Longitudinal studies of teacher development in elementary mathematics and science

Dan Hanley, Western Washington University
Temple Walkowiak, North Carolina State University
Model of Research-based Education (MORE) for Teachers

PIs: Dan Hanley, Matt Miller, Chris Ohana
Research Associates: Joe Brobst, Phil Buly, Susan Kagel, Tammy Tasker

Supported by the National Science Foundation DRK-12 Grant No. 1119678.
Project ATOMS: Accomplished Elementary Teachers of Mathematics & Science

PI: Temple Walkowiak
Co-PIs: Sarah Carrier, Ellen McIntyre, Steve Porter, Margareta Thomson, Jayne Fleener
Senior Researchers: James Minogue, Andrew McEachin, Michael Maher

Supported by the National Science Foundation, DRK-12 Grant No. 1118894
Goals for this Session

Participants will:

• learn about the two projects’ research designs, frameworks, instruments, analyses, and key findings, and

• engage in discussions about elementary teacher preparation in mathematics and science.
What are some important elements of effective math and science teacher preparation programs?
Study 1: Impacts of new science content course for elementary PSTs (SCED 20X: Physics and Everyday Thinking).

- Initial ideas
- Investigations
- Using evidence to make claims
- Sense-making
Study 3: Comparison of a learning-theory and a hands-on activity focus elementary science methods and practicum sequence

**Bellingham**
- Methods course (SCED 480) is a ten week course before internship
- Practicum course (SCED 490) places 2-3 students in B’ham classroom before internship for a quarter
- Learning-theory focus

**TEOP**
- 480 is a ten week course during their internship
- 490 currently during last quarter of internship and taught individually in their internship classroom
- Hands-on activity focus
<table>
<thead>
<tr>
<th>Study 1 Science Course</th>
<th>Treatment Groups</th>
<th>SCED 480 – Elem Sci Methods</th>
<th>SCED 490 – Elem Sci Practicum</th>
<th>Internship</th>
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<tbody>
<tr>
<td></td>
<td>Taken 20X No 20X</td>
<td>Pre-survey</td>
<td>Study 2 (Mentoring)</td>
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<tr>
<td></td>
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<td>Pre/post lesson critique</td>
<td>Post-survey</td>
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<td>Observation</td>
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<tr>
<th>Study 3 Methods/Practicum</th>
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<th>SCED 480 – Elem Sci Methods</th>
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<td></td>
<td>Bellingham TEOP</td>
<td>Pre-survey</td>
<td>Post-survey</td>
<td>Observation</td>
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</table>
• Learning Theory (LT)
  Lessons should elicit students’ initial ideas, have students use evidence to evaluate claims and support conclusions, connect to related concepts, etc.

• Confirmatory Science (CS)
  Students should be told the outcome before an activity, which should serve to reinforce the intended outcome or concept.

• Hands on (HO)
  Students should do hands-on activities even if the activities don’t provide relevant data, have students reflect on what they are learning, or are closely related to the intended science concept being examined.
LESSON CRITIQUE

PSTs rate the quality of a vignette of a 5th grade science lesson

- Hands-on
- High student engagement
- Lack of student learning
Effective Science Instruction: What does research tell us
(Banilower et al., 2010)

- Accurate, developmentally appropriate **Content**,  
- **Initial ideas** about the targeted idea,  
- **Examples/phenomena** about the targeted idea,  
- **Evidence** to draw conclusions and make claims,  
- **Sense-making**: Students make sense of the targeted idea in light of their initial ideas, evidence about the phenomena, and other science ideas that they already know, and  
- **Classroom culture** centered on students’ collegial relationships, sharing of ideas, and taking intellectual risks.
FINDINGS

Study 1
• Do 20X students have more sophisticated beliefs about Effective Science Instruction than non-20X students at the start of the elementary science methods and practicum sequence?

Yes for Confirmatory Science
Somewhat for Hands on

• Does the 20X course “prime” students for learning, such that they have greater increases in the sophistication of their beliefs about Effective Science Instruction over methods/practicum sequence than non-20X students?

No.
## Final estimation of fixed effects (with robust standard errors)

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-ratio</th>
<th>Approx. d.f.</th>
<th>P-value</th>
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<tr>
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**Confirmatory Science**

- **Pre and POST SURVEY**

![Bar chart showing the percentage of participants rated as sophisticated in different categories before and after intervention.](image)
### PRE and POST SURVEY

#### Final estimation of fixed effects (with robust standard errors)

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<thead>
<tr>
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<tbody>
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</table>
• Do 20X students teach higher quality science lessons during their practicum than non-20X students?

Yes.
Linear Regression model, controlling for GPA and mentee status
Significant difference for:
- Initial Ideas, p value= .036, effect size = .28
- Evidence, p value = .011, effect size = .26
• Do PSTs in a science methods/practicum sequence with a Learning-theory focus versus a Hands-on activity focus have *greater gains in the sophistication of their beliefs about Effective Science Instruction*

  No for Confirmatory Science factor.

  Yes for Hands On factor.
Final estimation of fixed effects
(with robust standard errors)

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### PRE and POST SURVEY

**Hands-on**

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</table>
• Do PSTs in a science methods/practicum sequence with a Learning-theory focus versus a Hands-on activity focus have greater gains in their ability to recognize important elements of Effective Science Instruction in a lesson?

Yes.
### Final estimation of fixed effects (with robust standard errors)

<table>
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<tr>
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<th>P-value</th>
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</table>
• Do PSTs in a science methods/practicum sequence with a Learning-theory focus versus a Hands-on activity focus teach higher quality science lessons during their internship?

Trend is Yes, but not statistically significant.
INTERN CLASSROOM OBSERVATIONS

Linear Regression model, controlling for GPA and mentee status
No significant differences
Study 2: Impacts of Mentoring on PSTs
Effective Science Instruction (Banilower et al, 2010)

- Elements of ESI
- Shift from teacher-focused to student-focused
- Data as a Third Point
HOW TO TALK ABOUT IT

Coaching

Consulting

Flexibility in Stance
Mentoring Conversations

Pre=40, Post=45, Delayed=19
Study 2: Impacts of high-quality mentoring

Initial mentoring conversations focused on classroom management from a consulting stance.

Subsequent mentoring conversations focused on student learning from a coaching stance.
Understanding of effective science instruction

Beliefs that mentoring improved their ability to collect observation data
Elementary science practicum students who were mentored (n=73) showed statistically greater gains in their understanding of ESI than their non-mentored peers (n=177). Stat sig at p=.019 using a two-level HLM.
Study 4: Newly inducted elementary science teachers’ beliefs and practices
Conclusions

• Taking a science content course grounded in learning-theory develops elementary PSTs’ beliefs about effective science instruction and their ability to incorporate these beliefs into their initial science teaching.

• Taking a methods/practicum sequence grounded in learning theory develops elementary PSTs’ ability to understand and recognize the difference between hands-on and minds-on science lessons.

• Short mentoring conversations can significantly impact PSTs’ beliefs about effective science instruction if they: 1) Focus on student thinking/learning, and 2) Model important, reflective questions.
Implications

• More intentional about making connections between PSTs’ science content courses and their methods/practicum courses to help develop their identity as a teacher of science, while they are in the role of a learner of science.

• In their science methods/practicum sequence, we want to draw on their experiences as a learner of science from the PET course to help them develop their skills and identity as a teacher of science.

• Develop systems to prepare teachers to mentor PSTs, and to place PSTs with trained mentors.
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Questions or Comments?

This work supported by the National Science Foundation DRK-12 Grant No. 1119678.
Project ATOMS: Accomplished Elementary Teachers Of Mathematics and Science

Temple A. Walkowiak

CADRE NSF DRK-12 PI Meeting
Washington, DC
June 2, 2016
Goals

- Outline briefly the features of NC State University’s STEM-focused elementary teacher preparation program
- Describe the research project → questions, design, measures, findings, and implications
Contact Info & Acknowledgements: NC State Elementary Program

- Paola Sztajn, Professor and Department Head
- James Minogue, Director of Undergraduate Programs
- Ann Harrington, Program Coordinator
- Sarah Carrier, Valerie Faulkner, Joanna Koch, Beth Sondel, Jill Grifenhagen, Angela Wiseman, Laura Bottomley
- Temple Walkowiak, Assistant Professor
tawalkow@ncsu.edu
Contact Info & Acknowledgements: Research Project

- **Temple Walkowiak**, Principal Investigator
  temple_walkowiak@ncsu.edu
- Co-PIs: Ellen McIntyre, **Sarah Carrier**, Steve Porter, Jayne Fleener, Margareta Pop Thomson
- Senior Researchers: **James Minogue**, Andrew McEachin, Michael Maher
- GRAs (current and former): Beth Adams, Carrie Lee, Ashley Whitehead, Daniell DiFrancesca
- Project Manager: Rebecca Lowe
- Study Coordinator: Terri Frasca

This work is funded by the National Science Foundation under Award #1118894. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of NSF.
Program Features

• Approximately 50-60 graduates per year

• Two years of general studies courses followed by two years of program courses and field experiences (professional studies)

• Approximately 833 contact hours in K-5 field placements (approximately 15 partner schools)

• Cross-cutting course components → 7 Essential Teaching Practices & Routines (e.g., attend to equity, align tasks with learning goals)
Program Features: General Studies (Freshman and Sophomore Years)

- A minimum of 27 credit hours (9 courses) of STEM content
  - 4 mathematics content courses that includes Calculus for Elementary Teachers (two-semester, 6-credit course)
  - 4 science content courses that includes Conceptual Physics for Elementary Teachers
  - 1 engineering design course (e.g., Design Thinking, Materials in Engineering)
- Four education/child-focused courses
  - Intro to Education
  - Child Development
  - Educational Psychology
  - Intro to Elementary Education (15 hours in K-5 classroom)
Program Features: Professional Studies  
(Junior Year)

<table>
<thead>
<tr>
<th>Fall Semester</th>
<th>Spring Semester</th>
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<tbody>
<tr>
<td>Mathematics Methods (K-2)</td>
<td>Mathematics Methods (3-5)</td>
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<td>Science Methods (K-2)</td>
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<td>Reading Methods (K-2)</td>
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<td>Classroom Management Seminar</td>
<td>Diversity Seminar</td>
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<tr>
<td>Field Placement in K-2 classroom</td>
<td>Field Placement in 3-5 classroom</td>
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<td>(86 contact hours → 3 hours per week</td>
<td>(86 contact hours → 3 hours per week</td>
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<td>plus two full-time weeks)</td>
<td>plus two full-time weeks)</td>
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# Program Features: Professional Studies (Senior Year)

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<td>Language Arts Methods</td>
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<td>Social Studies Methods</td>
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<td>Instructional Design Seminar (K-5)</td>
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Yearlong Field Placement in K-5 classroom

FALL: 121 contact hours → 3 hours per week plus three full-time weeks  
SPRING: Student Teaching = 525 contact hours
Project ATOMS

Project ATOMS: Accomplished Elementary Teachers Of Mathematics and Science

5-year grant project funded by NSF
Knowledge: Content Knowledge; Pedagogical Content Knowledge

Beliefs: Efficacy; Epistemological

Teaching Practices: Standards-Based

Student Outcomes

Project ATOMS
Research Questions

• DEVELOPMENTAL study component:
  – How do pre-service teachers develop in the dimensions of mathematics and science content knowledge, pedagogical content knowledge, teaching practices, and beliefs (i.e., self-efficacy and epistemological) through the ATOMS program and into their first two years of teaching?

• COMPARATIVE study component:
  – How do ATOMS teachers compare to non-ATOMS teachers on knowledge, beliefs, and instructional practices after one and two years of teaching?
  – After matching on demographic and school characteristics, how does student achievement in classrooms served by ATOMS beginning teachers compare to student achievement in classrooms served by other beginning teachers?
Research Questions

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  – How do pre-service teachers develop in the dimensions of mathematics and science content knowledge, pedagogical content knowledge, teaching practices, and beliefs (i.e., self-efficacy and epistemological) through the ATOMS program and into their first two years of teaching?

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  – After matching on demographic and school characteristics, how does student achievement in classrooms served by ATOMS beginning teachers compare to student achievement in classrooms served by other beginning teachers?
## Design:
Developmental Study Component

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<th>Study Year 3</th>
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<tr>
<td>F-Cohort</td>
<td>Freshman</td>
<td>Sophomore</td>
<td>Junior</td>
<td>Senior</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Year</td>
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<td></td>
<td>n=56</td>
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</tbody>
</table>

**Total n = 227**

**Yellow → 19 Case Studies**
Measures & Data Collection: Developmental Component

- **Knowledge**
  - DTAMS $\rightarrow$ Whole Numbers, Rational Numbers, Life Sciences, Physical Sciences (CRiMSTeD, 2008)
  - LMT-MKT $\rightarrow$ Number and Operations (LMT, 2004)

- **Beliefs**
  - MECS $\rightarrow$ Mathematics Experiences and Conceptions (Jong, Hodges, & Welder, 2012)
  - MTEBI $\rightarrow$ Efficacy (Enochs, Smith, & Huinker, 2000)
  - TBEST $\rightarrow$ Effective Science Instruction (Horizon Research, 2014)

- **Case Studies**
  - 22 Interviews and 12 video-recorded lessons
    - Junior Year: 7 interviews (4 focused on lessons/course projects)
    - Senior Year: 6 interviews (3 focused on implemented lessons)
    - First Year of Teaching: 9 interviews (6 focused on implemented lessons)
Theoretical Underpinnings: Knowledge, Mathematics

(Ball, Thames, & Phelps, 2008)
Findings, Developmental Study: Knowledge, Mathematics

Content Knowledge
(measured as percent by DTAMS, Knowledge Types I, II, III)

Pedagogical Content Knowledge
(measured as percent by DTAMS, Knowledge Type IV)
Findings, Developmental Study: Knowledge, Mathematics

Specialized Content Knowledge
(measured by LMT-MKT as IRT score)
Findings, Developmental Study:
Attitudes & Confidence, Mathematics (MECS)

Attitudes & Confidence
(MECS, Rasch scores)

![Graph showing changes in attitudes and confidence over time.]

- Pre-methods
- Post-methods
- Post-program
- Post-year 1

**Legend:**
- Blue line: Attitudes
- Red line: Confidence
Findings, Developmental Study: Knowledge, Science

DTAMS, Life Sciences (percent of total points on scale)

DTAMS, Physical Sciences (percent of total points on scale)
Findings, Developmental Study: Beliefs about Effective Science Instruction (TBEST)

Learning-theory aligned instruction
(Raw score, max = 66)

Confirmatory science instruction
(Raw score, max = 42)

Hands-on over all else
(Raw score, max = 18)
Findings, Developmental Study: Visions of Mathematics Instruction
(Walkowiak, Lee, & Whitehead, in process)

- Visions of Instruction (Munter, 2014; Hammerness, 2001)

- 18 participants
  - Describe effective elementary math lesson.
  - What should the teacher be doing during math instruction?
    What should the students be doing?

- VHQMFI Rubric (Visions of High-Quality Mathematics Instruction; Munter, 2014)

- Pre-Methods (PRE-M), Post-Methods (POST-M), and End of Program (EOP)

- 12 of 18 participants’ visions shifted to be more standards-based, but 14 participants remained same or declined in vision from POST-M to EOP.
Findings, Developmental Study: Identities as Teachers of Science
(Carrier, Whitehead, Walkowiak, Luginbuhl, & Thomson, under review)

• In-depth examination of three purposefully selected cases (based upon past experiences in science)

• Teacher preparation program influenced their identities as teachers of science.

• However, past experiences and school contextual factors played a key role in the development of their identities and how they implemented what they had learned in teacher preparation program.
Research Questions

• DEVELOPMENTAL study component:
  – How do pre-service teachers develop in the dimensions of mathematics and science content knowledge, pedagogical content knowledge, teaching practices, and beliefs (i.e., self-efficacy and epistemological) through the ATOMS program and into their first two years of teaching?

• COMPARATIVE study component:
  – How do ATOMS teachers compare to non-ATOMS teachers on knowledge, beliefs, and instructional practices after one and two years of teaching?
  – After matching on demographic and school characteristics, how does student achievement in classrooms served by ATOMS beginning teachers compare to student achievement in classrooms served by other beginning teachers?
## Design:
### Comparative Study Component

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Study Year 1</th>
<th>Study Year 2</th>
<th>Study Year 3</th>
<th>Study Year 4</th>
<th>Study Year 5</th>
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<tr>
<td>G-Cohort</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Year</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; Year</td>
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<td>J-Cohort n=56</td>
<td>Junior</td>
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<td>1&lt;sup&gt;st&lt;/sup&gt; Year</td>
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<td>P-Cohort n=56</td>
<td>Sophomore</td>
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<td>Junior</td>
<td>Senior</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Year</td>
</tr>
</tbody>
</table>
Measures & Data Collection:

- **Knowledge**
  - LMT-MKT → Number and Operations (LMT, 2004)
  - AIM → Ecosystems; Matter (Horizon Research, 2013)
- **Beliefs**
  - MECS → Mathematics Experiences and Conceptions (Jong, Hodges, & Welder, 2012)
  - MTEBI → Efficacy (Enochs, Smith, & Huinker, 2000)
  - TBEST → Effective Science Instruction (Horizon Research, 2014)
- **Instructional Practices**
  - Instructional Practices Log in Mathematics (IPL-M)
  - Instructional Practices Log in Science (IPL-S)
  - At least three video-recorded mathematics lessons
  - At least three video-recorded science lessons
Findings: Comparative Study Component, Post-1\textsuperscript{st} Year of teaching

<table>
<thead>
<tr>
<th></th>
<th>ATOMS (n = 49) Mean (SE)</th>
<th>Non-ATOMS (n =96) Mean (SE)</th>
<th>t-statistic</th>
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</thead>
<tbody>
<tr>
<td>LMT-MKT</td>
<td>.63 (.12)</td>
<td>.29 (.07)</td>
<td>2.57*</td>
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<tr>
<td>AIM Ecosystems</td>
<td>15.14 (.69)</td>
<td>15.21 (.46)</td>
<td>-.08</td>
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<td>AIM Matter</td>
<td>16.82 (.58)</td>
<td>16.47 (.48)</td>
<td>.66</td>
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<td>Attitudes (MECS)</td>
<td>2.62 (.23)</td>
<td>2.13 (.21)</td>
<td>1.50</td>
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<td>Confidence (MECS)</td>
<td>1.27 (.11)</td>
<td>1.06 (.10)</td>
<td>1.31</td>
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<td>TBEST (LT-aligned)</td>
<td>56.88 (.61)</td>
<td>56.45 (.63)</td>
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<td>TBEST (Confirm Sci)</td>
<td>25.69 (.82)</td>
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<td>TBEST (Hands-on)</td>
<td>9.53 (.40)</td>
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<td>Efficacy – STOE</td>
<td>1.12 (.13)</td>
<td>0.79 (.09)</td>
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</tbody>
</table>

*p < .05

Results are based on two-sample mean comparison t-tests with equal variances. Results were consistent with results of t-tests with unequal variances.
# Measures: IPL-M and IPL-S

<table>
<thead>
<tr>
<th>Scale (IPL-M)</th>
<th>Cronbach’s Alpha</th>
<th>Item Loading Range</th>
<th>Range of ICCs</th>
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</thead>
<tbody>
<tr>
<td>Problem Solving</td>
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<td>.62 - .87</td>
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<td>Connections</td>
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<td>.40 - .84</td>
<td>.20 - .36</td>
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<td>Procedural instruction</td>
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<td>.35 - .82</td>
<td>.20 - .43</td>
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<td>Math Talk</td>
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<td>.60 - .91</td>
<td>.24 - .46</td>
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<tr>
<td>Use of Representations</td>
<td>.802</td>
<td>.61 - .83</td>
<td>.32 - .51</td>
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<table>
<thead>
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<th>Scale (IPL-S)</th>
<th>Cronbach’s Alpha</th>
<th>Item Loading Range</th>
<th>Range of ICCs</th>
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<td>Low-level Sense-making</td>
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<td>.51 - .86</td>
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<td>High-level Sense-making</td>
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<td>.53 - .89</td>
<td>.17 - .28</td>
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<td>Communication</td>
<td>.880</td>
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<td>.16 - .27</td>
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<td>Basic Practices</td>
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<td>Integrated Practices</td>
<td>.925</td>
<td>.63 - .93</td>
<td>.11 - .19</td>
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</table>
Next Steps

COMPARATIVE
• Log Data
  – Compare two groups on scales
  – Instructional Profiles
• Student Outcomes
  – Compare two samples

DEVELOPMENTAL
• General Linear Models – developmental trajectories
• Qualitative Data – case study participants
Implications

• Programmatic Improvement
  – General studies courses → coherence with methods courses in pedagogy, scientific/mathematical practices?
  – Field placements – structure, quality

• Field of Elementary Teacher Education in Mathematics & Science
  – Role of field placements
  – School contextual factors
    • field placements and first jobs
  – Induction/support for novice teachers

• Potential of IPL-M and IPL-S
  – Research tool
  – Professional development tool
Contact Info & Acknowledgements: Research Project

- **Temple Walkowiak**, Principal Investigator
temple_walkowiak@ncsu.edu
- Co-PIs: Ellen McIntyre, **Sarah Carrier**, Steve Porter, Jayne Fleener, Margareta Pop Thomson
- Senior Researchers: **James Minogue**, Andrew McEachin, Michael Maher
- GRAs (current and former): Beth Adams, Carrie Lee, Ashley Whitehead, Daniell DiFrancesca
- Project Manager: Rebecca Lowe
- Study Coordinator: Terri Frasca

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Across-Project Themes

• Math and science content courses that model effective pedagogy and provide opportunities for students to reflect on attributes of the learning environment (the facilitation, the materials, the interactions with peers, etc.) and how those contribute to, or interfere with, their learning.

• Importance of support for novice teachers (preservice and induction years) by classroom teachers who have a shared vision of effective instruction and skills to facilitate mentoring conversations focused on student learning and those elements of effective instruction.

• What is developmentally appropriate knowledge and skills for novice teachers?
In what ways did today’s session reinforce, or make you think differently, about important elements of effective math and science teacher preparation programs?
What are some effective strategies for evaluating the quality and impacts of teacher preparation programs?
Longitudinal studies
of teacher development
in elementary mathematics
and science

Dan Hanley, Western Washington University
Temple Walkowiak, North Carolina State University