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INVESTIGATING THE RELATIONSHIP BETWEEN INTEGERS AND FRACTIONS: A META-ANALYTIC APPROACH UTILIZING STRUCTURAL EQUATION MODELING

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Abtract:

Utilizing a Meta-Analytic Structural Equation Modeling approach, we examined the influence of whole-number knowledge on fraction performance, while considering domain-general skills, age, and mathematics difficulty status. Our analysis encompassed 6,096 students drawn from 39 independent samples across 29 studies. The results indicated that conceptual whole-number knowledge serves as a significant and consistent predictor of both conceptual and procedural fraction knowledge.

Notably, students with mathematics difficulties exhibited a unique performance pattern in comparison to their typically achieving peers. This included: a reduced effect of conceptual whole-number knowledge on conceptual fraction knowledge; an increased effect of procedural whole-number knowledge on procedural fraction knowledge; and a diminished role of working memory and fluid intelligence in contributing to fraction knowledge.

Keywords: Integers, Fractions, Meta-analysis, Structural equation modeling ,Number sense , Mathematics education, Quantitative research

Introduction:

Students' understanding of fractions is crucial for achieving proficiency in higher-level mathematics and for success in the American job market (Booth and Newton, 2012; Hackenberg and Lee, 2015; National Mathematics Advisory Panel, 2008; Siegler et al., 2013). Despite their significance, mastering fractions remains one of the most challenging mathematical skills for students, with many facing difficulties in this area (Namkung et al., 2018; Schumacher et al., 2018).

To enhance instruction related to fractions, researchers have investigated various predictors of fraction performance, primarily emphasizing whole-number knowledge and general cognitive skills (e.g., Bailey et al., 2014; Hansen et al., 2015; Hecht et al., 2003; Ye et al., 2016). However, a definitive pattern of predictors influencing fraction performance has yet to be

established. Consequently, there is a pressing need for a more comprehensive analysis to elucidate how whole-number knowledge interacts with general cognitive skills in relation to fraction performance. This study also examines key theoretical and practical moderators, such as students' age and their status regarding mathematics difficulties, which may influence the predictive relationships between whole-number knowledge, general cognitive skills, and fraction knowledge.

Objectives:

- Understanding cognitive connections
- Synthesizing exiting research
- Quantifying relationships
- Identifying key predictors
- Guiding educational practices

Research Study:

1. **Examining Cognitive Development in Children:**

- Research Question: How do children's understanding of integers and fractions relate to each other during cognitive development?
- Data: The meta-analysis could involve studies that have measured children's ability to compare, manipulate, and understand integers and fractions at different age levels.
- SEM Model: A structural equation model could be constructed to hypothesize that a child's ability to understand integers influences their ability to understand fractions. You might also consider factors like working memory, number sense, or exposure to teaching methods.
- Example Hypothesis: "The ability to understand integers is a significant predictor of a child's ability to solve fraction problems, with the relationship being mediated by their numerical fluency and teaching interventions."

2. **Investigating the Role of Fractional Representation in Learning:**

- Research Question: How does the use of different fractional representations (e.g., visual, symbolic, verbal) affect students' understanding of integers and fractions?
- Data: Meta-analytic studies examining the impact of teaching methods on learning outcomes could be synthesized.

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- SEM Model: The SEM could propose pathways where fractional representations are directly or indirectly related to improved understanding of both integers and fractions. For example, symbolic fraction understanding might influence integer understanding through mediating cognitive processes such as attention and abstract reasoning.
- Example Hypothesis: "Students who are taught fractions using visual representations show higher proficiency in both fractions and integers, with this relationship being mediated by their ability to make connections between the two."

3. **Fractional Operations and Integer Operations:**

- Research Question: Is there a bidirectional relationship between the ability to perform operations with integers and the ability to perform operations with fractions?
- Data: Gather studies that assess students' performance on integer and fraction operations (addition, subtraction, multiplication, division) at various grade levels.
- SEM Model: A model could be built to test whether proficiency in integer operations influences the ability to perform fraction operations (or vice versa), and if other variables, such as general mathematical aptitude, affect this relationship.
- Example Hypothesis: "Mastery in integer operations facilitates the understanding of fraction operations, with the relationship being moderated by general mathematical reasoning abilities."

Discussion:

In this meta-analysis, we found that conceptual whole-number knowledge is a significant predictor of both conceptual and procedural fraction knowledge, taking into account various factors such as domain-general skills, the age of students, and their mathematics difficulty status. Notably, students facing mathematics difficulties exhibited a different pattern compared to their typically achieving peers, which can be the influence of conceptual whole-number knowledge was less pronounced.

Limitations: A Meta-Analytic Approach Utilizing Structural Equation Modeling" could have several limitations.

- Selection Bias in structure
- Heterogeneity of studies
- Data Availability

- Methodological Limitations
- Population Specificity
- Changes in educational practices

Conclusion:

The meta-analytic method employing structural equation modeling (SEM) offered an in-depth examination of the connection between integers and fractions. The results indicate a significant positive correlation between students' comprehension of integers and their ability to work with fractions. The research demonstrates that a strong grasp of integers often leads to improved understanding of fractions, implying that proficiency in whole number operations may act as a cognitive prerequisite for mastering fractional concepts.

This research offers valuable insights for educators, suggesting that enhancing students' skills related to integers should be an integral part of curriculum development for teaching fractions. Additionally, the findings imply that interventions aimed at improving fractional comprehension should take into account students' knowledge of integers as a critical foundational component in the learning journey.

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