Cognitive Skills and Mathematics Problem-Solving Performance

The purpose of this presentation is to engage teacher educators and pre-service/in-service elementary and middle-school teachers in reflecting on effective instructional and assessment strategies in mathematics and mathematics education. The types of mathematical activities that are provided to students, the inherent value in tapping into students’ cognitive strengths while improving their problem-solving performance on items that are not necessarily geared towards their strengths, the value of allowing students multiple formats for expressing conceptual understanding, and potential implications for designing appropriate assessment instruments will be discussed, as well as implications for effective differentiation of instruction and assessment.

The findings of a study that looked at relationships between students’ cognitive skills and their mathematics problem-solving performance will be presented and discussed. The purpose of this study was to examine the existence and strength of relationships between students’ cognitive skills and mathematical problem-solving performance. Specifically, relationships between students’ verbal, spatial, and analytical skills and their problem-solving performance on items that require a verbal response, items that require a spatial response, and overall problem-solving performance were investigated. The following questions were addressed by the study:

1. To what extent are students’ cognitive skills (i.e., their spatial, verbal, and analytical skills) related to their problem-solving performance on items that specifically require a verbal response, and on those that specifically require a spatial response?
2. To what extent are students’ cognitive skills related to each other?
3. What are the potential implications for teaching practice and teacher education?

According to Lesh and Zawojewski (2006), mathematics is learned through problem solving, and mathematical ideas develop along with problem-solving capabilities during the problem-solving process. Further, the importance of problem solving to conceptual development in mathematics and the building of strong mathematical connections is also emphasized in The National Council for Teachers of Mathematics’ (NCTM) Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989) and Principles and Standards for School Mathematics (NCTM, 2000). Researchers indicate that there is an interaction between students’ spatial skills and their production and use of drawings to solve mathematical word problems (Landau, 1984; Campbell, Collis & Watson, 1995), and between students’ verbal skills and their mathematical problem-solving performance (Battista, 1990; Fennema & Tartre, 1985). Specifically, spatial skills have been associated with higher level problem-solving performance (Landau, 1984; Tartre, 1990), and activities that require the use of verbal skills have been associated with higher cognitive functions such as critical thinking, sound reasoning, and problem solving (Albert, 2000; Jurdak & Abu Zein, 1998; Vygotsky, trans. 1962; 1978). Vygotsky’s (trans. 1962; 1978) discussions on language and its importance in problem solving indicate that students possess and use both spatial and verbal skills at varying levels based on their language development, and that both types of skills are important to the problem-solving process. While Vygotsky’s ideas are not specific to problem solving in mathematics, they are consistent with the findings reported by the aforementioned research in mathematical problem solving. A review of the literature also revealed assumptions of close links between verbal and logical/analytical skills, resulting in a lack of assessment of these skills as separate constructs. This study therefore sought to measure
each of the cognitive skills separately in order to clearly establish the existence and strength of any pair-wise relationships among the cognitive skills.

Ninety-eight students from the fifth- through eighth-grades were administered assessments of verbal skills, spatial skills, and logical/analytical skills, as well as a problem-solving instrument that consisted of a verbal (PST-Verbal) subtest and a spatial (PST-Spatial) subtest. Students’ scores on the problem-solving instrument and each of the assessments were analyzed using multiple regression analysis, and the results indicated statistically significant relationships between students’ cognitive skills and problem-solving performance on the PST-Verbal subtest, the PST-Spatial subtest, and overall problem-solving performance. Surprisingly stronger relationships were found, however, between spatial skills and PST-Verbal performance than between verbal skills and PST-Verbal performance, and stronger relationships were found between verbal skills and PST-Spatial performance than between spatial skills and PST-Spatial performance. Statistically significant pair-wise relationships were also found among the cognitive skills, with the strongest pair-wise relationship existing between verbal and analytical skills. The relationship between verbal and spatial skills, although not as strong as the one that exists between verbal and analytical skills, was also quite strong.

The findings described above have the potential to inform teacher educators and pre-/in-service teachers on the value of an understanding of the existing relationships between cognitive skills and problem-solving performance, and among the cognitive skills, to the design of instruction and assessments that are relevant and meaningful for the individual student. Effective differentiated instruction requires a clear understanding of where the student is (via assessment), and the use of assessment-driven data to design instruction that helps the student achieve an established learning goal requires an understanding of these relationships. According to Sternberg & Zhang (2001), cognitive styles affect how individuals process information, as well as their preferred mode of representation which, in turn, is likely to affect the types of tasks that they find difficult or easy. They note, however, that while individuals with stronger spatial skills generally learn best from pictorial presentations, and those with stronger verbal skills learn best from verbal presentations, regardless of cognitive style, individuals can use either mode of representation if they make a conscious choice. They believe that the educational focus should not necessarily be on who has/does not have a particular ability, but on how to capitalize on individual strengths, and how to develop learning potential.

Clearly, there are many complexities that exist within this area that have potential implications for appropriate and effective pedagogical decision making, as well as implications for collaboration among students and their teachers and peers.