Journal of Education and Learning; Vol. 4, No. 1; 2015
ISSN 1927-5250 E-ISSN 1927-5269
Published by Canadian Center of Science and Education

Discovering *Space* in the Elementary Classroom

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Received: July 22, 2014 Accepted: January 27, 2015 Online Published: February 19, 2015

doi:10.5539/jel.v4n1p35 URL: http://dx.doi.org/10.5539/jel.v4n1p35

Abstract

Recent studies have shown that strengths in spatial skills are a key to success in STEM (science, technology, engineering, and mathematics) careers. However, these skills are undervalued in our educational system and thus seldom incorporated in classroom teaching. As a first step towards changing the current practices, we worked with a group of elementary school teachers who participated in an in-service workshop on spatial thinking and problem solving. The workshop emphasized the meaning, importance, and malleable nature of spatial skills and introduced a simple spatial activity, QuickDraw, that could be implemented during group instruction time. Those teachers who implemented this activity over the course of the school year reported various benefits of practicing spatial skills. Implications for preparing students for STEM careers are discussed. (Contains 2 figures.)

Keywords: spatial ability, spatial thinking, STEM, teacher in-service

1. Discovering Space in the Elementary Classroom

The study of spatial ability in applied educational contexts is well under way given the need to identify and nurture young people’s spatial sense. This includes those individuals who hold promise for advancing disciplines that allow the US to maintain a competitive edge in a technically driven, global economy (Wai, Lubinski, & Benbow, 2009). However, the significance and practicality of spatial ability as a fundamental component of classroom practice still remains in question amongst educators and administrators of all grade levels, particularly in early education (Clements & Sarama, 2011).

Spatial ability, more broadly construed as the ability to create and manipulate mental images, has long been relegated to a secondary status relative to verbal and quantitative abilities (Mann, 2005). However, children’s awareness of their spatial skills as well as their ability to apply these skills in problem-solving situations are less likely to develop in meaningful and useful ways in traditional classroom settings. Moreover, children who can be considered “visual-spatial learners” are at an even greater disadvantage. Their special strengths (e.g., reading maps and building models) tend to be poorly valued and are likely to go unrecognized in our educational system (Clements & Sarama, 2011; Mann, 2001) despite the considerable need for future high school and college graduates to pursue careers in STEM (the well-cited acronym standing for science, technology, engineering and mathematics fields). Progress and performance in various STEM careers seem to be strongly tied to spatial ability (Newcombe & Frick, 2010; Wai et al., 2009). According to Benbow (2012), future STEM innovators who possess a talent for mathematical and spatial thinking can be identified early, and educational interventions can enhance the likelihood of success in careers in STEM. Therefore, its development should ideally begin as early as the elementary years. However, questions continue to emerge as to how spatial thinking may be best infused across curricula, and what kinds of teaching support spatial learning (Newcombe, 2010). To help better prepare students for STEM careers, it is necessary then to weigh the benefits of incorporating spatial ability instruction (Sundberg & Goodman, 2005) as part of the core requirements for teacher education (National Science Board, 2010). Geometry is one example where there is a need for substantial professional development in how to integrate content knowledge with spatial thinking (Clements & Sarama, 2011).

Both students and teachers should understand the meaning of spatial ability and how types of spatial skills can be effective problem-solving tools. A good deal of literature currently exists that describes creative approaches and/or activities to develop spatial thinking (Newcombe, 2010), particularly in the mathematics classroom (Bobis, 2008; Cross, Adefope, Lee, & Perez, 2012; Graf, 2010). However, questions remain if and to what extent meaningful connections between spatial abilities and problem solving are part of the learning experience. This area of inquiry is what drew us to develop an in-service for mathematics teachers to think and learn about space.

2. A Teacher In-Service on Spatial Ability

The overall purpose of the in-service was to advance teachers' knowledge of the meaning and efficacy of spatial ability, and how it can help their students become better problem solvers in mathematics and related disciplines. At the same time, we set out to focus on why thinking spatially is being increasingly recognized. Keeping in mind that the majority of participating teachers likely had minimal experiences in developing spatial ability as part of their K-12 and college curricula, we incorporated meaningful spatial tasks that assessed their degree of strength in this area. The following key ideas also provided a framework for the participants to openly share related experiences with spatial ability and teaching mathematics:

▪ Incorporating spatial ability instruction can help reduce an overemphasis on learning and using rules that tend to make little sense to students (Wheatley, 1997).

▪ Engaging students in spatial activities can facilitate mathematical discourse and in turn, enhance mathematical learning (Sundberg & Goodman, 2005).

▪ Instructional strategies that incorporate spatial thinking can encourage reflective abstraction, which can result in greater mathematics achievement (Wheatley, 1992).

The in-service was conducted at a private school in southern California at the beginning of the academic year. Nineteen K-6 elementary school teachers participated. Within the introduction, teachers were asked to complete two truncated standardized tests (mental rotation and paper folding) that assess types of spatial abilities. Most participants found the activity to be quite beneficial realizing their limited knowledge of spatial ability, as well as how types of spatial skills differentially influence problem-solving performance. As a result of their testing experience, teachers seemed far more comfortable to openly engage about their experiences with spatial ability in classroom practice.

Along with our open discussion, teachers were asked to complete a brief three-item questionnaire (see items/common responses below) that largely gauged their knowledge and practice of spatial ability activities in the classroom.

1) To date, briefly describe your experiences with nurturing the development of spatial ability in classroom practice.

- Building 3D figures and shapes
- Tangrams (puzzles)
- Pattern blocks
- Limited to text (geometry chapter)

2) In what ways, if any, do you see spatial ability as playing a role in teaching children to become better problem solvers?

- Building children's awareness that there is more than one way to solve a problem

3) How do you see your students benefiting from incorporating the use of spatial ability in classroom activities?

- Becoming better problem solvers in general
- Learning to think "outside the box"

Though most teachers responded to all three items, some did not, which implied little awareness and experience with spatial ability prior to the in-service. Moreover, it seemed that other teachers did not really consider in both past and present mathematics curricula just how spatial ability contributes toward greater problem-solving skills. With teachers' limited time and resources in mind, the in-service then turned toward how incorporating the spatial activity Quick Draw (Wheatley, 2007) can simultaneously meet the needs of students and teachers in the classroom.

2.1 Developing Spatial Ability with Quick Draw

Quick Draw (Wheatley, 2007) is simple, fun, cost efficient, and adaptable to students' capabilities irrespective of grade level. It is also considered an engaging mathematical activity that helps students develop their spatial ability through the use of visual images. Tied to the purpose of the in-service, the teachers participated in a trial run of the activity just as it would be conducted in the classroom. To begin, teachers were shown a geometric figure (see Figures 1 and 2 below for sample items) that was displayed using an overhead projector for a total of three seconds. The projector was then turned off. From there, the teachers were asked to draw on unlined paper what they saw. When the drawings were complete, they were then given a second look. Once the figure was completely uncovered, the teachers were then asked to describe what they saw and explain their corresponding sketches. As they listened to their fellow colleagues' descriptions, they became intrigued by the varied interpretations and openly shared their ideas in response.

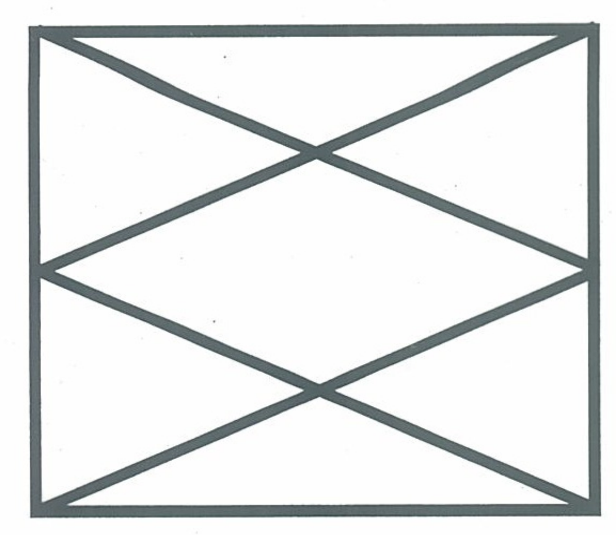

Figure 1. Quick draw sample item 1 (based on Wheatley, 2007)

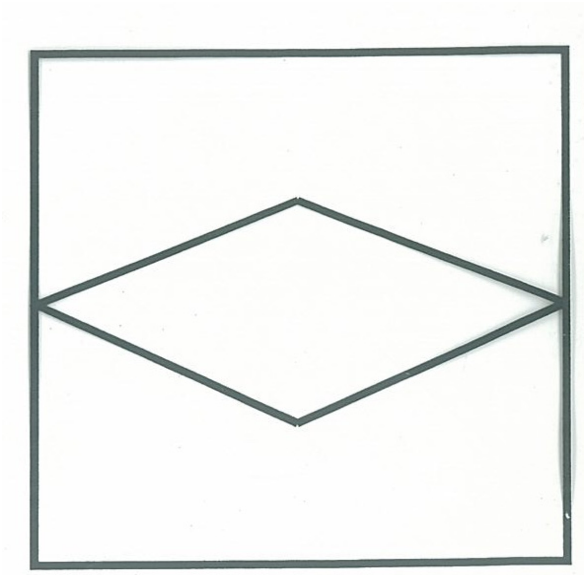

Figure 2. Quick draw sample item 2 (based on Wheatley, 2007)

2.2 Teachers' Feedback with Quick Draw

Over the course of the year, two teachers (4^{th}- and 6^{th}-grade levels) experimented with the Quick Draw activities as part of their curriculum. Both expressed a strong satisfaction in terms of what they felt their classes experienced. A summation of their feedback is as follows:

- Students actively constructed and exchanged ideas after each image was completely uncovered.

▪ Students enjoyed the challenge since mathematics textbooks tend to limit their opportunities to provide alternative problem solving opportunities in geometry.

▪ The activity did not involve much time, and many students still seemed to gain some understanding of what spatial ability means and how we are able to use it in everyday life.

▪ With repeated exposure, students expressed greater ease with remembering the details of more complex figures.

In building upon the key ideas addressed at the in-service, the 6th-grade teacher in particular shared that the Quick Draw activity proved to be a welcoming departure from the topics typically covered in their mathematics class. Normally, her students complete a given set of problems in the text after a lecture and question/answer period. Alternative approaches to problem solving are encouraged, but as she so clearly stressed, optimal use of class time in accordance with their curriculum is always a concern. As a result, the development of problem solving skills that do not rely upon the memorization of formulae is not strongly emphasized. With the Quick Draw activity, she felt that her students were able to work on their use of imagery in a way that facilitated open and constructive communication in a mathematical sense. The students also expressed a newfound interest in geometry considering their ability to draw upon a different type of problem-solving tool that is often underutilized in everyday classroom practice.

Of equal significance, students demonstrated their ability to reflect on the activity in how they presented and thought about alternative interpretations of each figure. In other words, students felt comfortable expressing and constructing their own mathematical ideas even when fellow classmates disagreed. These experiences are similar to those reported by Wheatley who stated that with the Quick Draw activity, "…discourse promoted reflection" (1992, p. 538). Keep in mind that the discussion of what students see is the focus rather than the quality of what is drawn. According to Wheatley (1992, 1997, 2007), teachers should also encourage their students to be creative with the activity by asking them to explain what a certain image may look like or to simply try to identify the different shapes that are involved.

The 4th-grade teacher also found that her students enjoyed the activity as evidenced by their constructive dialogue that surrounded the presentation of drawings and varied interpretations. They too expressed a greater interest and knowledge of geometric content. However, 4th graders seemed to encounter difficulty in grasping the relation between spatial ability and mathematics. The Quick Draw activity was mainly considered as some type of game or puzzle with little or no relevance to problem solving. Sixth graders, on the other hand, expressed some degree of insight into this relation by how they openly drew connections between the use of imagery and successful completion of the task at hand.

3. Concluding Remarks

Our in-service provided an opportunity for teachers to challenge themselves in what they know about spatial ability, and how well they were able to apply it when faced with two types of standardized spatial tasks. In the weeks that followed, a few of our participating teachers chose to more formally incorporate spatial thinking within their mathematics classes. Their students' experiences with Quick Draw revealed that producing and interpreting visual images seem to facilitate learning mathematical concepts and relations in a more meaningful way. Empirical evidence derived from a controlled, systematic approach to the use of Quick Draw would be needed to determine students' actual improvement in spatial ability. However, related studies (Casey et al., 2008; Edens & Potter, 2007; Tzuriel & Egozi, 2010) have shown that participation in spatially oriented activities enhances performance in the ability to visualize information. The significance of this line of research is highlighted in Uttal et al.'s (2013) recent meta-analysis that revealed spatial skills are highly malleable and can be improved. In addition, spatial skills were found to be durable and transferable across problem-solving situations. Uttal et al.'s findings also supported the notion that developing students' spatial abilities can increase students' interest in STEM careers, and even decrease the dropout rate amongst STEM majors.

In light of their collaborative, hands-on learning experience, our participating teachers agreed unequivocally (and even empathized in some cases) that future graduates' ability to succeed in STEM careers may be at stake if spatial thinking is not soon recognized as an essential component of traditional classroom practice starting from the early elementary years. An activity such as Quick Draw in the mathematics classroom can capture students' attention to focus on the task at hand, and it can also encourage them to openly engage with one another in a non-judgmental way. Thus, in the discovery of space, there may not be a right or wrong answer, but rather an opportunity to motivate alternative ways of thinking that could potentially enhance problem-solving success.

Acknowledgements

We would like to thank the faculty and staff of Pinecrest School Thousand Oaks who participated in the in-service. The rich discussions surrounding the role of spatial ability in the classroom have helped us to gain additional insights into future in-service and research endeavors. We applaud their commitment to better understanding the development of children's thinking and ways to subsequently improve the quality of their instruction.

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