Engineering Pedagogical Consideration for Gifted Spatial Learners and Non-spatial Learners

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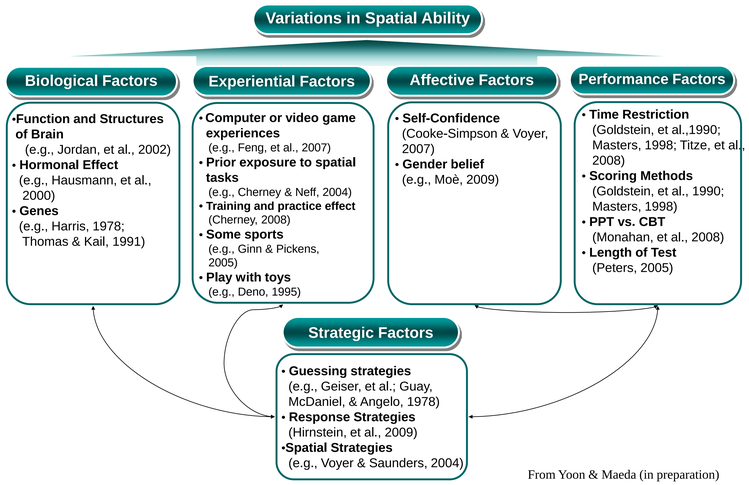
Objective

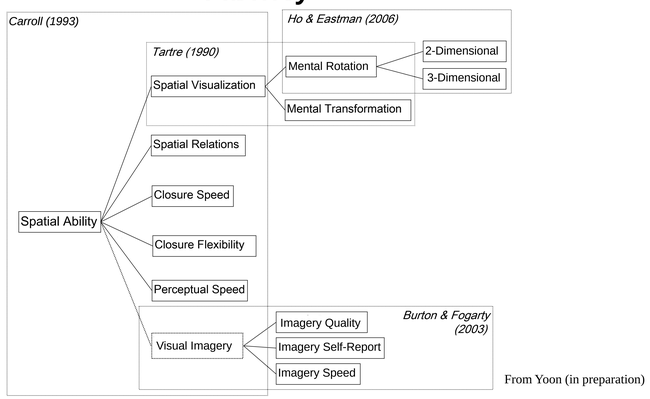
- Give an overview of research on spatial ability in engineering
- Explore characteristics of spatial ability including its sub-factors
- Discuss what educators need to know to embrace all levels of spatial and non-spatial gifted learners while engaging students in engineering activities
- Provide strategies to assist educators in offering engineering design experience.

Research on Spatial Ability



From Yoon & Maeda (in preparation)

Hypothetical Factor Structure Model of Spatial Ability



From Yoon (in preparation)

Spatial Ability as a Nurtured Trait: The Effect of Prior Experiences and Practice

- Experimental studies revealed a growing body of evidence programs or activities can improve students' spatial abilities.
- The training effect occurred across all education levels of students: elementary (e.g., Ben-Chaim, Lappan, & Hougang, 1988), middle (e.g., Ben-Chaim, Lappan, & Hougang, 1988; Noyes, 1997), high school (e.g., Blasko, Holiday-Darr, & Kremer, 2009; Clark & Ernst, 2008; Eraso, 2007), and college students (e.g., Sorby, 2001).
- The effect of spatial intervention was similar in both male and female students or even more effective for female students (e.g. Sorby 2001), and/or low spatial ability students (e.g., Sorby, 2007).

The Role of Spatial Ability in Engineering

- Engineering functions as a linking subject that can make connections with other subjects while engaging students in design activities.
- Engineering is a spatial subject that enables students who have spatial strength to reveal their talent and students who have spatial weakness to nurture spatial aptitude.
- Engineering frequently involves a high volume of spatial tasks (Hsi, Linn, & Bell, 1997).
- Spatial thinking necessarily occurs either latently or overtly during engineering activities.
- In addition to subject knowledge, spatial ability has been considered one crucial dimension of successful performance in engineering (Contero, Naya, Company, Saorin, & Conesa, 2005; Field, 2007).

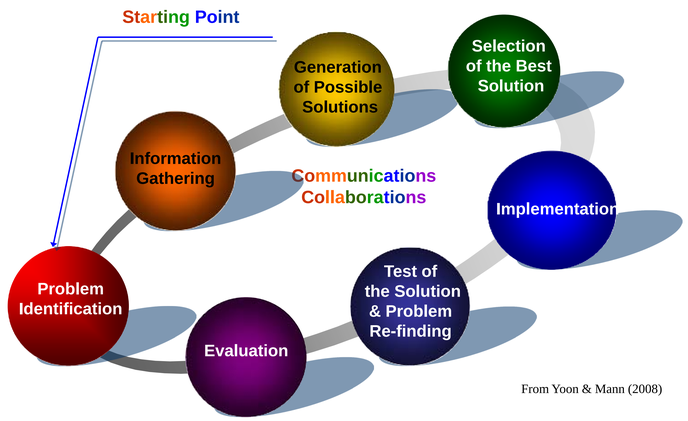
Engineering: An Attractive College Major for Gifted Students

- Among 196 choices of college majors, engineering was the top preference selected by 32.0% of the 99th percentile group and 21.6% of the 95th percentile group based on ACT composite scores (Kerr & Colangelo, 1988).
- Engineering was the top preferred degree acquired by male participants who responded to a 20 year follow-up study of the Study of Mathematically Precocious Youth (SMPY) (Lubinski and Benbow, 2006).

Current Status of Engineering Education in K-12

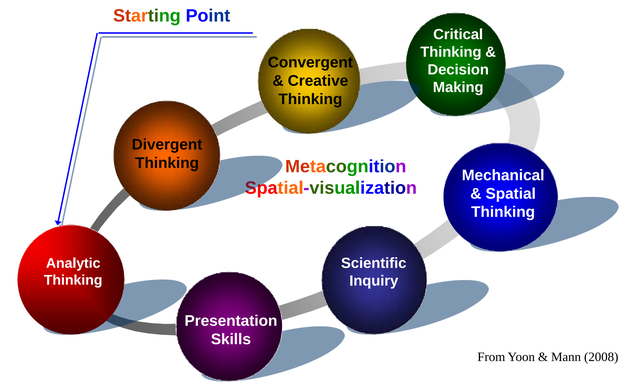
- The current K-12 curriculum was set up in 1892 to focus on the understanding of the natural phenomena and has not been changed to address human activities, i.e. engineering & technology (Miaoulis, 2005).
- As the United States has faced a shrinking engineering work force, the importance of K-12 engineering education has recently been emphasized (Houston, 2006; Katehi, Pearson, & Feder, 2009; Miaoulis, 2005).
- Today's curricula do not include enough opportunities to develop spatial ability (Webb, Lubinski, & Benbow, 2007). Engineering is an area full of spatial tasks, so engineering provides students with opportunities to reveal and nurture their spatial ability.
- Current schools' environments undermine spatially gifted students' potential to excel (Mann, 2005) as well as withhold opportunities to develop spatial ability from non-spatially gifted students.

Engineering Design



From Yoon & Mann (2008)

Engineering Design Thinking Process



From Yoon & Mann (2008)

Guidelines and Strategies for Offering Engineering Design Activities

- Commit some of your time to learning engineering concepts and activities.
- Increase the amount of time your students are engaged in spatial activities
- Integrate graphics to other subjects such as mathematics, science, and technology as well as engineering (Clark & Scales, 2006).
- Promote language that describes shapes and functions of objects, so students can articulate their tacit knowledge (Solobmon & Hall, 1996).
- Include more visual presentation of information; spatial cognition is activated by "the process of continuous spatial transformations" (Solomon, 1979).
- Provide opportunities to communicate processes or findings using graphics, symbols, drawings, image analysis, and simulation (Ernst & Clark, 2007).
- Drawing for engineering design is different from drawing in art. Rogers (1998) found that students frequently confused the design task with drawing pictures. Thus, encouragement of using graphicacy to reformulate students' ideas and images is recommended.
- Provide training and practice opportunities to raise/reinforce spatial ability. Brief instruction about a spatial strategy to solve spatial tasks was roughly equivalent to three years of natural development of the same ability (Rovet, 1983).
- Be aware that students who are usually good at school tasks, which tend to verbal, may struggle with spatial tasks, and vice versa, students who are usually poor at traditional tasks may excel on spatial tasks (Ishikawa & Kastens, 2005).
- Be sensitive to the possibility that female students in your class may need more practice or instruction on spatially demanding tasks. Researchers found that male students outperform female students on spatial performance in general (Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995).

Conclusion

Although engineering has been one of the most attractive majors for gifted students at the college level, there is a critical need for students to enter this field. Corresponding to the significant roles of spatial ability in engineering education, the present article reviewed literature on spatial ability of gifted students, and research results on spatial ability. Furthermore, by understanding distinct characteristics of spatial and non-spatial learners, we suggested several guidelines to promote educators' understanding of spatially diverse students' engineering learning in class. Visual and technical communication abilities are necessary and imperative for most jobs at present, and even more so for the future. A concentration on visual literacy situated in engineering activities will benefit all gifted students, whether or not they will choose engineering for future career.