

Alleviating Anxiety about Spatial Ability in Elementary School Teachers

Raedy M. Ping (rping@uchicago.edu)

Claire Bradley (cbradley1@uchicago.edu)

Elizabeth A. Gunderson (lizgunderson@uchicago.edu)

Gerardo Ramirez (ramirezg@uchicago.edu)

Sian L. Beilock (beilock@uchicago.edu)

Susan C. Levine (s-levine@uchicago.edu)

Department of Psychology, 5848 S. University Ave.
Chicago, IL 60637 USA

Abstract

We present data from a teacher professional development intervention, a work circle where researchers (expert in the domain of spatial reasoning) and teachers (expert in teaching in a classroom) worked together to develop spatial tools, based on lab evidence, which could be used in actual classroom lessons. We found that, although spatial anxiety was not directly addressed during work circle activities, teachers experienced a decrease in spatial anxiety (but not math or reading anxiety) over the course of the school year. Possible reasons why this intervention was successful in reducing teacher anxiety about spatial reasoning tasks are discussed.

Keywords: anxiety; spatial reasoning; teacher education

Introduction

The importance of studying student anxiety in educational settings has been well established, particularly within the domain of mathematics. Studies of math-specific anxiety find that math anxiety decreases performance in the moment because worries of doing badly use up important working memory resources that are necessary for doing difficult math (e.g., Ashcraft & Krause, 2007). On a more lasting level, math anxiety is associated with general avoidance of math as indexed by decreased motivation with respect to math as well as students' educational and career choices (Hembree, 1990). For example, students who experience greater math anxiety are less likely to pursue careers in such disciplines as science, technology, engineering and mathematics, often referred to as the STEM disciplines (Chipman, Krantz & Silver, 1992). Thus, alleviating student math anxiety has important implications for both short-term and long-term outcomes.

Domain-specific anxiety might be even more important to study in teachers, since they have opportunities and responsibilities to directly impact groups of students. Moreover, elementary math majors have the highest average math anxiety of any college major (Hembree, 1990). The overwhelming majority of teachers in early elementary school are female (National Education Association, 2003), and women are more likely to experience math anxiety than men (Hembree, 1990). This sex difference may be in part due to women's anxiety about confirming a stereotype that women are just not good at math; this fear is known as stereotype threat (e.g., Spencer, Steele & Quinn, 1999). For example, a multitude of studies demonstrate that telling test-

takers that the test is diagnostic of their math intelligence/ability results in increased anxiety and poorer performance in women but not in men—men even automatically experience a boost in performance when tests are described as being diagnostic (see Walton & Cohen, 2003 for a meta-analysis).

Highlighting the importance of addressing teacher math anxiety, a recent study showed that 1st and 2nd grade female teachers' math anxiety impacted their female students' (but not their male students') learning of math over the school year (Beilock, Gunderson, Ramirez & Levine, 2010). Teachers' math anxiety was directly related to girls' math performance at the end of the school year, but not at the beginning. In contrast, boys' math performance was not related to teacher anxiety at either time point. Further, teacher math anxiety was related to girls' likelihood of endorsing the stereotype that girls are good at reading and boys are good at math at the end of the school year, but not at the beginning, and was unrelated to boys' likelihood of endorsing the stereotype at either time point. A mediation analysis showed that the effect of teacher math anxiety on end-of-year performance was mediated by girls' endorsement of the negative stereotype about girls and math. All of these analyses controlled for teacher math ability, making the importance of alleviating teacher anxiety clear, especially in domains where stereotypes about ability are common.

One such domain, intimately related to math, is spatial reasoning. Compared to research in the domain of math, little is known about the relationship between anxiety, performance, and educational and career choices with respect to spatial reasoning. Lawton (1994) developed a self-report measure of spatial anxiety (or navigation anxiety to be more precise) and found that women reported higher levels of anxiety than did men. Moreover, spatial anxiety was also negatively correlated with a preference for choosing the most effective wayfinding strategy, one that requires constructing an objective cognitive map of one's surroundings (as opposed to an easily-disrupted route strategy that relies on memorizing a series of one's own moves). As with math, spatial anxiety is related to gender, performance and preferences.

Given the finding that teacher math anxiety affects student math performance, studying the relationship between teacher spatial anxiety and student spatial

performance is important. There is preliminary evidence to suggest that teacher spatial anxiety negatively impacts student spatial performance (Gunderson, Ramirez, Beilock & Levine, in progress). First and 2nd grade students whose teachers reported higher levels of spatial anxiety improved less on a mental rotation task during the school year when compared to students whose teachers reported lower levels of spatial anxiety. These results are particularly striking when considering that, as for math, females are especially likely to be anxious about space and, as mentioned, also comprise the majority of teachers in early elementary school (reflecting this, 17 of 19 teachers in the Gunderson et al. study were female).

It is also important to pay attention to students' spatial learning because early spatial ability is related to later school performance as well as educational and career choices regarding science and math (e.g., Wai, Lubinski & Benbow, 2009). Later in life, women are underrepresented in STEM careers (National Center for Education Statistics, 2001). Taken together, these facts highlight the importance of finding methods of decreasing teacher spatial anxiety and improving students' spatial learning.

Here, we present data from a group of kindergarten through 2nd grade teachers who participated in a work circle with researchers focused on the domain of spatial reasoning. The main goals of the work circle were: a) to familiarize elementary school teachers with the domain of spatial reasoning, b) to inform teachers about lab studies in the field of spatial reasoning, focusing on research about using spatial tools for teaching mathematical concepts, and c) to bring together researchers (experts in spatial reasoning and how it develops in early childhood) and teachers (experts in educating young children within the classroom setting using their particular curricula) to refine "Spatial Toolkit" activities that were based on lab studies for use in the classroom. Teachers implemented and augmented Toolkit activities throughout the school year and reported back to the work circle to discuss ideas for further refinement, ideas for other content that could be taught spatially, and questions that future lab research could address. Although spatial anxiety was not directly addressed during the work circle intervention, we hypothesized that participating in the work circle might reduce teacher anxiety about spatial reasoning, for several reasons.

First, the work circle intervention focused not on teaching teachers in the spatial domain directly, but rather on understanding how spatial abilities develop within children and in creating spatial tools for teaching children (and why lab research predicts that certain tools will work). Previous research has shown that when math instruction for preservice elementary school teachers focuses on how math concepts should be taught to students, teachers' math anxiety decreases relative to math education classes that focus on instructing the teachers in the domain of math directly (Tooke & Lindstrom, 1998). In other words, teacher education that focuses on how to teach a domain reduces anxiety about that domain more than teacher

education that focuses on the content of the domain itself. Focusing on how to teach spatially, and not focusing directly on teaching teachers spatial skills, might have a similar alleviating effect on their anxiety about spatial reasoning.

Second, evidence from the stereotype threat literature demonstrates that being told that the skill or ability being tested is malleable (rather than fixed) eliminates negative performance effects associated with stereotype threat (Aronson, Fried & Good, 2002). Describing research about how spatial reasoning abilities develop over time and how those abilities can be both improved and used was a major part of the work circle intervention. We reasoned that informing female teachers about research demonstrating that spatial skills are malleable (not fixed, as is commonly believed) might thus decrease their spatial anxiety, if any of that anxiety is due to stereotypes about gender and spatial ability that favor men.

Third, additional evidence from the stereotype threat literature shows that, if a member of a negatively-stereotyped group is provided with examples of other members from that group who are successful in the stereotyped domain, negative effects of stereotype threat can be alleviated (McIntyre, Paulson & Lord, 2003). We reasoned that since the researchers involved in the work circle were women, this aspect of the intervention might decrease the spatial anxiety of the female teachers. Although we did not test this by having male researchers work with a group of teachers, a decrease in teacher spatial anxiety would be consistent with this hypothesis and could lead to systematic study of this question. For these reasons, we hypothesized that teacher anxiety in the domain of spatial reasoning—specifically—would be alleviated by our work circle intervention.

Method

Participants

Fourteen teachers (12 female, 2 male) from 7 Chicago area schools (5 public, 2 private) who taught either kindergarten, 1st or 2nd grade participated in the work circle. One teacher was a science teacher who spent time in different 1st and 2nd grade classrooms, and the other teachers taught in a single classroom throughout the day. Four teachers had participated in a pilot study the year before and agreed to participate for another year. The other ten teachers responded to flyers posted in the offices of their schools or placed in mailboxes of kindergarten, 1st and 2nd grade teachers at the schools of teachers who had participated in the previous work circle. Teachers were paid hourly for the time they spent in the week-long intervention at the end of the summer vacation and also received a gift card at the end of the following academic year.

Materials

The heart of the work circle intervention consisted of a full week of intensive meetings between teachers and

researchers that took place in August, toward the end of the summer vacation. At the beginning of the week-long intervention, teachers completed three self-report questionnaires to assess the levels of their spatial, math, and reading anxieties. Participants were asked to rate how anxious they would feel in various situations on a scale from 1 (not at all anxious) to 5 (very anxious). Example questions from the spatial anxiety questionnaire include how anxious you would feel “trying a new route that you think will be a shortcut without the benefit of a map” and “locating your car in a very large parking lot” (SAQ; Lawton, 1994). Example questions from the math anxiety questionnaire include how anxious you would feel “taking the math section of a standardized test” and “opening a math or statistics book and seeing a page full of problems” (short Mathematics Anxiety Rating Scale; Alexander & Martray, 1989; shortened version of 98-item MARS Suinn, 1972). Example questions from the reading anxiety questionnaire include how anxious you would feel “taking the verbal section of a standardized test” and “opening an English book and seeing a long story” (Zbornik & Wallbrown, 1991). Teachers also completed the anxiety measures at the end of the school year.

Procedure

During the week of meetings before the school year, teachers were introduced to the concept of spatial reasoning and lab research about its importance in children’s thinking and learning. A pilot study suggested that teachers were largely unfamiliar with the domain of spatial reasoning (Krakowski, Ratliff, Gomez & Levine, 2010). Thus, we started out by demonstrating that spatial reasoning skills are malleable and can be improved with practice or various kinds of instruction. We then focused on presenting evidence of how instruction that utilizes spatial language, gesture, and spatial alignment can be used to teach topics within a variety of content areas including measurement, graphs, fractions and map reading. These presentations took place over the first three days of the work circle.

Teachers were also presented with a Spatial Toolkit that contained example activities of how to use evidence supported spatial tools in the classroom. Researchers developed the activities included in the Toolkit in collaboration with the teachers who participated in the work circle the previous year. The Toolkit was introduced to the teachers and discussed during one day of the work circle. Next, teachers broke into small groups to take these lesson ideas and come up with concrete ways of applying them to their curriculum. These small groups then presented their activities to the larger group. The small group work took place over three days and presentations of the teachers’ activities occurred on the last day of the week.

For example, researchers presented the results of a training study that found that teaching students to measure objects misaligned with the zero-point on a ruler by laying discrete one-inch transparent plastic units on top of the ruler improved students’ performance on this typically

challenging task (Levine, Kwon, Huttenlocher, Ratliff & Dietz, 2009). This study was then turned into a Toolkit activity, a worksheet where students would be instructed to use unit-chips to help them measure items misaligned with the zero-point on a ruler. During the work circle teachers were asked to take the idea of using discrete units on a ruler and transfer it to the number line, a tool that is used on a daily basis in elementary school classrooms. Teachers then presented their ideas to the large group. Some examples of teacher-generated activities included using units of different sizes on the number line to teach addition/subtraction and multiplication/division.

During the school year, teachers were asked to fill out daily checklists to keep track of the spatial activities they were using. Teachers were instructed to describe any activities they used that contained spatial content and in which subjects (i.e., math, science, language arts, etc.) those lessons would be included. Teachers were also asked to record whether they used any Spatial Toolkit activities by checking a box next to the listed activities. These checklists were picked up from schools on a bi-weekly basis throughout the year.

Teachers also attended a refresher meeting during the winter, which served as an opportunity to ask questions and discuss issues they had encountered during the first half of the school year. One-on-one interviews were also conducted during this meeting. During these interviews teachers were asked about which activities they were using on a regular basis, the particular subjects for which these activities were useful, how students reacted to the spatial activities, and whether they felt their teaching had changed as a result of participating in the work circle. During these interviews, teachers also described ways they had augmented the Toolkit activities.

During the spring of the school year, teachers were videotaped for about half of a school day. They were asked to teach a lesson using the number line and a lesson using a map, with the specifics of these lessons left up to the teachers.

At the end of the school year teachers attended a wrap-up meeting where they were given the post-intervention spatial, math and reading anxiety measures. This also served as an opportunity for a final discussion about the year.

Results

One male teacher dropped out of the study after the summer intervention. In addition, two female teachers and the other male teacher did not complete the anxiety questionnaires at the end of the school year. Data from the ten remaining teachers (all female) were analyzed.

Teacher measures of anxiety were entered into a repeated-measures ANOVA with Anxiety Type (3: spatial, math, reading) and Time (2: pre-intervention, post-intervention) as within-subjects variables. Results are presented in Figure 1. We found a main effect of Anxiety Type ($F(2, 18)=5.60$, $p<0.05$); planned contrasts showed that spatial anxiety ($M=2.98$, $SE=0.28$) was on average higher than reading

anxiety ($M=2.00$, $SE=0.22$) and that math anxiety ($M=2.20$, $SE=0.24$) did not significantly differ from either of the other types. There was a marginally significant main effect of Time ($F(1, 9)=3.81$, $p<0.09$); on average, anxiety scores marginally decreased from pre-intervention ($M=2.52$, $SE=0.19$) to post-intervention ($M=2.27$, $SE=0.18$).

The research question under study here involves the change in spatial anxiety from the beginning to the end of the school year. We hypothesized that, since teachers were participating in professional development focusing on spatial reasoning, anxiety about spatial reasoning would decrease from the beginning to the end of the school year, while math and reading anxiety would not be affected by our specialized intervention. The analysis of interest, then, is the interaction between Anxiety Type and Time. This interaction was significant, $F(2, 18)=5.64$, $p<0.05$. Paired samples *t*-tests revealed that spatial anxiety decreased from pre-intervention to post-intervention (pre $M=3.34$, $SE=0.37$; post $M=2.61$, $SE=0.25$; $t(9)=2.55$, $p<0.05$) while reports of math anxiety (pre $M=2.10$, $SE=0.24$; post $M=2.31$, $SE=0.26$; $t(9)=-1.29$, *ns*) and reading anxiety (pre $M=2.11$, $SE=0.24$; post $M=1.88$, $SE=0.21$; $t(9)=1.75$, *ns*) did not change significantly over time.

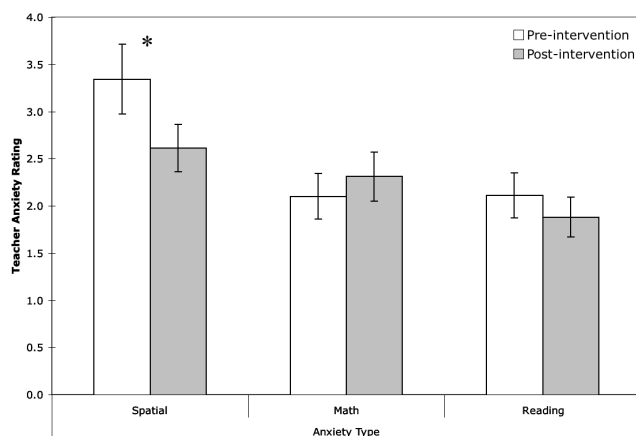


Figure 1: Teacher reports of anxiety, pre-intervention (white bars) and post-intervention (gray bars). There was a significant interaction between Time and Anxiety Type. Spatial anxiety decreased from pre to post, while math and reading anxiety did not change. Error bars are SEM. $*p<0.05$.

Discussion

Since teacher anxiety can impact student learning outcomes (Beilock, et al., 2010; Gunderson, et al., in progress), the importance of finding ways to decrease teacher anxiety is clear. Participating in a work circle intervention in the domain of spatial reasoning, which included an intensive week-long intervention as well as follow-ups and opportunities to use newly created spatial activities throughout a school year, resulted in a decrease in kindergarten through 2nd grade teachers' spatial (but not math or reading) anxiety. This study represents a

preliminary step toward learning how to decrease teacher anxiety in the domain of spatial reasoning. Our intervention did not focus on decreasing anxiety—it focused on bringing teachers and researchers together to discuss the field of spatial reasoning and to design classroom interventions using lab-tested spatial tools.

However, we do not yet know whether this particular intervention had any effect on the students (that data is currently being analyzed). Previous research does suggest that teacher math anxiety is associated with a general avoidance of math—teachers who are high in math anxiety, for example, spend less time preparing for math lessons and even use math instruction time for other subjects (Swetman, Munday & Windham, 1993). Since spatial reasoning is not even a part of the curriculum—there is no subject in school called “spatial reasoning”—teacher avoidance of spatial reasoning based on anxiety might be even more extreme. If being in our intervention decreased teacher spatial anxiety and, by extension, increased the amount of instructional time spent on spatial activities, students spatial learning should benefit.

It should be noted that the intervention we describe here was lengthy. Although the bulk of the actual intervention took place in a week of meetings before the school year started, teacher anxiety was measured at the very beginning of that the first week and again at the very end of the school year. As such, the current study does not allow us to see the time course of this phenomenon. Is it the case that simply completing the week-long intervention (or even shorter) would decrease spatial anxiety? Or, is it necessary for the effects to build over time, perhaps because teachers gain confidence in their spatial skills as they implement lessons with spatial content? How long would such effects last? This preliminary study cannot address questions of time course such as these.

Indeed, we do not know which elements of our intervention were responsible for the decrease in teacher anxiety. There were two general components of the intervention: the intensive week-long intervention, and the opportunity to use that information throughout the year. Even during the first week, we focused on many different aspects of spatial reasoning. Within one week, teachers were given a “crash-course” in research having to do with spatial reasoning. Then, they were introduced to roughly a dozen spatial tools for teaching different concepts. Then, they focused on particular tools and worked together to develop classroom activities based on those tools. They then presented those activities to the work circle teachers and researchers and received feedback. During the winter interviews, teachers reported having used spatial tools in their teaching, even in contexts that had never been discussed during the work circle, such as teaching handwriting or managing the classroom. They reported that they used spatial tools most often during math and science lessons, and they also frequently augmented the originally designed spatial activities. Returning to the measurement example described above, several teachers reported using

unit-chips during activities with bar graphs and number lines to help their students understand the importance of counting intervals and understanding the concept of “unit”.

Because all of the teachers whose data we analyzed were female, we cannot tell how much of the decrease in spatial anxiety comes from alleviating anxiety that stems from stereotype threat, or if our results are more generalizable. To some degree, it does not really matter since over 90% of early elementary school teachers are female (NEA, 2001).

On a positive note, we have learned that teacher’s anxiety about the spatial domain can be decreased through the approach we took, and that they also report increases in their use of spatial activities in the classroom. Our future work will focus on identifying the precise aspects of the intervention that were critical in achieving these results, and also examine the impact of this kind of intervention on student learning, both in terms of their spatial reasoning and in mathematics and science, where spatial skills have been shown to play an important role in levels of achievement.

Acknowledgements

This research was supported by a grant from the National Science Foundation (Spatial Intelligence Learning Center Grant SBE0541957).

References

- Alexander, L. & Martray, C. (1989). The development of an abbreviated version of the Mathematics Anxiety Rating Scale. *Measurement and Evaluation in Counseling and Development*, 22, 143-150.
- Ashcraft, M. H. & Krause, J. A. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin and Review*, 14(2), 243-248.
- Aronson, J., Fried, C. & Good, C. (2002). Reducing the effects of stereotype threat on African American college students by shaping theories of intelligence. *Journal of Experimental Social Psychology*, 38, 113-125.
- Beilock, S. L., Gunderson, E. A., Ramirez, G. & Levine, S. C. (2010). Female teachers’ math anxiety affects girls’ math achievement. *Proceedings of the National Academy of Sciences, USA*, 107(5), 1060-1063.
- Chipman, S. F., Krantz, D. H. & Silver, R. (1992). Mathematics anxiety and science careers among able college women. *Psychological Science*, 3(5), 292-295.
- Gunderson, E. A., Ramirez, G., Beilock, S. L. & Levine, S. C. (in progress). Teachers’ spatial anxiety impacts children’s mental rotation ability.
- Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education*, 21(1), 33-46.
- Krakowski, M., Ratliff, K., Gomez, L. & Levine, S. C. (2010). Spatial intelligence and the research-practice challenge. In Gomez, K., Lyons, L. & Radinsky, J. (Eds.) *Learning in the Disciplines: Proceedings of the 9th International Conference of the Learning Sciences (ICLS 2010)—Volume 1, Full Papers*. International Society of the Learning Sciences: Chicago, IL.
- Lawton, C. A. (1994). Gender differences in way-finding strategies: Relationship to spatial ability and spatial anxiety. *Sex Roles*, 30, 765-779.
- Levine, S. C., Kwon, M., Huttenlocher, J., Ratliff, K. & Dietz, K. (2009). Children’s understanding of ruler measurement and units of measure: A training study. In Taatgen, N. A. & van Rijn, H. (Eds.), *Proceedings of the 31st Annual Conference in the Cognitive Science Society*. Cognitive Science Society.
- McGlone, M. & Aronson, J. (2006). Social identity salience and stereotype threat. *Journal of Applied Developmental Psychology*, 27, 486-493.
- McIntyre, R. B., Paulson, R. & Lord, C. (2003). Alleviating women’s mathematics stereotype threat through salience of group achievements. *Journal of Experimental Social Psychology*, 39(1), 83-90.
- National Center for Education Statistics (2001). *Post Secondary Institutions in the United States: Fall 2000 Degrees and Other Awards Conferred 1999-2000* (National Center for Education Statistics, Washington, D. C.).
- National Education Association (2001). *Status of the American Public School Teacher 2000-2001* (National Education Association, Washington, D. C.).
- Spencer, S. J., Steele, C. M. & Quinn, D. M. (1999). Stereotype threat and women’s math performance. *Journal of Experimental Social Psychology*, 35(1), 4-28.
- Suinn, R. M. (1972). *Mathematics Anxiety Rating Scale-MARS*. Fort Collins, CO: Rocky Mountain Behavioral Sciences Institute.
- Swetman, B., Munday, R. & Windham, R. (1993). Math-anxious teachers: Breaking the cycle. *College Student Journal*, 22(4), 421-427.
- Tooke D. J. & Lindstrom, L. C. (1998). Effectiveness of a mathematics methods course in reducing math anxiety of preservice elementary teachers. *School Science and Mathematics*, 98(3), 136-139.
- Wai, J., Lubinski, D. & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over fifty years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, 101, 817-835.
- Walton, G. M. & Cohen, G. L. (2003). Stereotype lift. *Journal of Experimental Social Psychology*, 39, 456-467.
- Zbornik, J. J. & Wallbrown, F. H. (1991). The development and validation of a scale to measure reading anxiety. *Reading Improvement*, 28(1), 2-13.