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Critical Factors for Effective and Equitable NGSS Science Teaching Practices

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Critical Factors for Effective & Equitable NGSS Science Teaching Practices
(Paper set)

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Presentation Repository Version

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National Science Foundation
WHERE DISCOVERIES BEGIN

Grant Overview

NSF Noyce Track I, Phase II Grant (2015-2020) ($800,000)*

Longitudinal Evaluation of Noyce Science Teachers to Determine Sources of Effective Teaching

- 5-year grant that began September 2015
- 60% of grant dedicated to the Noyce stipends (30 stipends at $16,000 each) in MAT program.
  - **Supporting diverse learners.** Noyce recipients must teach 2 years at a high-need school (or district).
- Remainder of grant used to investigate two models of science teacher preparation.

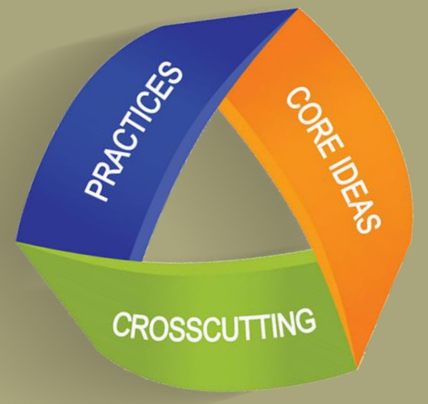
****** NSF Track I, Phase I ($1.2 million) (2010-2016) = 60 stipends***

Comparison of Two Science Teacher Preparation Programs

Our NSF Noyce Phase II grant has enabled us to add a comparison group to our longitudinal study of MAT graduates started in Phase I.

Program	Undergraduate	MAT
Science Coursework	***Prior and concurrent to acceptance:*** Sufficient science coursework for Nebraska secondary science teaching endorsement (24 credit hours in one are with another 12 hours among other 3 areas).	***Prior to Acceptance:*** Undergraduate major in one area of science; some MA students have graduate-level science coursework or advanced degree.
Education Coursework	***Pre-professional Education Coursework:*** Foundations of Education; Adolescent Development & Practicum (13 credit hours)	***Required MA Coursework:*** Intro to Educational Research; Curriculum Theory; Teacher Action Research Project; Teaching ELLs in the Content Area. ***Optional MA Coursework:*** Reading in the Content Area; History and Nature of Science
Common Coursework	Accommodating Exceptional Learners; Adolescent Development / Human Cognition; Science Teaching Methods (two classes, each with a practicum experience); Multicultural Education / Pluralistic Society	
Resulting Degree	BA Secondary Science Education	MA with emphasis in science teaching

Introduction: NGSS Vision into Practice



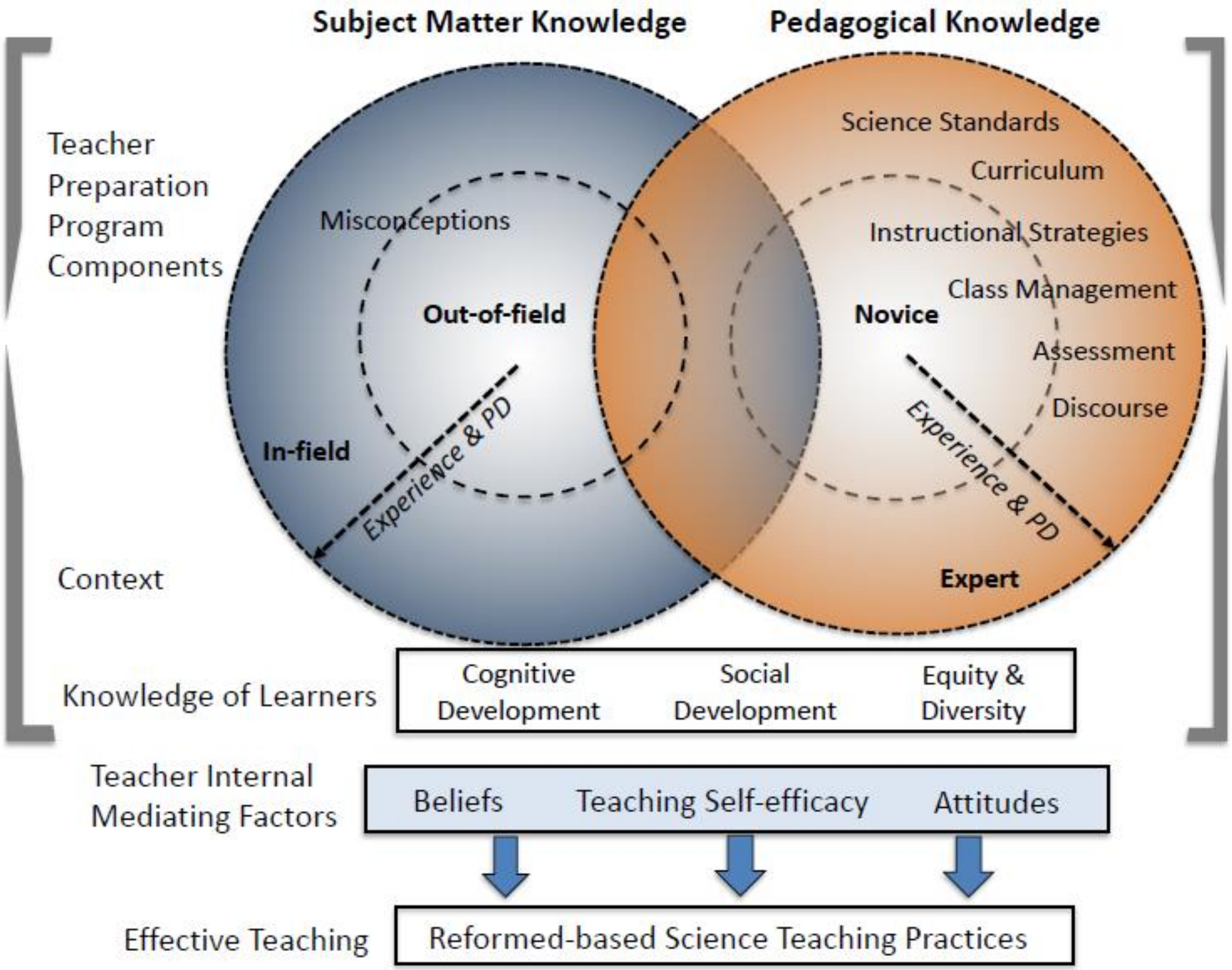
- Models of inquiry-based instruction have been around for decades, but have been **difficult to achieve in practice** (Cuban, 1993; Crawford,2014).
- The *Next Generation Science Standards (NGSS)* are grounded in inquiry-based instruction and learning.
- NGSS require science teachers to be fluid in their selection, development, and implementation of **curriculum** within three dimensions of science learning:
  a) **disciplinary core ideas**
  b) **scientific and engineering practices**
  c) **cross-cutting concepts**
- All dimensions require that science teachers have a **strong understanding of science** and **continue to learn** effective ways of teaching.

Research Approach and Methodology

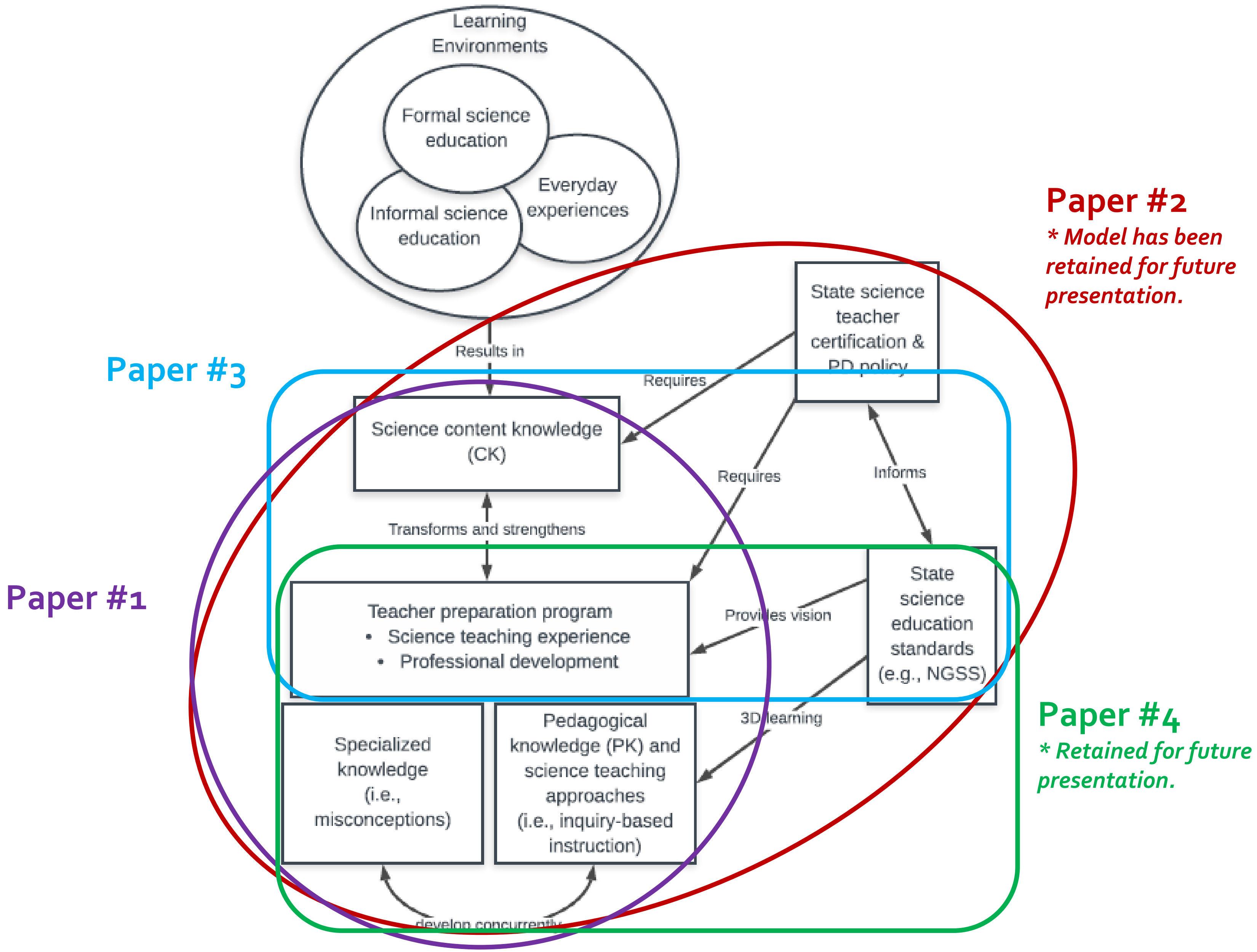
Overarching question:

What leads to effective secondary science teaching?

Conceptual Framework: Teacher Preparation to Effective Science Teaching
(Lewis, et al., 2020)



Beginning Science Teachers Longitudinal Study Conceptual Framework & Presentation Papers



Science Teachers' Subject Matter Knowledge Impacts Inquiry-based Instruction

Lyrica L. Lucas
University of Nebraska-Lincoln

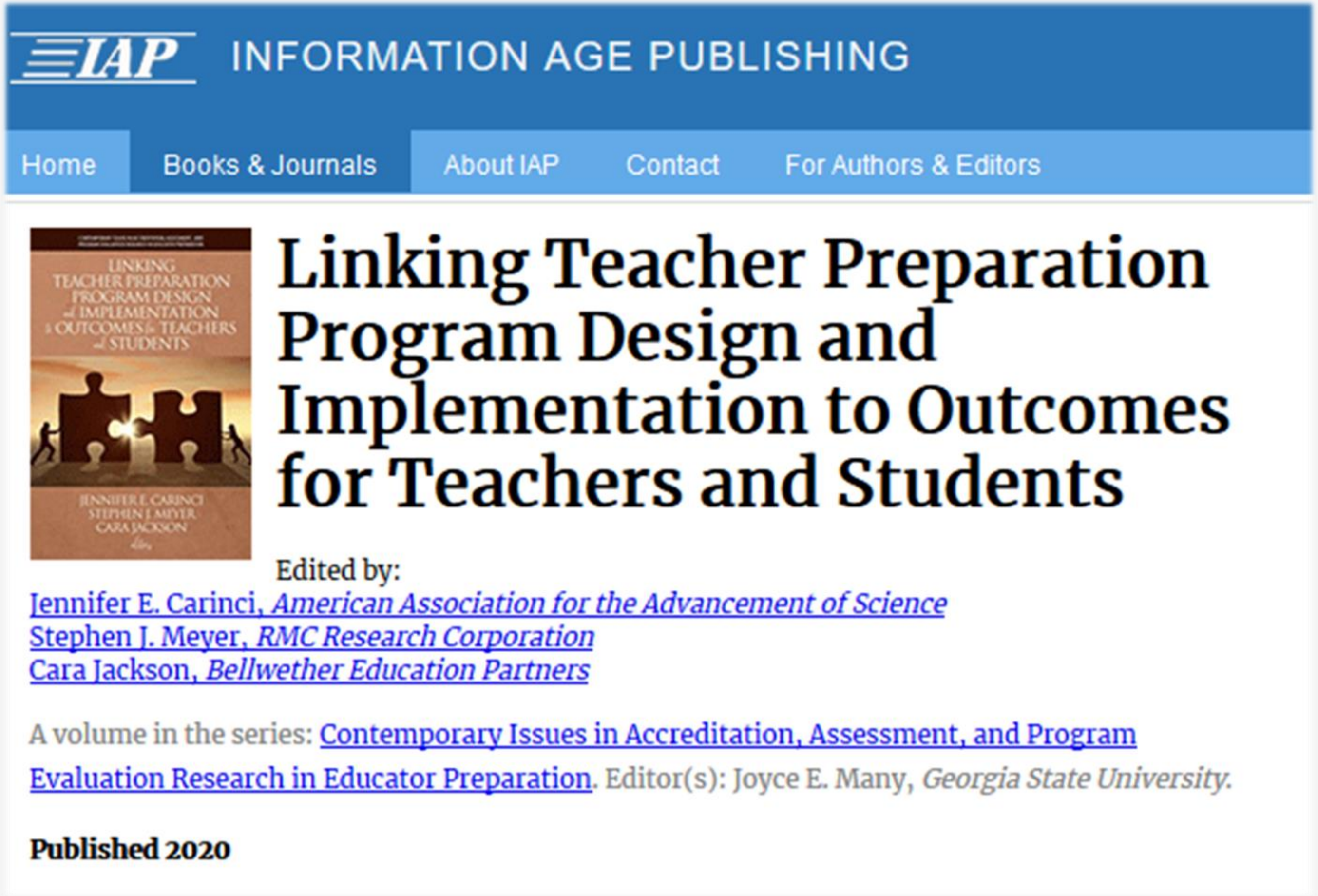
What we know about SMK and effective science teaching

- Knowing content or subject matter is crucial to effective teaching which characteristically takes learners' experiences, interests, and needs into account (Ball, 2000; Van Driel, Berry, & Meirink, 2014).

- There is a need for studies about science teachers' SMK and its influence on effective science instruction to shape policies on teacher education programs, teaching certification, evaluation, and hiring processes (Sadler & Sonnert, 2016; Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013).

- Our team published a chapter in a new book:

    Lewis, E. B., Rivero, A., Musson, A., Lucas, L., Tankersley, A., & Helding, B. A. (2019). Chapter 4: Educating Effective Science Teachers: Preparing and Following Teachers into the Field. *Linking Teacher Preparation Program Design and Implementation to Outcomes for Teachers and Students. Charlotte, NC: Information Age Publishing.*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Linking Teacher Preparation Program Design and Implementation to Outcomes for Teachers and Students

Edited by:
Jennifer E. Carinci, *American Association for the Advancement of Science*
Stephen J. Meyer, *RMC Research Corporation*
Cara Jackson, *Bellwether Education Partners*

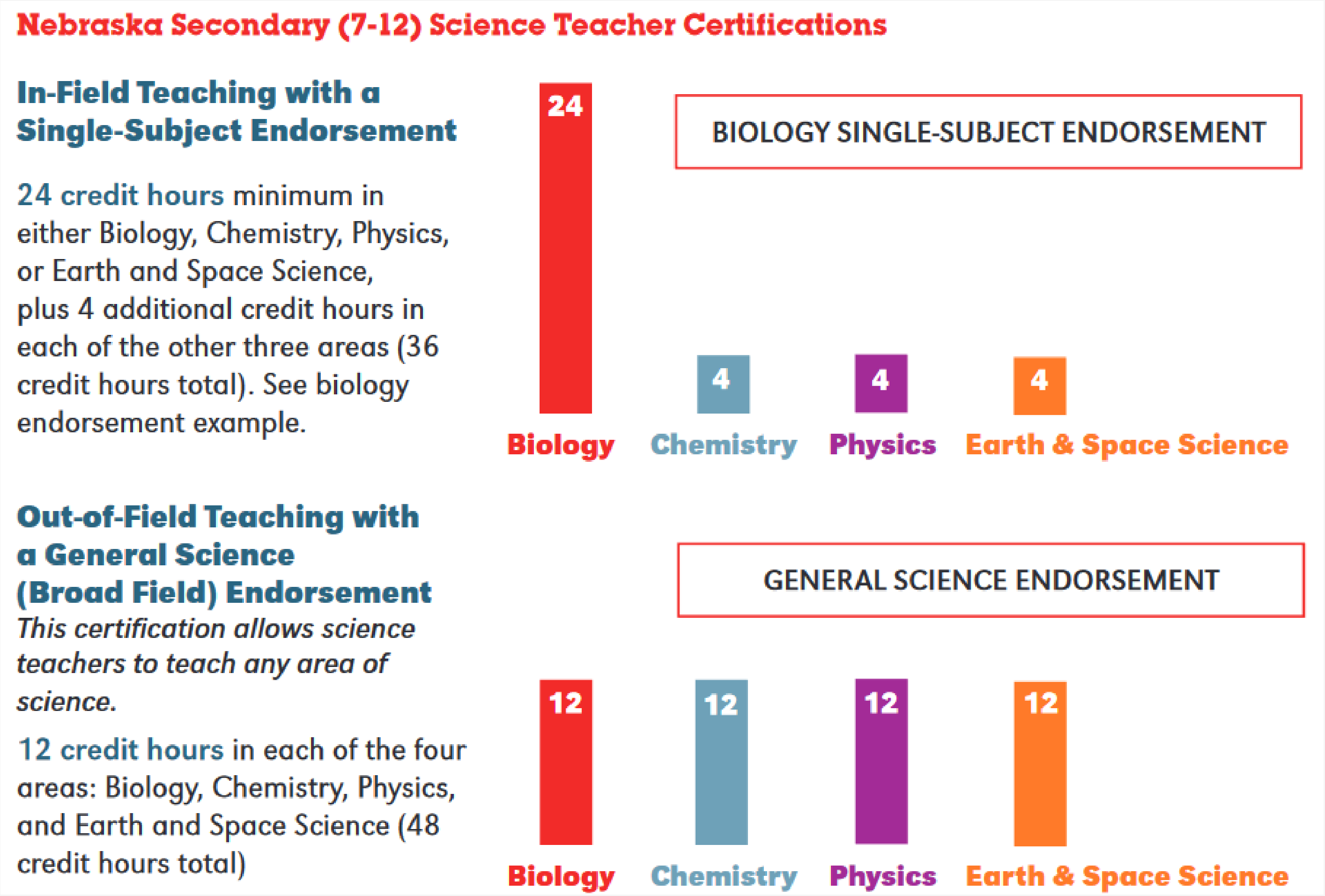
A volume in the series: Contemporary Issues in Accreditation, Assessment, and Program Evaluation Research in Educator Preparation. Editor(s): Joyce E. Many, *Georgia State University.*

Published 2020

What we know about SMK and effective science teaching

- Identifying minimum qualifications that lead to effective teaching practices, has been a challenging task for designing science teacher education programs (National Research Council [NRC], 2010; Lewis et al., 2020).

- Content knowledge in science is not something teacher education provides consistently (Wilson, Floden, & Ferrini-Mundy, 2001).



Lewis, E.B., Lucas, L., Tankersley, A., & Hasseler, L. (2019). *Why domain-specific science knowledge matters in teacher certification: Focusing on evidence for effective science teaching.* University of Nebraska-Lincoln.

Research Questions

Purpose. To investigate the relationship between science teachers' SMK and the degree of their implementation of inquiry-based instruction.

1. What is the relationship between science teachers' SMK and their inquiry-based instruction behaviors?

2. Which specific factors of inquiry-based instruction are influenced by teachers' SMK?

   credit hours and grade point average (GPA) for each area of science (physics, chemistry, life science, ESS), math credit hours, and math GPA

Science SMK → Inquiry-based Instruction

Methods

Participants

- In-service science teachers (with zero to seven years of teaching experience)
- Graduated from two science teacher preparation programs, a 14-month masters' (MA) and a four-year bachelor's program (BS)
- Participated in class observations (2015-2019)

Instrument

- Electronic Quality of Inquiry Protocol (EQUIP) (Marshall, Smart, & Horton, 2010) with 19 sets of observable behaviors.

IV. Instructional Factors					
Construct Measured		*Pre-Inquiry (Level 1)*	*Developing Inquiry (2)*	*Proficient Inquiry (3)*	*Exemplary Inquiry (4)*
I1.	Instructional Strategies	Teacher predominantly lectured to cover content.	Teacher **frequently lectured** and/or used demonstrations to explain content. Activities were **verification only**.	Teacher **occasionally lectured**, but **students were engaged in activities** that helped develop conceptual understanding.	Teacher occasionally lectured, but students were engaged in investigations that **promoted strong conceptual understanding**.
I2.	Order of Instruction	Teacher explained concepts. Students either did not explore concepts or did so only after explanation.	Teacher asked **students to explore concept before receiving explanation**. Teacher explained.	Teacher asked students to **explore before explanation**. **Teacher and students explained**.	Teacher asked students to explore concept before explanation occurred. Though perhaps prompted by the teacher, **students provided the explanation**.
I3.	Teacher Role	Teacher was center of lesson; rarely acted as facilitator.	**Teacher was center of** lesson; **occasionally** acted as **facilitator**.	Teacher **frequently** acted as facilitator.	Teacher **consistently and effectively** acted as a facilitator.
I4.	Student Role	Students were consistently passive as learners (taking notes, practicing on their own).	**Students were active to a small extent** as learners (highly engaged for very brief moments or to a small extent throughout lesson).	**Students were active as learners** (involved in discussions, investigations, or activities, but not consistently and clearly focused).	Students were **consistently and effectively active as learners** (highly engaged at multiple points during lesson and clearly focused on the task).
I5.	Knowledge Acquisition	Student learning focused solely on mastery of facts, information, and/or rote processes.	Student learning focused on **mastery of facts** and process skills without much focus on understanding of content.	Student learning required **application of concepts** and process skills in new situations.	Student learning required **depth of understanding** to be demonstrated relating to content and process skills.

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Methods

Data

1 **Inquiry-based instruction**

- *N*=807 science lessons. Each observed lesson was coded using the qualitative descriptors in the EQUIP instrument
- Exploratory factor analysis (EFA) was conducted on the 19-item EQUIP instrument
  - Factor 1: Instructional and curricular attributes
  - Factor 2: Discourse attributes

2 **Subject matter knowledge**

- Teachers' transcript information to determine typical discipline-specific science coursework
- Credit hours and GPA

	Observed Science Lesson	*n*(%)
School Year	2015-2016	212 (26)
	2016-2017	219 (27)
	2017-2018	228 (28)
	2018-2019	148 (18)
Lesson Level	High School	597 (74)
	Middle School	210 (26)
Lesson Topic	Chemistry	148 (18)
	Physics	158 (20)
	Biology	350 (43)
	Earth and Space Science	115 (14)
	Engineering	23 (3)
	General Science	13 (2)

Methods

Analysis

- Multivariate multiple regression using SMK measures (credit hours and GPA), teaching experience, and lesson level as predictors and EQUIP factor scores as criterion.
- Analysis was conducted by subject area (chemistry, physics, life science, and earth and space science).
- Statistical analysis and visualization were conducted using *car* (Fox & Weisberg, 2019), *tidyverse* (Wickham et al., 2019) and *heplots* (Fox, Friendly, & Monette, 2009) packages in R.

Science SMK → Inquiry-based Instruction

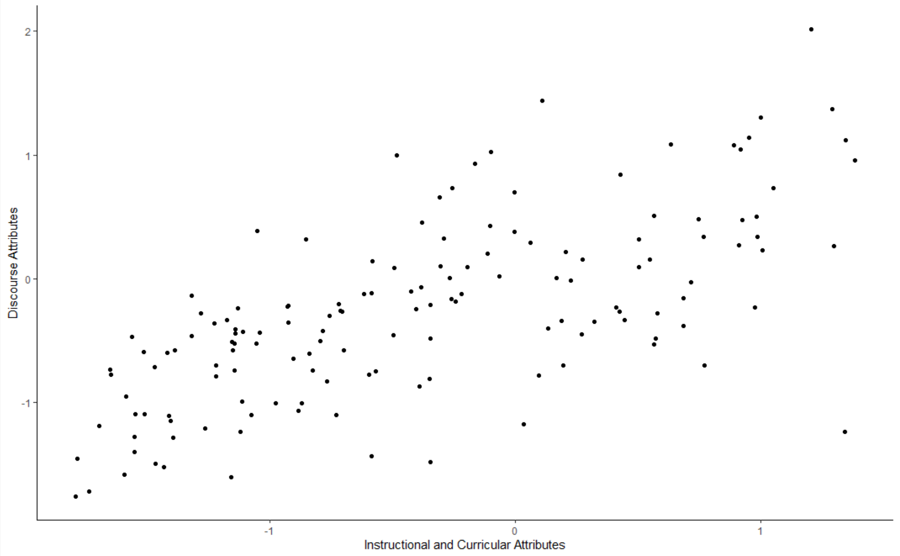
- EQUIP factors:

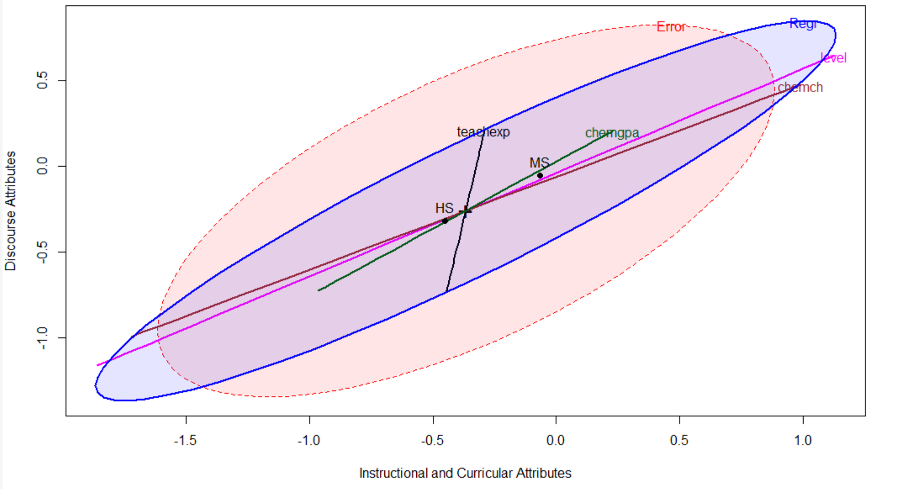
  Factor 1: Instructional and curricular attributes

  Factor 2: Discourse attributes

Results: Chemistry

Potential predictors of inquiry-based instruction in chemistry, *n*=148	
Teaching experience in years, *M*(*SD*)	2.83 (1.35)
Lesson level: HS, *n*(%)	113 (76)
Lesson level: MS, *n*(%)	35 (24)
Chemistry credit hours, *M*(*SD*)	23.6 (15.1)
Chemistry GPA, *M*(*SD*)	3.17 (0.58)





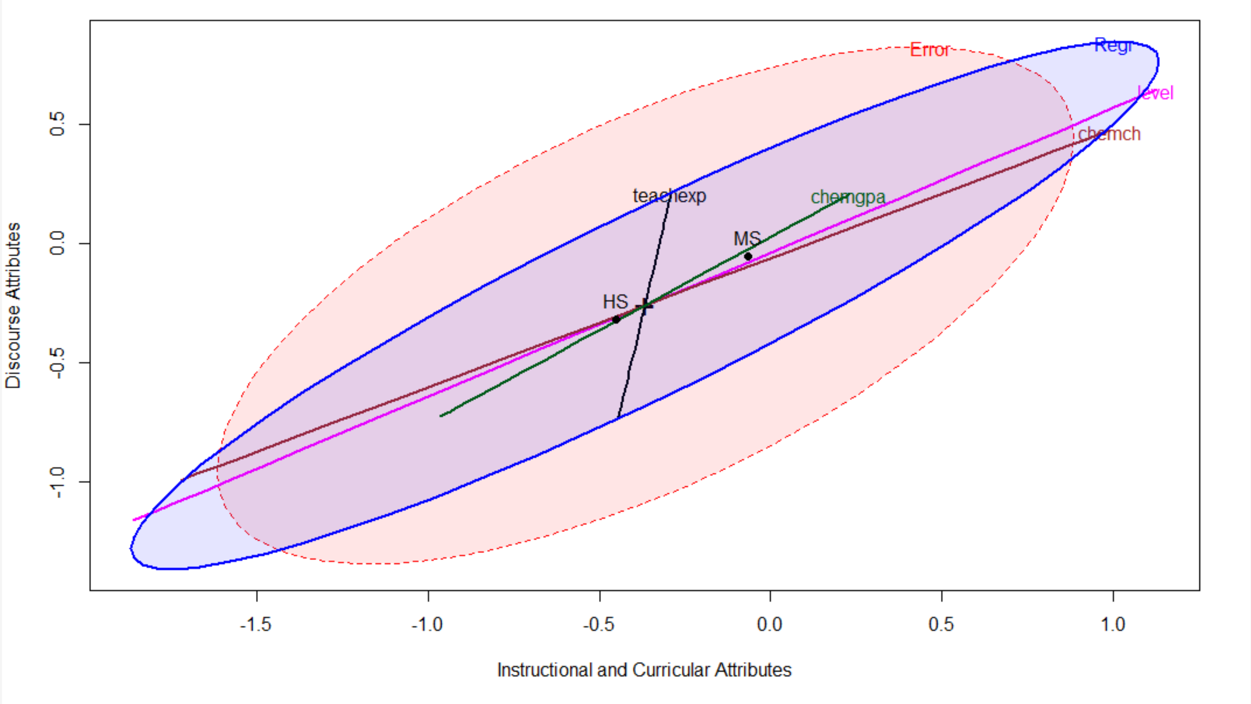
Lesson level and chemistry credit hours are significant predictors of inquiry-based instruction.

- Overall multivariate test. The main effects of lesson level ($F(2,139)=4.40$, Wilks' $\lambda=0.94$, $p=0.01$, partial $\eta2=0.06$) and chemistry credit hours ($F(2,139)=3.60$, Wilks' $\lambda=0.95$, $p=0.03$, partial $\eta2=0.05$) on the combined inquiry factors are statistically significant.

Results: Chemistry

Instructional and Curricular Attributes

- Middle school lessons had a higher mean factor score, leaning more toward reform-based than traditional instruction.
- The more chemistry credit hours a teacher has taken, the higher the corresponding factor scores representing inquiry-based strategies and curricular choices.



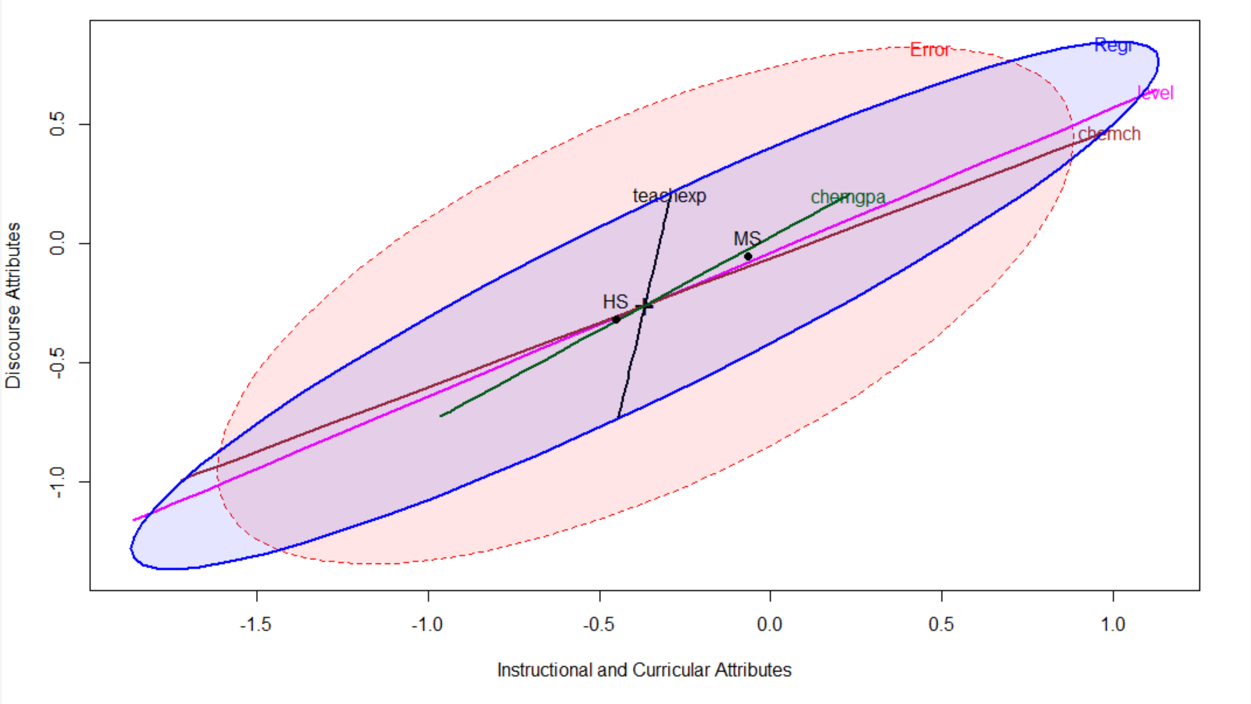
Univariate multiple regression. For instructional and curricular attributes, the overall univariate test is significant ($F(4,140)=4.24$, $R^2=0.11$, $p=0.003$). Among the partial tests for individual predictors, lesson level ($p=0.004$) and chemistry credit hours ($p=0.008$) were significant.

Results: Chemistry

Discourse Attributes

- Discourse in middle school level was more inquiry-based compared to high school.

Univariate multiple regression. For discourse attributes, the overall univariate test is also significant ($F(4,140)=4.24$, $R^2=0.08$, $p=0.02$). Among the partial tests for individual predictors, only the lesson level was significant ($p=0.04$).

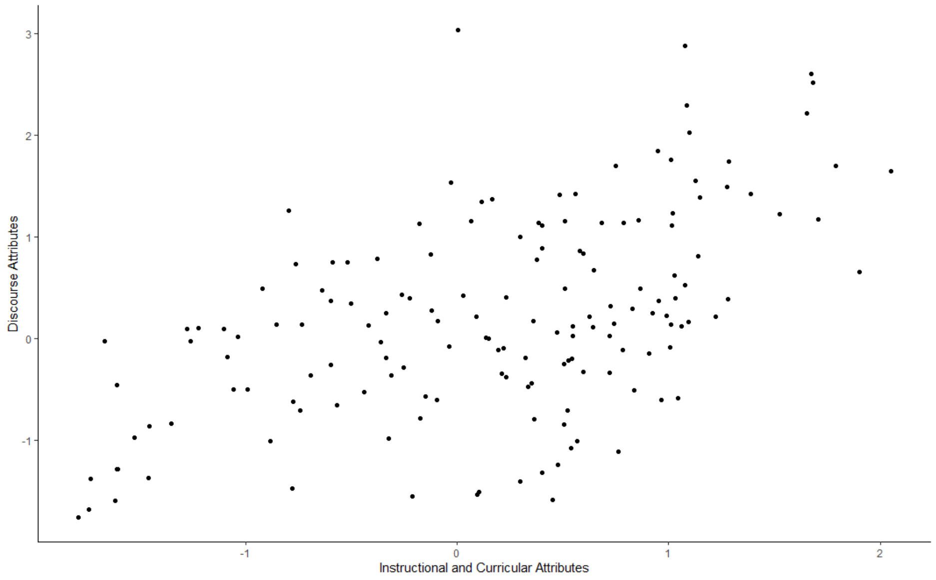


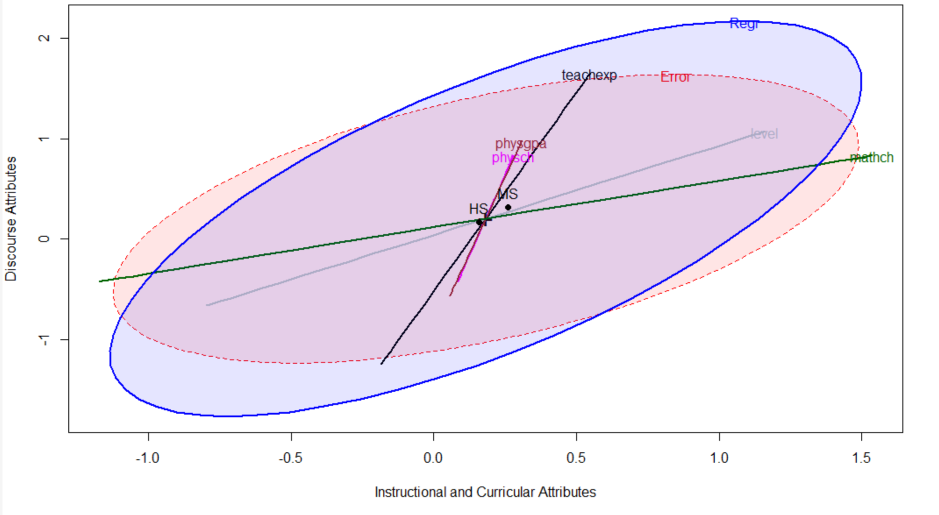
Results: Physics

Potential predictors of inquiry-based instruction in physics, *n*=158	
Teaching experience in years, *M*(*SD*)	2.92 (1.82)
Lesson level: HS, *n*(%)	120 (76)
Lesson level: MS, *n*(%)	38 (24)
Physics credit hours, *M*(*SD*)	23.7 (21.6)
Physics GPA, *M*(*SD*)	3.29 (0.47)
Math credit hours, *M*(*SD*)	

Teaching experience and math credit hours are significant predictors of inquiry-based instruction.

- Overall multivariate test. The main effects of teaching experience in years ($F(2,151)=3.34$, Wilks' $\lambda=0.96$, $p=0.04$, partial $\eta 2=0.04$) and math credit hours ($F(2,151)=3.31$, Wilks' $\lambda=0.96$, $p=0.03$, partial $\eta 2=0.04$) on the combined inquiry factors are statistically significant.





Results: Physics

Instructional and Curricular Attributes

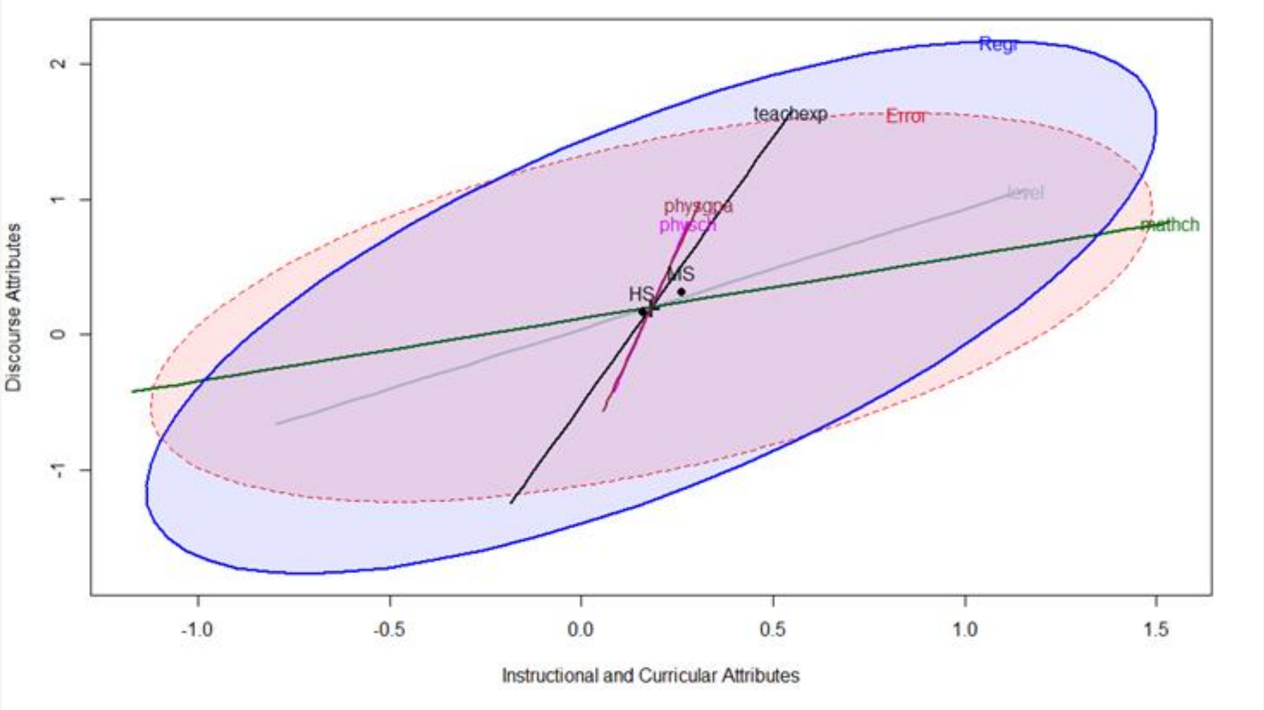
- The model does not perform significantly better compared to a null model.

Univariate multiple regression. For instructional and curricular attributes, the overall univariate test is not significant ($F(5,152)=2.07$, $R^2=0.07$, $p=0.07$).

Discourse Attributes

- Inquiry-based discourse practices improve with teaching experience.

Univariate multiple regression. For discourse attributes, the overall univariate test is also significant ($F(5,152)=3.80$, $R^2=0.11$, $p=0.003$). Among the partial tests for individual predictors, only teaching experience was significant ($p=0.01$).

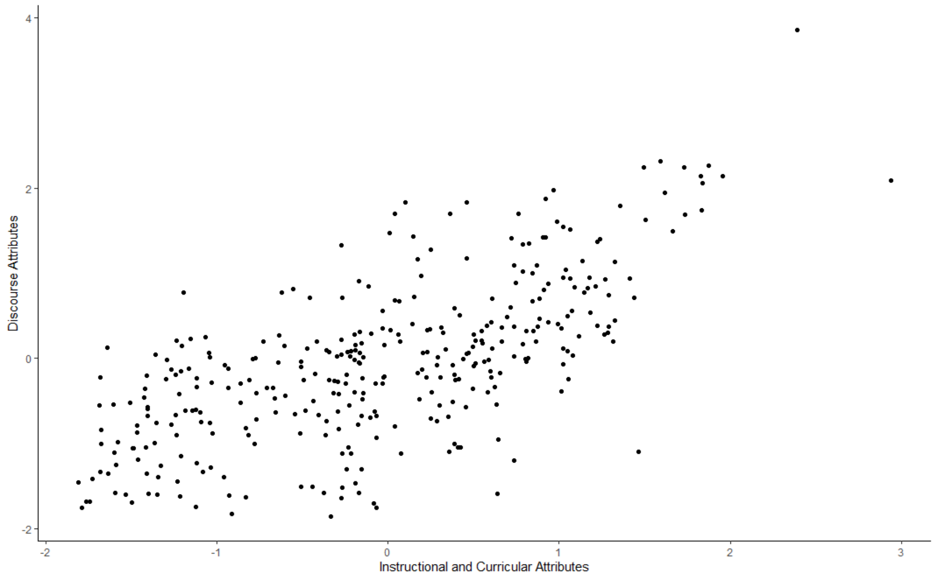


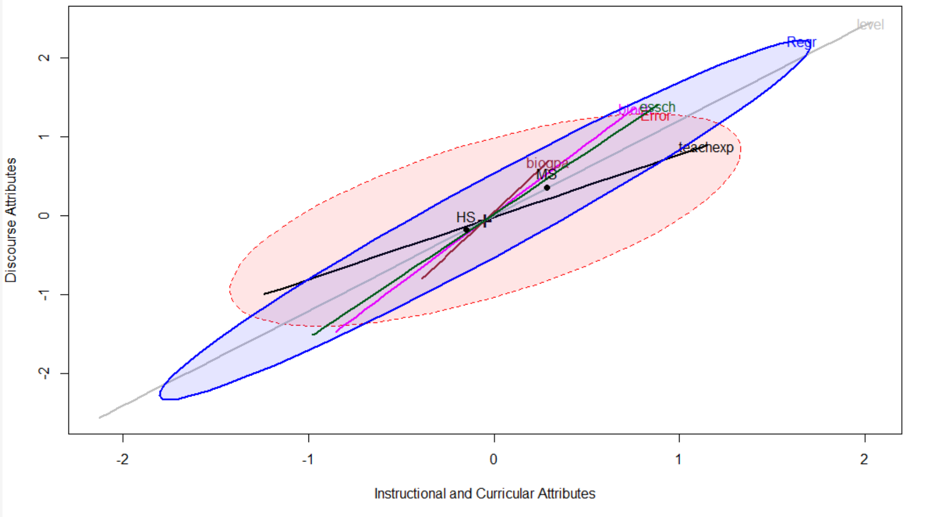
Results: Life Science

Potential predictors of inquiry-based instruction in life science, *n*=350	
Teaching experience in years, *M*(*SD*)	3.26 (1.66)
Lesson level: HS, *n*(%)	266 (76)
Lesson level: MS, *n*(%)	84 (24)
Biology credit hours, *M*(*SD*)	35.2 (14.3)
Biology GPA, *M*(*SD*)	3.44 (0.46)
ESS credit hours, *M*(*SD*)	8.37 (4.75)

Lesson level, biology credit hours, and ESS credit hours are significant predictors of inquiry-based instruction.

- Overall multivariate test. The main effects of lesson level ($F(2,340)=10.93$, Wilks' $\lambda=0.94$, $p=0.04$, partial $\eta2=0.07$), biology credit hours ($F(2,340)=3.43$, Wilks' $\lambda=0.98$, $p=0.03$, partial $\eta2=0.02$), and ESS credit hours ($F(2,340)=3.57$, Wilks' $\lambda=0.98$, $p=0.03$, partial $\eta2=0.02$) on the combined inquiry factors are statistically significant.

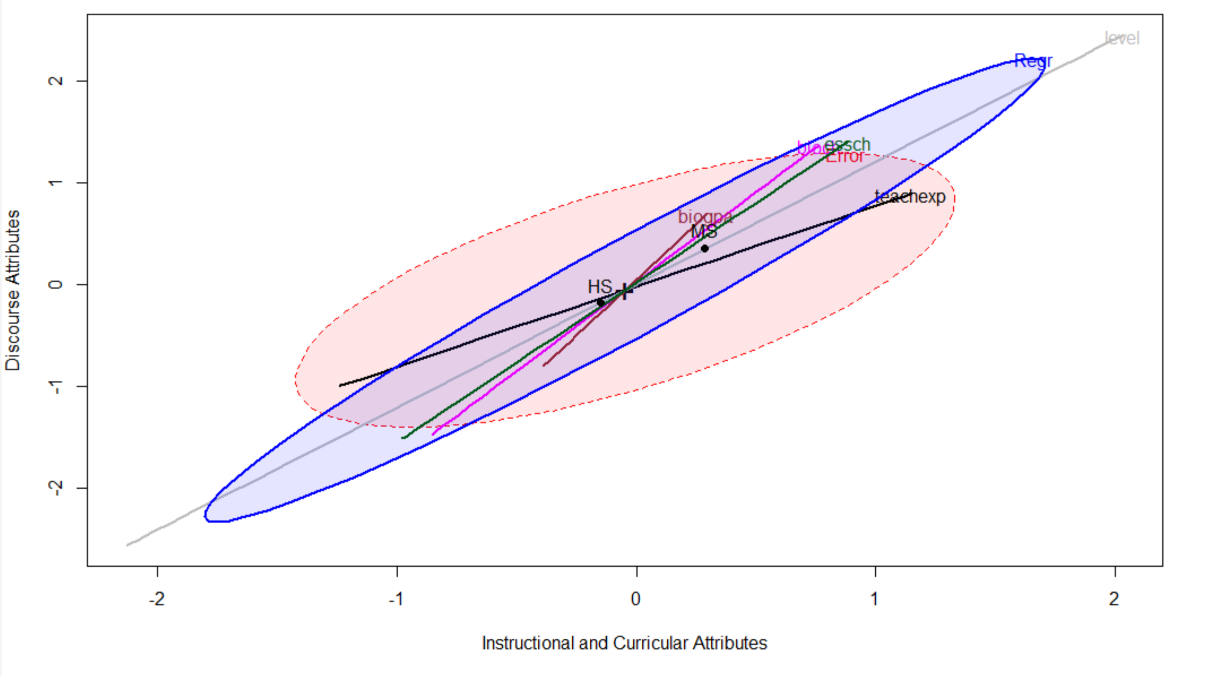




Results: Life Science

Instructional and Curricular Attributes

- Inquiry-based practices improve with teaching experience.
- Middle school lessons had a higher mean factor score, leaning more toward reform-based than traditional instruction.

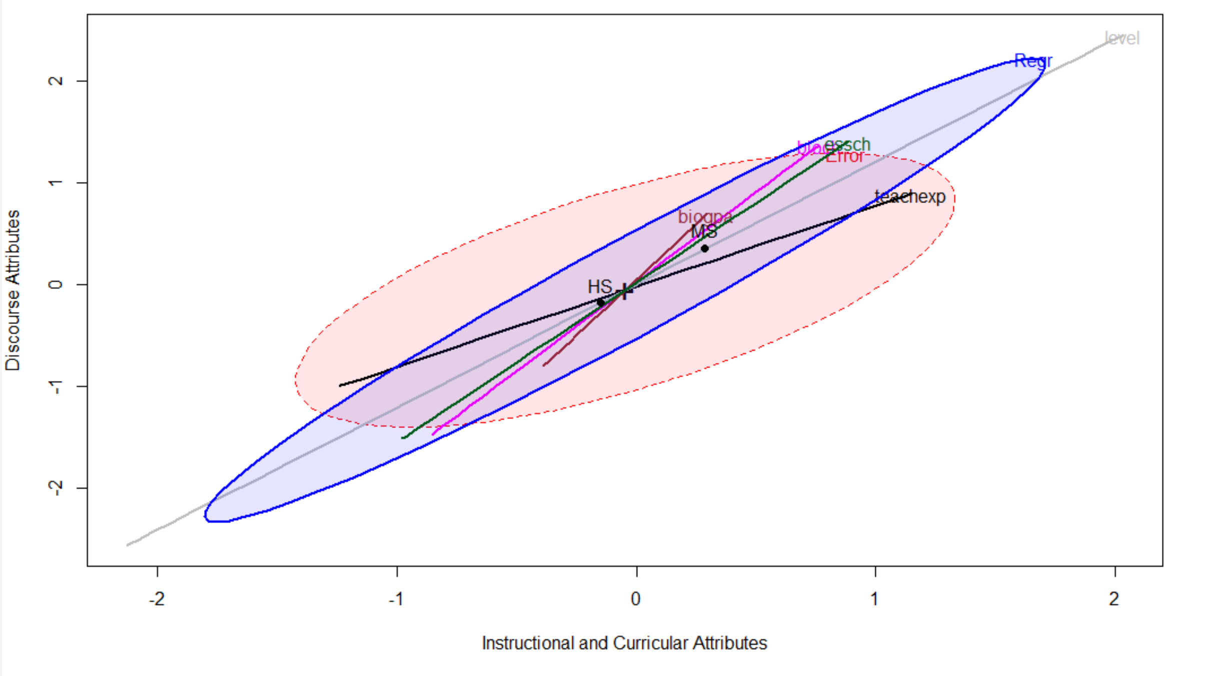


Univariate multiple regression. For instructional and curricular attributes, the overall univariate test is significant ($F(5,341)=5.96$, $R^2=0.08$, $p<0.001$). Among the partial tests for individual predictors, teaching experience ($p=0.03$) and lesson level ($p<0.001$) were significant.

Results: Life Science

Discourse Attributes

- Middle school lessons had a higher mean factor score, leaning more toward reform-based than traditional instruction.
- The more biology and ESS credit hours a teacher has taken, the more inquiry-based their discourse practices are in the classroom.



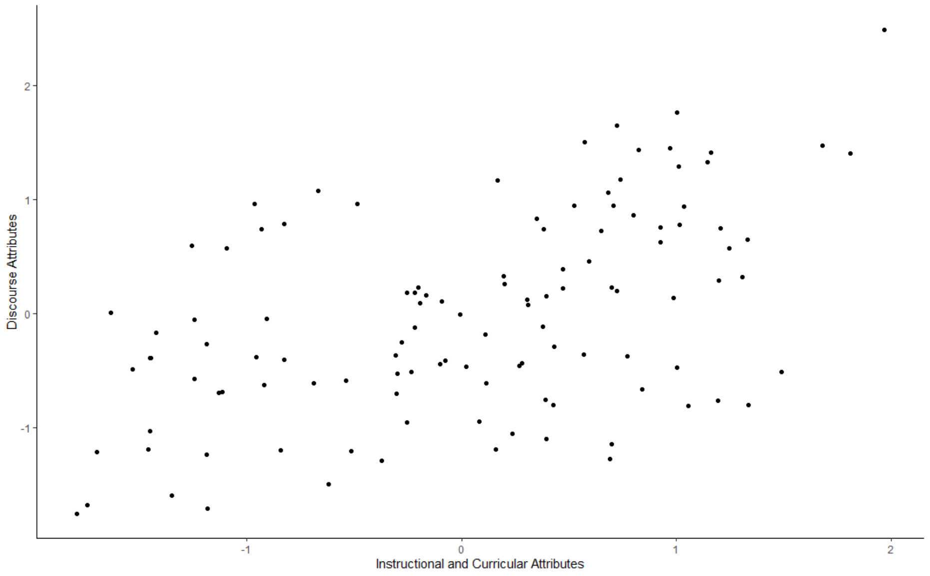
Univariate multiple regression. For instructional and curricular attributes, the overall univariate test is significant ($F(5,341)=10.14$, $R^2=0.13$, $p<0.001$). Among the partial tests for individual predictors, lesson level ($p<0.001$), biology credit hours ($p<0.01$) and ESS credit hours ($p<0.01$) were significant.

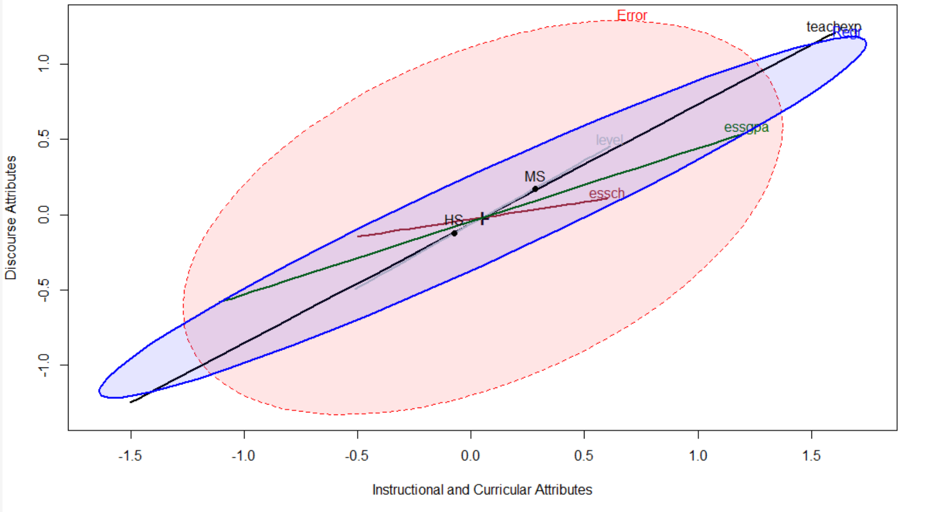
Results: Earth and Space Science (ESS)

Potential predictors of inquiry-based instruction in ESS, *n*=115	
Teaching experience in years, *M*(*SD*)	2.57(1.48)
Lesson level: HS, *n*(%)	74 (64)
Lesson level: MS, *n*(%)	41 (36)
ESS credit hours, *M*(*SD*)	11.9 (7.5)
ESS GPA, *M*(*SD*)	3.57 (0.42)

Teaching experience is a significant predictor of inquiry-based instruction.

- Overall multivariate test. The main effect of teaching experience ($F(2,108)=4.87$, Wilks' $\lambda=0.92$, $p<0.01$, partial $\eta 2=0.08$ on the combined inquiry factors is statistically significant.



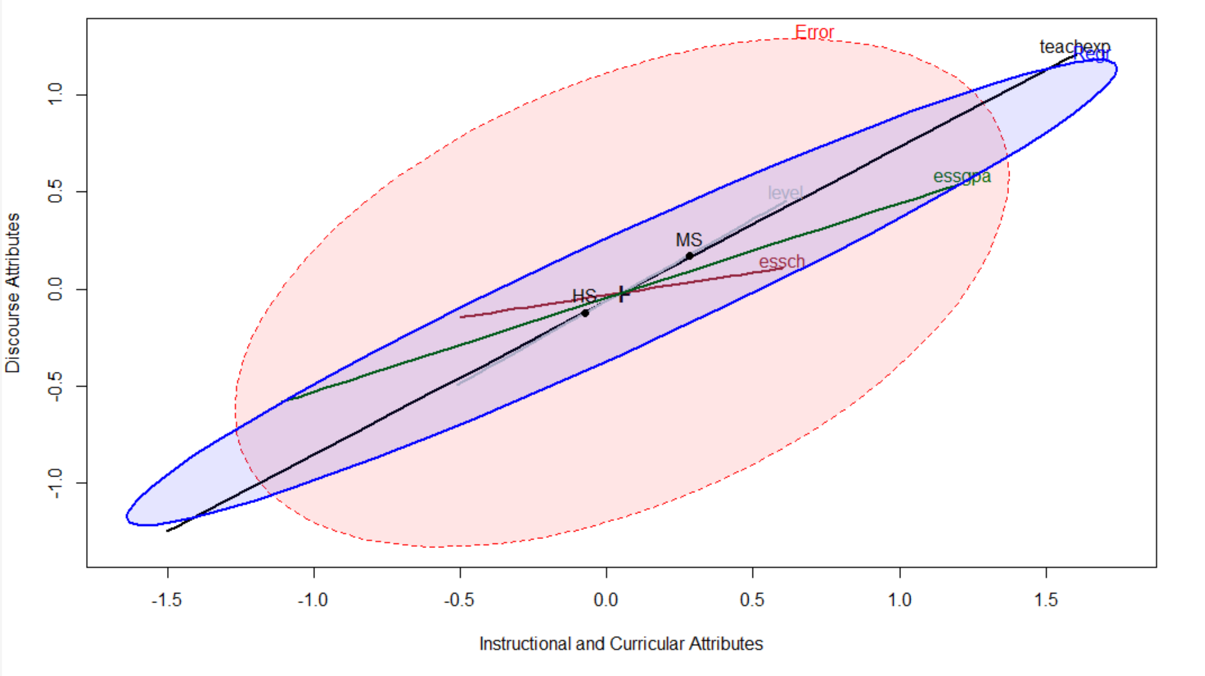


Results: Earth and Space Science (ESS)

Instructional and Curricular Attributes

- Inquiry-based practices improve with teaching experience.
- GPA is positively associated with inquiry-based teaching.

Univariate multiple regression. For instructional and curricular attributes, the overall univariate test is significant ($F(4,109)=4.38$, $R^2=0.14$, $p<0.003$). Among the partial tests for individual predictors, teaching experience ($p=0.004$) and ESS GPA ($p=0.03$) were significant.



Results: Earth and Space Science (ESS)

Discourse Attributes

- The model does not perform significantly better compared to a null model.

Univariate multiple regression. For instructional and curricular attributes, the overall univariate test is not significant ($F(4,109)=2.44$, $R^2=0.08$, $p=0.05$).

Summary: SMK models of inquiry-based instruction

		More inquiry-based	Less inquiry-based
Chemistry	Overall inquiry-based instruction	Middle school, more chemistry credit hours	High school, less chemistry credit hours
	Instructional and curricular attributes	Middle school, more chemistry credit hours	High school, less chemistry credit hours
	Discourse attributes	Middle school	High school
Physics	Overall inquiry-based instruction	More teaching experience, more math credit hours	Less teaching experience, less math credit hours
	Instructional and curricular attributes	-	-
	Discourse attributes	More teaching experience	Less teaching experience
Life science	Overall inquiry-based instruction	Middle school, more biology credit hours, more ESS credit hours	High school, less biology credit hours, less ESS credit hours
	Instructional and curricular attributes	More teaching experience, middle school	Less teaching experience, middle school
	Discourse attributes	Middle school, more biology credit hours, more ESS credit hours	High school, less biology credit hours, less ESS credit hours
Earth and space science	Overall inquiry-based instruction	More teaching experience	Less teaching experience
	Instructional and curricular attributes	More teaching experience, high ESS GPA	Less teaching experience, low ESS GPA
	Discourse attributes	-	-

Summary: SMK models of inquiry-based instruction

- Inquiry-based instruction may vary by grade level (chemistry, life science).

- More discipline-specific science coursework is associated with higher levels of inquiry-based instruction (chemistry, physics, life science).

- Teaching experience improves inquiry-based instruction (physics, ESS).

Implications

- Ensure that teachers are adequately prepared to teach discipline-specific science subjects by providing appropriate and robust coursework guided by empirical research.
- Emphasize and model inquiry-based instruction (instructional strategies, curricular choices, discourse) for different subjects and grade levels

- Teaching experience might be associated with variable opportunities for teachers to engage in professional development.
- Inquiry-focused PD could address the need for increased inquiry-based instruction in high school.

- How are college-level science courses taught? Do introductory science courses provide inquiry learning experiences? Do preservice teachers need advanced science courses to experience learning by inquiry?
- How does SMK compared with other teacher-level, student-level, and school-level factors impact science instruction?

1 Teacher preparation

2 Professional development

3 Future research

Questions?

Contact Me

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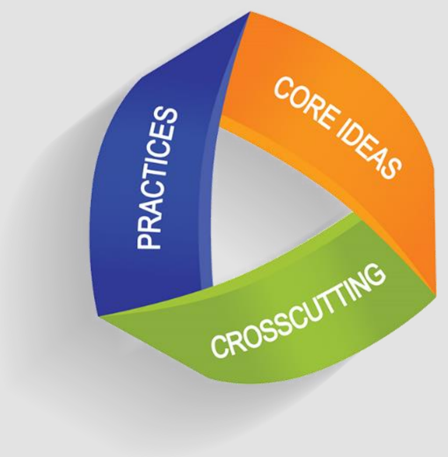
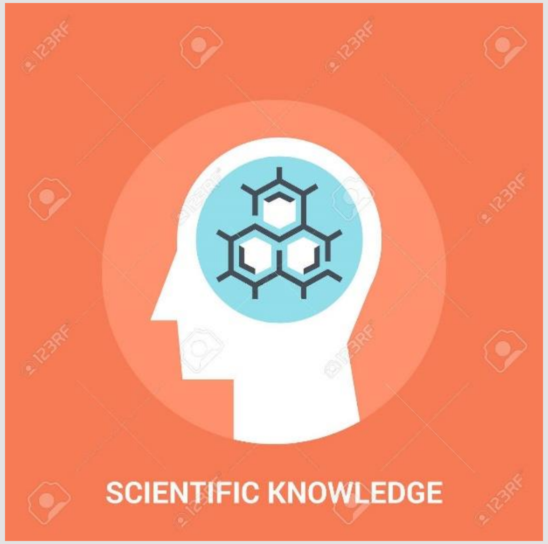
Paper #2:
Science Teachers' Professional Development

Elizabeth Lewis, Amy Tankersley, Elizabeth Hasseler, & Lyrica Lucas
University of Nebraska-Lincoln
Brandon Helding, Boulder Learning, Inc.





Teacher Preparation: *Subject Matter Knowledge and Effective Teaching*

- Teachers' SMK via a robust teacher preparation program contributes to successful teaching.
- SMK provides support to develop PCK (Kind, 2009; Shulman, 1986).
- There is a strong relationship between what the teachers know and how they teach (De Jong, Veal, & Van Driel (2002).
  - For example, in our previous research (Lewis, et al., 2020) we found that teachers needed at least **30 credit hours in chemistry at a 3.2 GPA** in order to reliably pass a test of common high school-level misconceptions.
  - Furthermore, we connected teachers' SMK to the level of inquiry-based teaching; in **predicting inquiry-based teaching practices** the **total number of chemistry credit hours** taken by a teacher accounted for **19% of the variance in their use of inquiry** in their science lessons (Lewis, et al., 2020).

Post-Teacher Preparation: *The Critical Importance of Teacher Professional Development*

- With the NGSS, it is critical to **continue to provide science teachers with professional development** who are capable of advancing science education reform priorities.
- Upon graduation from teacher preparation programs, knowledge of effective teaching continues to grow through experience and PD.
  - **Plateaus at about 5-6 years**, resulting in little difference on average compared with teachers with **10 years** of experience (Darling-Hammond, 2000; U.S. National Center of Educational Statistics, 2000).
- Thus, the main source of learning occurs through their **choices of teacher professional development (PD)** (Luft & Hewson, 2014).
- Learning new ways to teach effectively makes teachers' work **more satisfying and builds confidence**.
- The **lack of teacher PD** can be detrimental to not only teachers' growth, but also their students' scientific literacy.

Primary Research Questions

The focus of this study was to investigate the relationship of elective teacher PD through the following questions:

1. What % of teachers engage in **within-** and **out-of-school district *PD activities***?
2. Is there a **difference** between teachers prepared at the undergraduate versus graduate level in terms of the ***amount and types of teacher PD*** they choose?

Research Participants & Survey Data Collection

- Data collected **2015 – 2019,** resulting in a **4-year** longitudinal dataset.
- Surveyed beginning **(0-3 years)** and mid-career **(4-7 years)** science teachers annually at the end of each school year to document their PD activities.
- Teachers identified:
  - **science-specific** (e.g., completing a college-level science course)
  - **pedagogical-focused** PD activities
  - an estimate of ***how many hours they logged***
  - **state-sponsored** science content related PD
  - if they attended their state, regional, or national **science teachers' conference**

Context & Response Rate

***N* = 146 responses**

- **92%** of teachers taught in the same state in which they completed their teacher education program.
- This state does **not require teacher PD.**
- Across years individual teachers:
  - **41.8%** responded once
  - **19.4%** twice
  - **17.9%** three times
  - **20.9%** in all four years

Analytic Methods

We used:

1. Descriptive statistics to describe teacher PD patterns
2. Two-way ANOVA

Survey Findings

- ***No significant difference*** *in the total amount of PD between* beginning and mid-career teachers.
- There was ***a significant difference*** in the amount of PD between teacher alumni who became certified from the **undergraduate** (*n*=50) and **MAT** (*n*=96) programs.
- However, when the specific categories are taken individually there were **few practical differences.**

In-District PD

- **91%** of teachers reported engaging in some PD each year, with about **66%** of PD occurring within their school district.
- However, only **39%** of in-district PD activities had a focus on ***both science content and pedagogy*** (e.g., science curriculum development work).

Out-of-District PD Activities

50% of teachers reported attending PD outside of their district, which included a variety of PD types:

- **6.8%** took a course at a college/university
- **11% took a workshop at an Educational Service Unit (ESU)**
- **3.4%** engaged in a research experience for teachers
- **4.1% attended an NSTA workshop**
- **2.7%** did an AP/IB science course training
- **14.4% other type of PD (e.g., online course, science-related technology training)**
- **7.5%** engaged in more than one type of PD
- **Only about 11% of teachers attended science teacher conferences at state, regional, and national levels.**

Note: *For teachers who participated in the survey multiple times, they may not have engaged in out-of-district PD activities every year.*

Implications

- Most of the teachers came from one state that ***did not require*** teacher PD to maintain their teaching credentials.
- While nearly all teachers in the study were engaged in professional development,
  - 66% of teachers had access to PD in their school districts, but ***only 39% of in-district PD had a science content focus.***
- Each year only 50% of the study's teachers sought out-of-district PD, which focused on science content and/or how to teach a particular science subject.
  - This included only a small number of teachers (11%) each year who attended a science teacher conference to acquire new ideas and resources for teaching science.
- Thus, if science education reform is a priority, then it is recommended that teachers ***be required to engage in teacher PD by their states***.

Future Work *(Proposal to be submitted for NARST 2021 conference)*

- We presented an exploratory SEM at the ESERA 2019 conference in Bologna, Italy.
  - We found that having membership in a **high-quality teacher preparation** program (i.e., MAT program) coupled with **ongoing professional development** was important for inquiry-based instruction once teachers had been in classrooms longer.
  - In other words, while both teacher preparation program and ongoing professional development were important, ***they were important differently over time.***
- Our investigation into the relationship between teacher professional development and their degree of inquiry-based teaching will employ the use of confirmatory SEMs and targeted MANOVAs.

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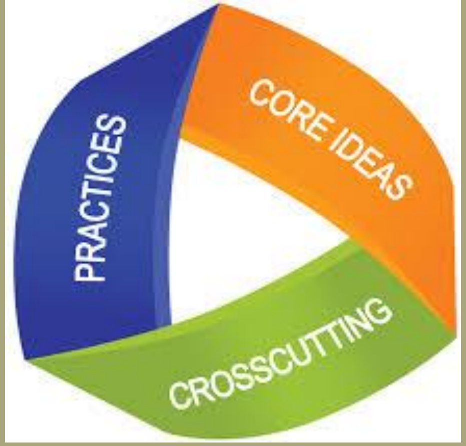
Paper #3: Connections between Teacher and Classroom Variables, and use of NGSS Scientific Practices

Amy Tankersley, Elizabeth Hasseler, Lyrica Lucas, & Elizabeth Lewis

Paper #4: NGSS-aligned Science Lesson Exemplars (Retained)

Elizabeth Hasseler, Elizabeth Lewis, Lyrica Lucas, Amy Tankersley

Background



- In 2017, Nebraska adapted the Next Generation Science Standards which are three dimensional standards that integrate disciplinary core ideas, science and engineering practices, and crosscutting concepts (NGSS Lead States,2013)

- The adoption of NGSS will requires teachers to provide instruction that connects content and process of science in ways that helps students develop deep understanding (Kloser,2014).

- Effective adoption of these new standards will requires teachers to adopt more constructivist ideas and transform from instructor to facilitator (Porcaro, 2011).

Problem

Implementation of NGSS can be problematic because:

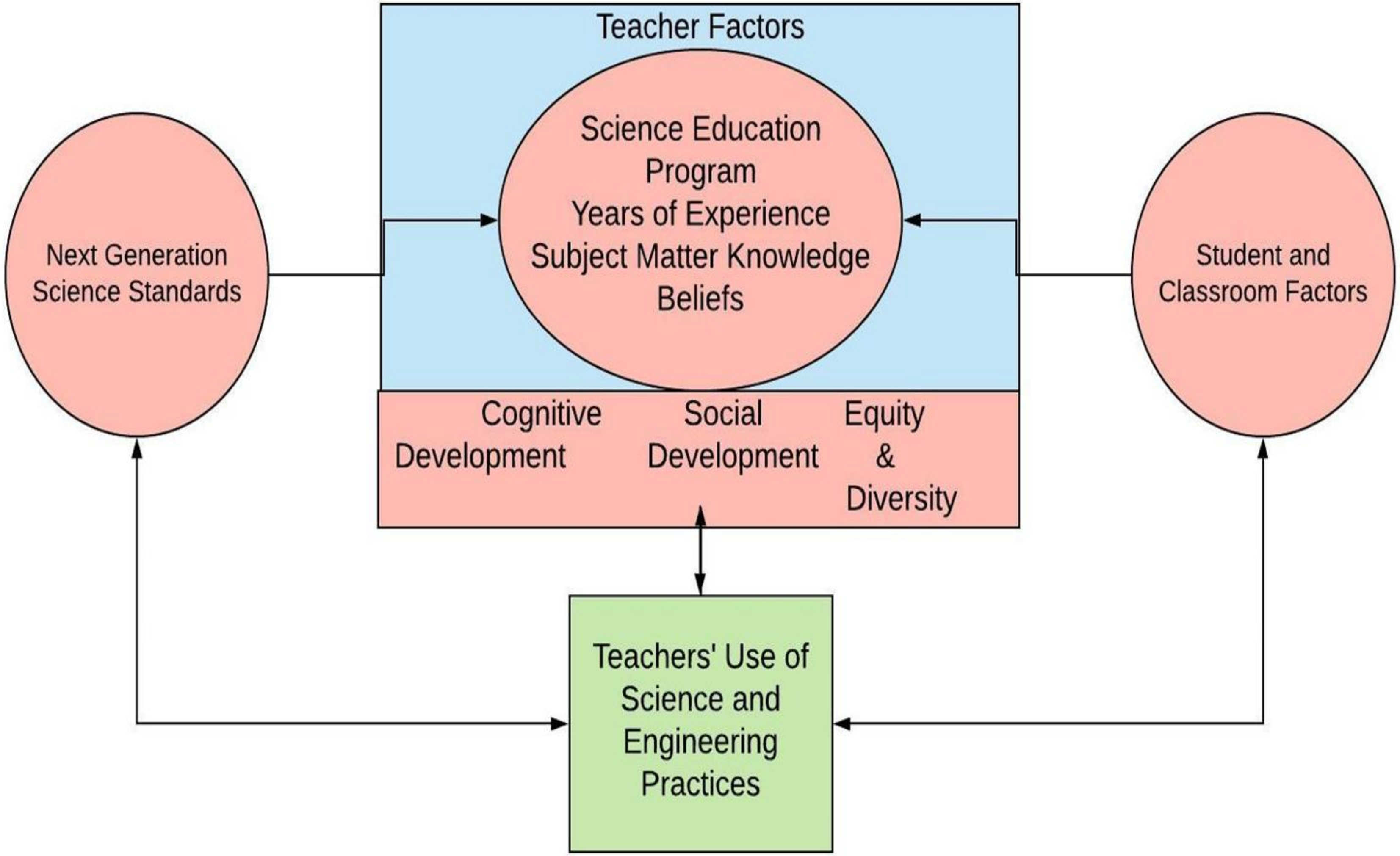
- New teachers still tend to revert to didactic and instructivist pedagogy in their classrooms (Dalgarno &Colgan, 2007).
- There is still confusion about inquiry and the implementation of authentic science experiences in the K-12 classroom (Capps and Crawford, 2013).
- There is some evidence that teachers may be unclear on the scientific practices and their use in the classroom (Carpenter et al.,2015; Sandoval & Kawaski, 2016).
- This lack of clarity and the relative newness of the standards mean that we have little knowledge on how teachers implement three-dimensional standards in science classrooms.

Research Questions

With this study we seek to explore:

1. What influences teachers' use of NGSS Scientific Practices in secondary science classrooms?
2. How do middle and high school teachers integrate inquiry and the NGSS Scientific Practices in various science subjects?

Conceptual Framework



Participants and Data Collection

- We observed teachers **5-6 times** per year (2015-2019).
- For each teacher we collected subject, certification subject(s), %FRL, program, and level.
- After each observations we interviewed each teacher collecting a **4-5 days** of lesson summaries.
- Each lesson summary was coded for teachers' instructional practices including science and engineering practices.
- For each day a "1" was recorded if the teacher engaged students in the practice and a "0" if the practice was not engaged in by the students.

Participants and Data Collection

- For this analysis we used the data from 65 teachers and 792 lessons:
  - 55 Physics Lessons
  - 97 Chemistry Lessons
  - 249 High School Biology Lessons
  - 391 Middle school or 9th grade classrooms

- 70% of teachers taught in-field (24+ credit hours)
- 43% taught in a high need schools
- 66% graduated from our MAT program

Results:
All Subjects

The predictors accounted for **9%** of the variance

$F(6,7789) = 13.028$, $p<0.001$, $R^2 = 0.090$

Significant Predictors:

- Program ($\beta = 0.128$, $p < 0.001$)
- Subject ($\beta = -0.206$, $p < 0.001$)
- Location of class in a high-need school ($\beta = 0.113$, $p = 0.001$)

Non-significant Predictors:

- Level ($\beta = -0.063$, $p = 0.073$)
- In-/Out-of-field ($\beta = -0.033$, $p = 0.328$)

Physics Results

The predictors accounted for **5.2%** of the variance:

$F(4,50) = 0.688$, $p<0.604$, $R^2 = 0.052$

Non-significant Predictors:

- Program ($\beta = 0.157$, $p=0.476$)
- Location of class in a High Needs School ($\beta = 0.129$, $p=0.389$)
- Level ($\beta = -0.092$, $p=0.658$)
- In-/Out of Field ($\beta = -0.053$, $p=0.722$)

Chemistry Results

The predictors accounted for **14%** of variance in teachers the use of SP

$F(4,93) = 3.793$, $p = 0.007$, $R^2 = 0.140$

Significant Predictors:

Program ($\beta = 0.266$, $p = 0.008$)
Location of class in a High Needs School ($\beta = -0.212$, $p = 0.031$)

Non-significant Predictors:

Years of Experience ($\beta = -0.170$, $p = 0.083$)
In-/Out-of-field ($\beta = -0.87$, $p = 0.377$)

Chemistry: Most and Least Commonly Used Practices

Most Commonly Used Scientific Practices	Least Commonly Used Scientific Practices
• Using Mathematical and Computational Models (51.1%) • Analyzing and Interpreting Data (18.8%)	• Argumentation from Evidence (0.5%) • Constructing Explanations (4.1%) • Obtaining, Evaluating and Communicating Information (7.0%)

High School Biology Lessons

The predictors accounted for **5.3%** of the variance in the mean use of SPs

$F(4,245) = 3.49$, $p = 0.010$, $R^2 = 0.053$

Significant Predictors:

- Program ($\beta = 0.171$, $p = 0.016$)
- Years of Experience ($\beta = 0.178$, $p = 0.009$)
- Number of Credit Hours ($\beta = 0.150$, $p = 0.045$)

Nonsignificant Predictors:

- Free and Reduced Lunch ($\beta = 0.035$, $p = 0.590$)

Biology: Most and Least Commonly Used Practices

Most Used Scientific Practices	Least Used Practices
• Analyzing and Interpreting data - (22.5%) • Obtaining, Communicating, and Evaluating Information (17.1%) • Developing and Using Models (13.7%)	• Argumentation from Evidence (2.7%) • Asking Questions (4.0%) • Constructing Explanations (6.7%)

Implications for Science Education

- Our findings relate to prior work on SEPs using a large volume of teacher self-reported lesson summaries, supported with observations, that indicate that teachers are comfortable with some practices more than others, (e.g., French & Burrows, 2018) and therefore plan for, and implement more practices than others (Antink & Brownstein, 2016).
  - In our study, this implementation varied by subject area taught.
- When preparing teachers for using NGSS, teacher educators should attend to content knowledge along with pedagogical knowledge to improve their use of SEPs.
- In terms of curricular reform, there is a need for instruction and teacher professional development on preparing and enacting lessons that allow students to construct explanations, argumentation, and other communication.

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WHERE DISCOVERIES BEGIN

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