ○ **Analyze patterns and relationships**	
● *Number & Operations in Base Ten* ○ **Work with numbers 11-19 to gain foundations for**	

place value **○ Extend the counting sequence** **○ Understand place value** **○ Use place value understanding and properties of operations to add and subtract** **○ Use place value understanding and properties of operations to perform multi-digit arithmetic** **○ Generalize place value understanding for multi-digit whole numbers** **○ Perform operations with multi-digit whole numbers and with decimals to hundredths**	
● ***Number & Operations- Fractions*** **○ Develop understanding of fractions as numbers** **○ Extend understanding of fraction equivalence and ordering** **○ Build fractions from unit fractions** **○ Understand decimal notation for fractions, and compare decimal fractions** **○ Use equivalent fractions as a strategy to add and subtract fractions** **○ Apply and extend previous understandings of multiplication and division**	
● ***Measurement & Data*** **○ Describe and compare measurable attributes** **○ Classify objects and count the number of objects in each category** **○ Measure lengths indirectly and by iterating length units** **○ Tell and write time** **○ Represent and interpret data** **○ Measure and estimate lengths in standard units** **○ Relate addition and subtraction to length** **○ Work with time and money** **○ Solve problems involving measurement and estimation** **○ Geometric measurement: understand concepts of**	

area and relate area to multiplication and to addition ○ **Geometric measurement: recognize perimeter** ○ **Solve problems involving measurement and conversion of measurements** ○ **Geometric measurement: understand concepts of angle and measure angles** ○ **Convert like measurement units within a given measurement system** ○ **Geometric measurement: understand concepts of volume** ○ **Calculate expected values and use them to solve problems** ○ **Use probability to evaluate outcomes of decisions**	
● ***Geometry*** ○ **G-CO Congruence** ○ **G-SRT Similarity, Right Triangles, and Trigonometry** ○ **G-C Circles** ○ **G-GPE Expressing Geometric Properties with Equations** ○ **G-GMD Geometric Measurement and Dimension** ○ **G-MG Modeling with Geometry**	
● ***Ratios & Proportional Relationships*** ○ **Understand ratio concepts and use ratio reasoning to solve problems** ○ **Analyze proportional relationships and use them to solve real-world and mathematical problems**	
● ***The Number System*** ○ **Apply and extend previous understandings of multiplication and division to divide fractions by fractions** ○ **Compute fluently with multi-digit numbers and find common factors and multiples** ○ **Apply and extend previous understandings of numbers to the system of rational numbers**	

○ **Apply and extend previous understandings of operations with fractions** ○ **Know that there are numbers that are not rational, and approximate them by rational numbers**	
● ***Expressions & Equations*** ○ **Apply and extend previous understandings of arithmetic to algebraic expressions** ○ **Reason about and solve one-variable equations and inequalities** ○ **Represent and analyze quantitative relationships between dependent and independent variables** ○ **Use properties of operations to generate equivalent expressions** ○ **Solve real-life and mathematical problems using numerical and algebraic expressions and equations** ○ **Expressions and Equations Work with radicals and integer exponents** ○ **Understand the connections between proportional relationships, lines, and linear equations** ○ **Analyze and solve linear equations and pairs of simultaneous linear equations**	
● **Statistics & Probability** ○ **S-ID Interpreting Categorical and Quantitative Data** ○ **S-IC Making Inferences and Justifying Conclusions** ○ **S-CP Conditional Probability and the Rules of Probability** ○ **S-MD Using Probability to Make Decisions**	
● **Functions** ○ **F-IF Interpreting Functions** ○ **F-BF Building Functions** ○ **F-LE Linear, Quadratic, and Exponential Models** ○ **F-TF Trigonometric Functions**	
● **Number & Quantity** ○ **N-RN The Real Number System**	

○ **N-Q Quantities** ○ **N-CN The Complex Number System** ○ **N-VM Vector and Matrix Quantities**	
● **Algebra** ○ **A-SSE Seeing Structure in Expressions** ○ **A-APR Arithmetic with Polynomials and Rational Expressions** ○ **A-CED Creating Equations** ○ **A-REI Reasoning with Equations and Inequalities**	
● **Modeling**	

**repeat additional rows as needed*

Questions for Consideration:

- How do you assess prior knowledge from goal 1 for graduate teacher candidates?
- To what extent do students' experiences **across their coursework** provide opportunities to develop knowledge of each of the critical ideas they will be expected to teach students?
- Are there particular critical ideas that are emphasized to a greater or lesser extent?
- Are there particular critical ideas that are *not addressed* but should be?
- What course(s) and experiences emphasize the critical ideas? Are there other courses and experiences that are not listed, but that should be?
- What technological tools are integrated in the teaching of science and mathematics content coursework?
- What components of engineering are integrated in teaching of science and mathematics coursework (as outlined by the Engineering Working Group)?
- Are the approved curricula student-centered, using a lens for cultural responsiveness (as consistent with Framework for K-12 Science Education and NCTM Equity Principle)?
- What is *cultural responsiveness?* (define in footnotes)

Scoring Rubric for Goal 1:	**Beginning**	**Developing**	**Integrating**
The curriculum of the teacher education program (TEP) addresses the disciplinary core ideas (critical ideas) that teacher candidates will be	The TEP addresses some of the critical ideas. Some courses and experiences do not address the critical ideas	The TEP addresses most of the critical ideas in a robust manner across multiple course contexts.	The TEP addresses each of the critical ideas in depth across multiple courses contexts and experiences.

expected to teach.	fully.		
The curriculum of the teacher education program (TEP) addresses the cultural responsiveness that teacher candidates will be expected to teach.	The TEP addresses some cultural responsiveness. Some courses and experiences do not address cultural responsiveness fully.	The TEP addresses most cultural responsiveness in a robust manner across multiple course contexts.	The TEP addresses each cultural responsiveness in depth across multiple courses contexts and experiences.
The curriculum of the teacher education program (TEP) addresses explicit engineering ideas that teacher candidates will be expected to teach.	The TEP addresses some of the engineering ideas. Some courses and experiences do not address the engineering ideas fully.	The TEP addresses most of the engineering ideas in a robust manner across multiple course contexts.	The TEP addresses each of the engineering ideas in depth across multiple courses contexts and experiences.
The curriculum of the teacher education program (TEP) addresses the technological tools for teaching that teacher candidates will be expected to teach.	The TEP addresses some of the technological tools for teaching. Some courses and experiences do not address the technological tools for teaching fully.	The TEP addresses most of the technological tools for teaching in a robust manner across multiple course contexts.	The TEP addresses each of the technological tools for teaching in depth across multiple courses contexts and experiences.

GOAL TWO: PCK FOR CRITICAL IDEAS

The focus of the next level of assessment is the extent to which the program supports robust PCK development for each critical idea identified in goal 1. This analysis can be repeated for each of the critical ideas (disciplinary core ideas or math domains) identified in goal one. Analysis should focus on *what is emphasized* in regard to each component and *how* it is emphasized (e.g., readings, assignments, in-class experiences, etc.). Consideration should also be given to whether that critical idea is explicitly or implicitly addressed. This purpose of this analysis is to help TEP programs identify missed opportunities to support the development of teacher candidates' PCK knowledge and PCK skills (in practice).

Table 2. Inventory of PCK emphasis for critical ideas

	Opportunities for developing *knowledge,* and specific knowledge outcomes				**Developing *Skills***
Matter and Energy in Systems	Knowledge of Curriculum	Knowledge of Instructional Strategies	Knowledge of Learners	Knowledge of Assessment	PCK in practice

Course or experience #1: *example: 490*	*Examine BPS kits/NGSS -understand vertical alignment of topics & goals for teaching energy*	*Engage in model lesson about the practice of modeling energy transfer*	*Common student misconceptions about energy*	*Summative assessment examples given*	*490 - implement energy curriculum (some students)*
Course or experience #2-20x					
Course or experience #3					

Questions for Consideration:

- To what extent do students' experiences across their coursework provide opportunities to develop PCK for the critical ideas?
- What elements of PCK are not addressed that should be? Through what courses/experiences?
- How is Technological Pedagogical Content Knowledge (TPCK or TPACK) embedded in the TEP?
- How does the TEP integrate cultural responsiveness (as consistent with Framework for K-12 Science Education and NCTM Equity Principle) in the knowledge of learners?

Scoring Rubric for Goal 2:	**Beginning**	**Developing**	**Integrating**
The TEP provides candidates opportunities to develop the knowledge bases of PCK for teaching the critical ideas.	The TEP addresses some component knowledge bases of PCK for the critical ideas. Some courses and experiences do not address PCK fully.	The TEP addresses most of the components of PCK across multiple course contexts. Some opportunities for enactment (PCK skill) are included.	The TEP addresses each of the component knowledge bases of PCK and the development of PCK skill in depth across multiple courses contexts and experiences.
The TEP provides candidates opportunities to develop the knowledge bases of TPCK or TPACK for teaching the critical ideas.	The TEP addresses some component knowledge bases of PCK for the critical ideas. Some courses and experiences do not address PCK fully.	The TEP addresses most of the components of PCK across multiple course contexts. Some opportunities for enactment (PCK skill) are included.	The TEP addresses each of the component knowledge bases of PCK and the development of PCK skill in depth across multiple courses contexts and experiences.
The TEP provides candidates	The TEP addresses some	The TEP addresses most of the	The TEP addresses each of the

opportunities to develop the knowledge bases of culturally responsive teaching .	component knowledge bases of PCK for the critical ideas. Some courses and experiences do not address PCK fully.	components of PCK across multiple course contexts. Some opportunities for enactment (PCK skill) are included.	component knowledge bases of PCK and the development of PCK skill in depth across multiple courses contexts and experiences.

GOAL 3: CANDIDATES ENACTING PCK

The final goal of analysis focuses on teacher candidates enacting specific PCK strategies into their practice. University faculty and field supervisors in TEP reflect upon and refine their teacher candidates' level of enactment of PCK.

Questions for consideration:

- What evidence is there of teacher candidates using tasks of teaching in their practice?
- What reflection opportunities are teacher candidates given to enact on their development of PCK?
- How are the various components of PCK reflected to inform instruction?

Table 3. Inventory of PCK Enactment

	Method- What opportunities are university faculty providing the teacher candidates to enact on these?	Frequency- How many times they enact this for one critical idea?	Frequency- For how many different critical ideas is this enacted?	Depth- How has this become a habit of mind?	Opportunities for Reflection- How candidates use PCK to inform planning, teaching and assessment?
How are teacher candidates embedding knowledge of curriculum in their practice?					
How are teacher candidates embedding knowledge of instructional strategies in their practice?					
How are teacher candidates embedding knowledge of learners in their practice?					
How are teacher candidates embedding knowledge of					

assessment in their practice?					
How are teacher candidates embedding use of technology in instruction?					

PROGRAM REFLECTION

STEM and TEP faculty complete this analysis to reflect upon and refine their approaches by considering the extent to which the experiences deepens candidates' subject matter knowledge, makes key aspects of teaching visible to candidates, engages candidates in enacting their PCK, and supports candidates in developing tools and dispositions to continue their PCK development beyond their TEP program. (Each of these criteria are elaborated upon below)

- **Develop subject matter knowledge for teaching –** This refers to the extent to which an experience helps prospective teachers deepen their understanding core ideas in the STEM disciplines and how those ideas connect to one another. This includes understanding how different concepts build on one another, what makes some concepts difficult for learners to understand, and how those ideas can be represented.
- **Make key aspects of teaching visible to prospective teachers (representation and decomposition of practice) –** This refers to the extent to which an experience helps makes visible key aspects of teacher decision-making and professional reasoning, and engages prospective teachers in unpacking the complexity of teaching practice and the interplay with the teaching context.
- **Engage prospective teachers in authentic tasks and experiences (approximation of practice) –** This refers to the extent to which an assignment helps prospective teachers engage in authentic activity; that is, activity that is congruent with the work of teaching and that allows prospective teachers to experiment with new skills, roles and ways of thinking with more support. This also refers to the extent to which the activity requires novices to make their thinking and decision-making visible by requiring more detailed information than may be typical in the everyday work of teaching.
- **Develop the tools and dispositions to learn from their practice –** This refers to the extent to which an assignment helps prospective teachers reflect upon and learn from their practice (next steps) based upon analysis of evidence.

	Not supported	**Limited support**	**Adequate support**	**Exemplary support**
Deepen subject matter knowledge for teaching ● **Anticipating student thinking around specific science ideas**				

• **Designing, selecting, and sequencing learning experiences and activities** • **Monitoring, interpreting, and acting on student thinking** • **Scaffolding meaningful engagement in a science learning community** • **Explaining and using examples, models, representations, and arguments to support students' scientific understanding** • **Using experiments to construct, test, and apply concepts**				
Make key aspects of teaching visible: knowledge of curriculum				
Make key aspects of teaching visible PCK: knowledge of learners				
Engage in approximations of practice/enactment of PCK				

Develop the tools and dispositions to develop PCK further				