

From Research to Meta-Research to Practice - The Development of an Educational Learning Environment Framework for School Algebra

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Literature Review

School algebra plays an important role as the gatekeeper to higher-level mathematics and is critical to the pursuit of a career in the Science, Technology, Engineering, and Mathematics (STEM) fields (O'Shaughnessy, 2015). Thus, it is imperative to understand the teaching and learning of algebra in grades K-12.

Difficulties with school algebra begin when middle-school students are asked to transition from arithmetic to school algebra (Sharpe, 2019), whereupon they must use letters to represent sets of indeterminate quantities (Ely & Adams, 2012). Further difficulties emerge in high school as students are asked to generate equations from word problems and use these equations to solve problems (Kieran, 2007). Researchers have reported that algebraic understanding in elementary schools may help set the stage for later learning (Carragher, Schliemann, & Schwartz, 2008). Rakes and colleagues (2010) demonstrated that implementing empirically-tested algebra teaching approaches can address the difficulties students experience with school algebra. Other research has indicated that greater parental involvement (Fan & Chen, 2001), better school climate (Gietz & McIntosh, 2014), and higher levels of student engagement (Lei, Cui, & Zhou, 2018) are each associated with improved overall academic achievement. **Despite extensive primary studies and a few meta-analyses detailing the effect of each of the four constructs on academic achievement, scholars have not yet fully explored the pattern of findings across research studies and grades, nor have they developed a framework that integrates these constructs.** Without this ELE framework for school algebra, the field is left with a piecemeal picture of how to approach the teaching and learning of school algebra in secondary grades.

The research goal of this project is to conduct meta research (i.e., an integration of meta-analysis and qualitative meta-synthesis). **This is to gain an understanding of the generalizable themes of four constructs of parental involvement, school climate, algebra teaching approach and student engagement on algebra achievement for students in grades K-12.** The proposed meta-research is designed to synthesize the results of educational literature by (1) conducting a separate meta-analysis and qualitative meta-synthesis for each of the four constructs, (2) conducting a meta-synthesis to combine the results from both the meta-analysis and the qualitative meta-synthesis for each of the four constructs, and (3) conducting a research synthesis by analyzing the four meta-syntheses to develop the ELE framework for school algebra.

In addition, **this study will establish a basis for integrating research with education, by enabling the Principal Investigator (PI) to teach, train and mentor undergraduate students, graduate students, and postdoctoral researchers in meta-research.** Also, the project will provide undergraduate and graduate STEM students with experience conducting meta-research within a semester-long research seminar.

Meta-Research

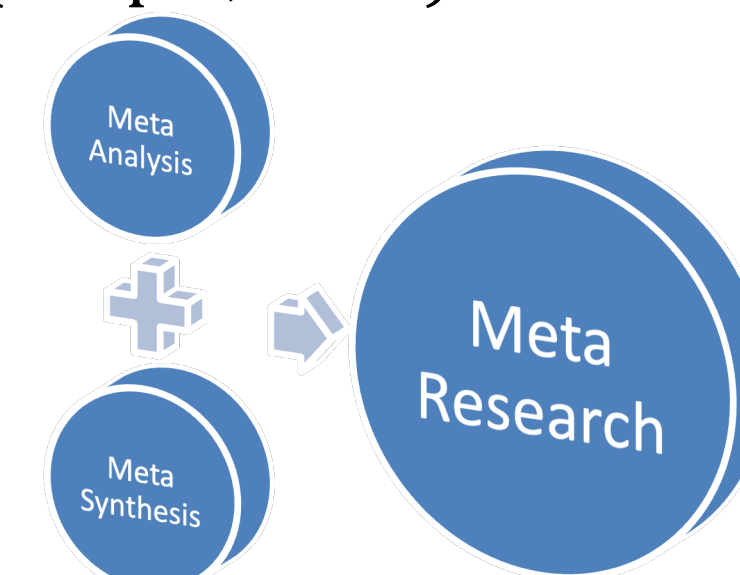
Meta-Research is a mixed methods study that integrates the results of a meta-analysis with the rich qualitative descriptions of a qualitative meta-synthesis to provide data-driven results of what works, for whom, and under what conditions.

A "meta-analysis uses a statistical procedure that aggregates and condenses a body of Quantitative research studies to a common standard metric, such as a mean effect size" (Finlayson & Dixon, 2008; Thunder & Berry, 2016, p.319). A meta-analysis provides a means of statistically combining quantitative data reported throughout a given body of literature to examine results across a significantly greater combined population (Cooper, 2017).

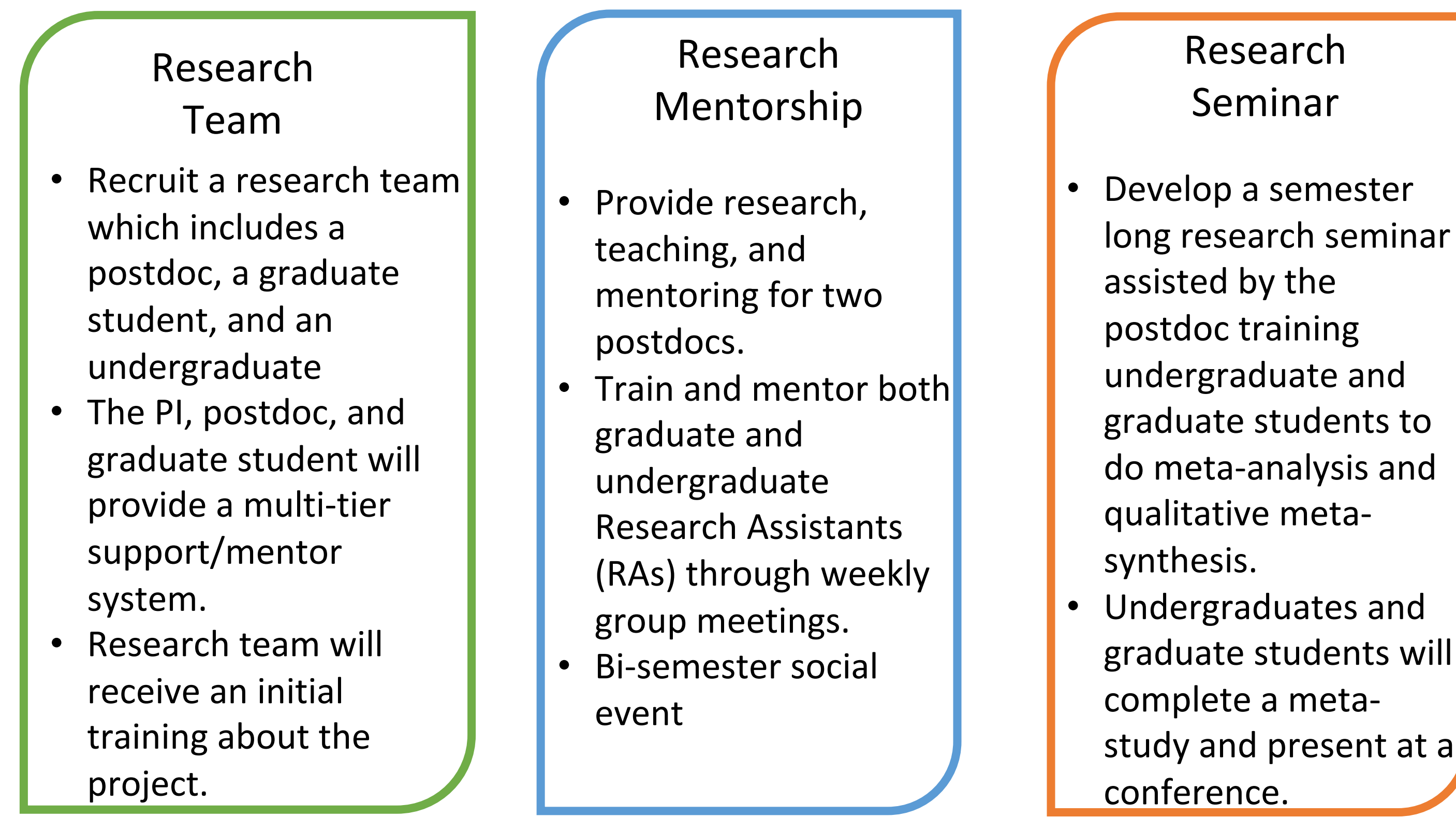
A qualitative meta-synthesis uses a "deliberate process of selecting [qualitative research] studies with an emphasis on synthesizing, analyzing, and interpreting findings across the selected studies" (Thunder & Berry, 2016, p.319). Erwin, Brotherson, and Summers (2011) provides three rationales for conducting a qualitative meta-synthesis in education:

- (1) synthesizing, analyzing, and interpreting a large body of qualitative research on a related topic to identify common themes and provide deeper insights that may not be obvious in a single study.
- (2) It goes beyond what practices/interventions work to help understand how, when, or why a practice could be effective.
- (3) Not only can it make sense of multiple research studies, it can also identify gaps and omissions in the research.

The results of a meta-research study can then be used by researchers and educators alike to develop interventions for students and professional development for teachers.



Multi-Tiered Mentorship



Principal Investigator

- Mentorship of postdoc to enrich future research and collaborations.
- Weekly meetings with RAs discussing research.
- Annual meetings to discuss research goals.

Postdoctoral Researcher

- Use the resources of UNH to develop and promote a personal research agenda.
- Mentor undergraduate and graduate students.

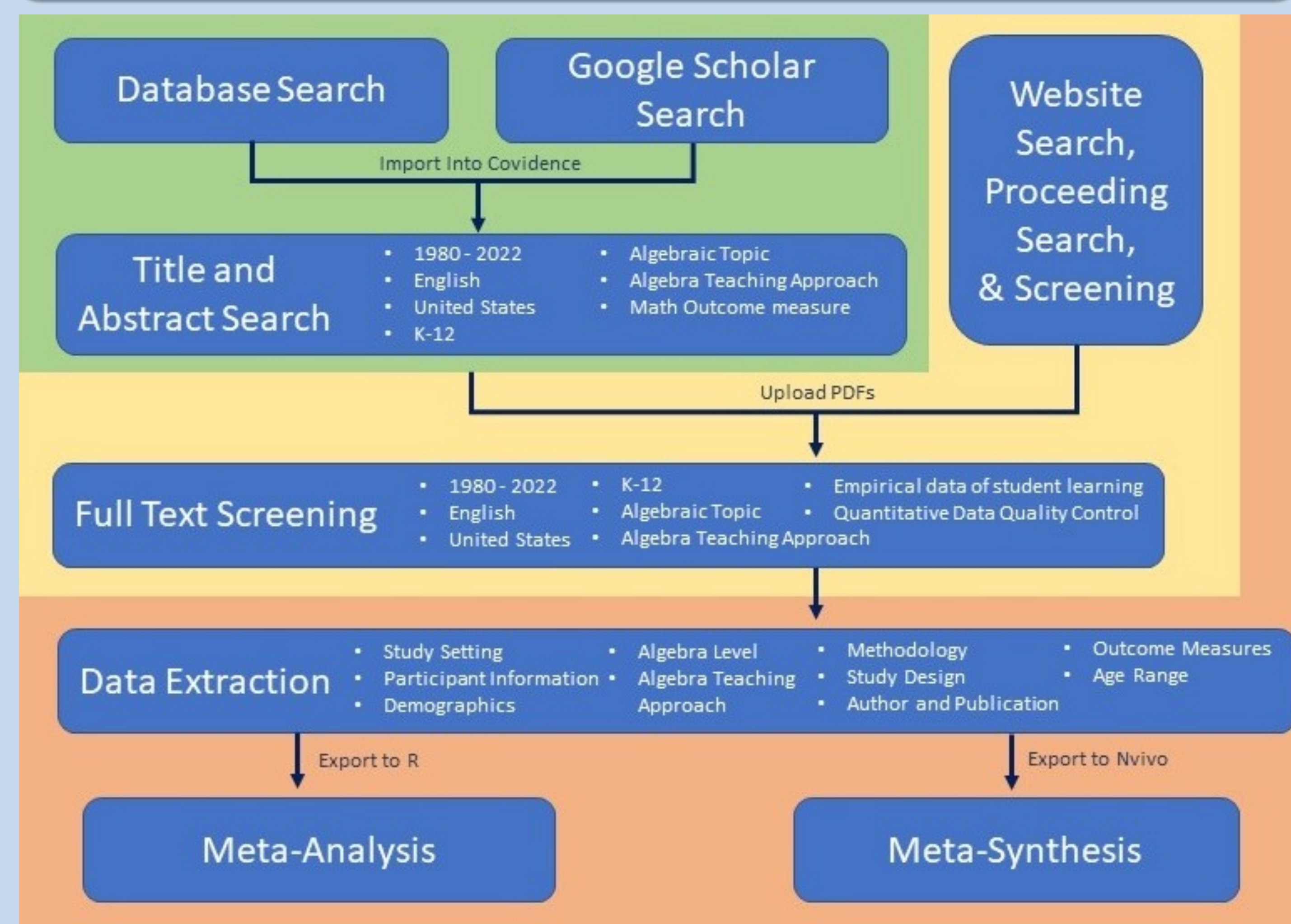
Graduate Researcher

- Assist with meta-research.
- Participate in a meta-research seminar.
- Co-author manuscripts and present at conferences.

Undergraduate

- Assist with literature searches, screening, and data extraction.
- Present at undergraduate research conference

Meta-Research Process



Practice Screening

For the first round of screening, screeners had to answer the following questions with either a yes, maybe, or no. The paper would only move on if the answer was yes.

- Does the study involve algebra or an algebra-related topic (equation, function, variable) or algebraic reasoning (patterns, relations, quantitative relationships, change in various contexts)?
- Does the study involve at least one of the following teaching approach:
 - A strategy or intervention for learning about algebra, functions, or equations?
 - A program or instructional technique for learning about algebra, functions, or equations?
 - A game, technological tool, or curricular materials for learning about algebra, functions, or equations?

PROBLEM SOLVING IN SCHOOL MATHEMATICS BASED ON HEURISTIC STRATEGIES.

Novotná et al. 2014

The paper describes one of the ways of developing pupils' creative approach to problem solving. The described experiment is a part of a longitudinal research focusing on improvement of culture of problem solving by pupils. It deals with solving of problems using the following heuristic strategies: Analogy, Guess -- check -- revise, Systematic experimentation, Problem reformulation, Solution drawing, Way back and Use of graphs of functions. Most attention is paid to the question whether short-term work, in this case only over the period of three months, can result in improvement of pupils' abilities to solve problems whose solving algorithms are easily accessible. It also answers the question which strategies pupils will prefer and with what results. The experiment shows that even short-term work can bear positive results as far as pupils' approach to problem solving is concerned.

During the project, screeners often had problems determining if an intervention was an algebra intervention due to papers like the one above. As a result, an analysis was conducted of the algebra and intervention literature to identify the characteristics of an algebra intervention. The results were synthesized into three questions that could be used for full text screening shown below:

Does the study implement?	Does the study involve?	Does the study address?
<ul style="list-style-type: none"> Instruction Learning Curricula Technology Tutoring Manipulatives Teacher Development 	<ul style="list-style-type: none"> Generalizing Modeling Representing & Symbolizing Justifying Relating Graphing Validating Expressing Solving Graphing Conjecturing Reasoning Solving Noticing 	<ul style="list-style-type: none"> Quantities Generalized Arithmetic Co-variation Expressions or Equations Equality Properties of Number Systems Operations Variable/Change Patterns Graphs/Models Functions

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This material is based upon work supported by the National Science Foundation under grant #2142659. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF.

