# Mathematical Self-Efficacy of Middle School Students Solving the Rubik Cube

Omar Arizpe Jerry Dwyer
omar.arizpe@ttu.edu jerry.dwyer@ttu.edu
Department of Mathematics & Statistics, MS 1042
Texas Tech University, Lubbock, TX 79409

Tara Stevens
tara.stevens@ttu.edu
Department of Educational Psychology, MS 1071
Texas Tech University, Lubbock, TX 79409

***Abstract***

A solution to the Rubik's Cube was introduced to an eighth grade mathematics class. The purpose of this study was to determine if an introduction to a solution to the Rubik's Cube could enhance students' problem-solving abilities, increase their general interest in mathematics, and enhance students' problem solving self-efficacy. Pre and Post Surveys were administered. The results revealed a significant increase in students' problem solving abilities and self-efficacy, but no significant increase was found in student interest. Interestingly, further analysis revealed a statistically significant increase in girls' problem solving skills but not in boys. This may have been as a result of the algorithmic approach taken to solve the Rubik's Cube.

**Key words:** mathematical efficacy, problem solving, Rubik Cube

## 1. Introduction

A group of middle school students was presented with a systematic solution to the Rubik's Cube with the goal of enhancing the students' problem solving abilities through an activity that was both fun and understandable. The purpose of this study was to evaluate the students' changes in problem solving abilities, including pattern recognition, spatial sense and ability to solve multi-step problems, as they interacted with the Rubik's cube activities. A mixed methods approach utilizing surveys, interviews and problem sets was implemented to investigate if the presentations positively influenced the students' problem solving abilities. Because the Rubik's Cube activities were also developed to increase students' self-efficacy and overall interest in mathematics, the present study also evaluated increases in these factors.

Students are familiar with word problems in their mathematics classes; however, they often find these to be challenging and not interesting. Sometimes mathematical games may be used to provide a more enjoyable and non-threatening learning environment. We felt that the practicing of most games which utilize one's problem solving skills could be useful, but may not enhance the student's problem solving confidence. The idea then arose of introducing a solution to the Rubik's Cube to students. The researchers hoped the students would not only enjoy their time working with the Rubik's Cube, but would also feel a sense of accomplishment after being able to solve it, thus raising their confidence in their problem solving abilities. Numerous studies have assessed the success of using games to develop problem-solving skills, but a thorough search of the literature revealed no research linking problem solving ability and the Rubik's Cube.

Students were given a problem pretest and an interest inventory before the first lesson was presented. The pretest aimed to test the students' pattern recognition, spatial abilities, and ability to perform multi-step problems. The interest inventory attempted to assess the students' general attitudes toward mathematics. The researchers presented lessons, in a lecture style, which were approximately 10 minutes in length, and then spent approximately 20 minutes helping the students to master the steps of the solution of the Rubik's Cube that had been presented. Students were encouraged to ask questions, and to work both independently and collaboratively when attempting to understand a particular step of the solution.

The solution of the Rubik's Cube we chose was a more visual approach in an attempt to minimize the amount of memorization needed. The researchers wanted the students to be forced to think through the solution, utilizing their spatial skills, as much as possible. We feel pattern recognition, spatial skills, and solving a multi-step problem were all integral components of the solution we presented. The first two thirds of the solution of the Rubik's Cube were introduced via spatial skills and multi-step methodology. The final third of the solution focused on pattern recognition.

## 2. Literature Review

Little is known about how to teach students to be better problem solvers (Charles & Lester, 1984). Some question whether teaching problem solving methods has any place in our mathematics classrooms. Owen and Sweller (1989) state, "...there appears to be no evidence that problem solving search per se has beneficial consequences."(p. 326) The main argument Owen and Sweller make against teaching problem solving methods in mathematics classes is the uncertainty that students will transfer problem solving techniques to solve mathematics problems. There are others who believe the contrary. Lawson (1990) states, "recent work on transfer of learning suggests that efficient operation of general problem-solving strategies can be expected to lead to successful transfer provided that the student has a well-organized knowledge base."(p. 409)

Researchers who believe there is something to be gained in the classroom through problem solving have conducted studies assessing the use of games to enhance problem solving. Lach and Sakshaug (2004) conducted a study using these methods, which provided a variety of interesting results. They noted "Games are naturally motivating and fun, games facilitate individualization of assessment and instruction, and games make the abstract more concrete."(p. 1) They also concluded that playing mathematics games could enhance students' spatial abilities and algebraic reasoning. This study had both a control group and an experimental group. Both groups consisted of upper middle-class students who scored above the 30th percentile in math on the Stanford Achievement Test. At the beginning and completion of the study both the control and experimental groups were given a pre-test and a post-test. Both groups scored similarly in the pre-test. The researchers found a positive statistically significant difference in their experimental group's pre-test and post-test scores. There was no statistically significant difference between the pre-test and post-test scores of the control group.

Instructional game playing in classrooms is strongly supported by Blum and Yocom (1996). They claim that games can increase motivation and allow students a fun way to practice skills they have already learned. Klein and Freitag (1991) and Olsen and Platt (1992) found that games helped students' problem solving skills because the games gave them a chance to solve problems in a non-threatening environment. Another factor to consider when playing games is the competition factor that inevitably invades a classroom. Brown (1985) argued that the combination of both fun and competition or challenging self-competition might be the best way for students to benefit from games. In addition to the possible benefits to the development of problem solving skills, the mastery experienced in mathematical game playing facilitates students' feelings of self-efficacy, which is also related to positive approaches to solving problems. Bandura (1995) defines self-efficacy as "the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations." (p.2) Research has been conducted in an attempt to find a correlation between self-efficacy and students' ability to problem solve. Liu, Hsieh, Cho and Schallert (2006) conducted a study that implemented a computer-enhanced problem-based learning environment to investigate the relationships among students' self-efficacy, attitude towards science and achievement. They found self-efficacy to be a statistically significant predictor of achievement. Bandura (1996) also has investigated the relationship between self-efficacy and academic achievement. He found that parents' academic efficacy for their children and the student's social-efficacy and self-efficacy affect scholastic achievement. Self-efficacy has also been found to be an important predictor of mathematics achievement (Stevens, Olivárez, Lan, & Tallent-Runnels, 2004). Bandura (2001) later found that students' perceived efficacy is the main determinant of their perceived professional self-efficacy and career choice. This is why it is imperative we understand how to positively influence self-efficacy in the domain of mathematics problem solving as it not only pertains to immediate achievement outcomes but to later career choices as well.

Ufuktepe and Ozel (2002) have posited that many children in primary education develop varying degrees of math phobia. This results in consequences such as a decrease of self-efficacy, which is influenced by physiological feedback in addition to actual mastery experiences (Bandura, 1986), and weak problem solving skills. They found that integrating fun in the mathematics classroom gives students a non-threatening environment raising their self-efficacy, and teaches them not to be afraid of making mistakes. The students also realized that self-efficacy and the ability to generate ideas toward the solution to a specific problem were more important than the answer itself. Hanlon and Schneider (1999) conducted a study showing that raising self-efficacy can result in statistically significant higher exam scores on a mathematics proficiency exam and problem solving performance assessment respectively.

Mixed results have been found in studies attempting to find gender-related differences in problem solving abilities. Ronning and McCurdy (1982) conducted a problem-solving study consisting of 150 junior high school students. There were two main findings in their study. They found no statistically significant difference between the different grade levels, and even though the boys slightly outperformed the girls, they found no statistically significant gender difference in their study. One group of researchers who found significant results was Zambo and Follman (1993). They found "significant gender related differences in the overall process of problem solving in favor of females." (p. 1) They concluded that an algorithmic approach to problem solving could be gender biased in favor of females.

## 3. Procedures

### 3.1 Procedure Synopsis

The students involved in this study were from a middle school in the southwestern United States. The study was conducted during the Spring 2006 semester. This middle school is a private school with a low student-teacher ratio. The participants were part of an eighth grade algebra class consisting of thirteen students, six boys and seven girls. Of these students 76.9% described themselves as White/Other, 15.4% as Hispanic, and 7.7% as Asian. The class participating in this study was chosen because of the longstanding relationship with the researchers, and the smaller class size offered at the school. A more intimate classroom setting was also a better fit for such a hands-on, visual study.

A pre-test and the Mathematics Interest Inventory (Stevens & Olivárez, 2005) were administered to the students on the first meeting, and the same tests were given at the conclusion of the study. This interest inventory was used to assess the students' attitudes towards mathematics by stating a series of phrases to which the students used a scale from one to seven to rate how each statement "sounded like them." This list of statements consisted of phrases such as: "I see how I can use math in everyday life," or "I prefer easy math over math that is hard."

We comprised a pre/post test consisting of five questions to assess the students' progress in their problem solving and critical thinking skills. These problems were picked from various online sources and a College Algebra textbook.

We met with the students once a week for a total of fourteen weeks. The students were introduced to a solution to the Rubik's Cube. Once the majority of the class was able to solve the Rubik's Cube, the students played problem-solving games using the Rubik's Cube. To give the students the opportunity to practice certain concepts they might have struggled with during a lesson, two Rubik's Cubes were left in the class during the week.

A mixed methods approach was used to analyze the data. Mainly statistical methods were used to analyze the students' pre-test and post-test differences, but qualitative research was also conducted. We tape-recorded conversations with some of the students to hear their reactions to the lessons and to determine if they felt more confident with their problem solving abilities.

### 3.2 Problem Set

The problems selected to assess the problem solving and critical thinking skills of the students tested the students' pattern recognition, spatial sense, and ability to solve multi-step problems. We believed each of these skills could be exercised during the lessons; hence the lessons were designed as such. The test had a maximum score of fifteen points. These points were given for correct answers for which students showed their thought processes in writing when applicable. We visited the students a total of fourteen times over a period of 5 months. To ensure there were no biases toward any students during the lessons, or during the grading process, none of the assessments were reviewed until the completion of the study.

Problem I asked which number should come next in the series and to explain your answer. Problems II and III were selected to assess the students' spatial abilities. The students had to visualize the forming of a box from six faces and had to determine if the configuration was possible. Problem IV used both pattern recognition and spatial skills where students had to visualize a rotation and a reflection. Problem V evaluated the students' ability to solve a multi-step word problem. On all problems we attempted to understand the thought process of the students if they showed work and gave partial credit accordingly.

**3.3 Lessons**

The lessons were designed to be an interesting and fun way to approach the Rubik's Cube. We felt that a visual approach would be the best fit for the study. This approach gave the students more opportunities to focus on a three-dimensional puzzle and challenge themselves to think in a three-dimensional setting rather than strictly memorizing a solution. The students needed absolutely no prior knowledge of mathematics, or problem solving to participate in the study. The lessons are essentially 12 steps of a multi-step solution to the Rubik's Cube. In these lessons the students learn different techniques for solving different spatial patterns arising in the Rubik's Cube. We provided a Rubik's Cube for every student and left two in the classroom so that students could practice between lessons.

Most students found the first step fairly simple, and seemed excited that they understood what was asked of them. For those who found this task more difficult, many of them seemed frustrated and worried that they were falling behind the rest of the class. The main problem students had was finding the different tiles needed to carry out a certain task. Many of those struggling would get confused about what they were looking for and why they were looking for it. It was very pleasing to see the vast majority of the class was highly motivated to learn, although, there were two students who did not seem interested. Those who did understand became even more enthusiastic and interested to learn further steps of the solution to Rubik's Cube. The main step the students struggled with was the idea of *hiding*, or moving a tile to a specific location without altering other tiles. Many students struggled with this process and how to properly employ it. The ability to master hiding was the turning point for most of the class. Either the students understood the steps necessary to complete this stage of the Rubik's Cube or became disinterested and gave up. Some students took longer than others to understand these necessary steps, and this was their turning point as well.

About a month passed between the second and third lessons, and many students forgot most of what they had previously learned. Hence, the third lesson was used as a review of the first color of the Rubik's Cube. The review was very beneficial to some of the students who had been struggling previously. This gave them another opportunity to grasp the material they had been striving to solve. The students struggled considerably with the concept of switching the middle pieces. Some of the students might not have been adequately prepared to move on to this step, which could have accounted for this problem. Once students realized what needed to be done and why it needed to be fixed, they struggled considerably less.

At about the middle point of the lessons motivation became a concern. The class was beginning to split between the students who understood the last lesson and those who did not. The majority of students who did not understand were quickly becoming discouraged and extremely frustrated when they saw their peers grasping the concepts that they did not understand.

We were very surprised with the progress of the students the following week. Some of the students started taking Rubik's Cubes home to practice, and others were getting help from their classmates on aspects of the Rubik's Cube with which they were struggling. We chose to expose the students to a solution of the Rubik's Cube that was as visual as possible, but memorized steps were inevitable. At this point the students were familiar enough with the Rubik's Cube that learning memorized moves came to them easily.

A problem that arose from their enthusiasm was that a couple students could not wait for the completion of our lessons to finish the solution to the Rubik's Cube. These students found other solutions to the Rubik's Cube online and taught themselves the remainder of the solution. The main reason this became a problem was when these students struggled with a particular step in their online solutions, we were unable to help them.

Lessons IX & X were the most challenging lessons of our project. Only two memorized moves were needed to finish the solution of the Rubik's Cube and were used in conjunction with one another. Not only were the students being introduced to two of the most difficult moves they had seen, but strategy was also involved. The main struggle students had was in recognizing how to use a combination of these moves in order to finish the solution to the Rubik's Cube. The entire tenth lesson was dedicated to this issue. We assisted students who were having these types of problems, and this gave students who had fallen behind some time to catch up with the rest of the class.

## 4. Results

### 4.1 Problem Set Results

The main objective of this study was to determine if a solution to the Rubik's Cube was related with an increase in students' problem solving and critical thinking skills. The students were given a pre-test before and post-test at the completion of the lessons. To determine the outcome of the study, the statistical results of the pre-tests and post-tests were analyzed.

Thirteen students took both the pre-test and post-test. Table 1 has an overview of the statistical results of our data. The pre-test and post-test consisted of five questions, and had a maximum score of 15 points. Three of these questions were free response and two were multiple-choice. Partial credit was awarded with the free response problems.

Table 1: Summary of Problem Set Results

| | N | Mean | Median | St. Dev. | Minimum | Maximum |
|---|---|---|---|---|---|---|
| Pre-test | 13 | 6.2 | 6 | 2.77 | 3 | 13 |
| Post-test | 13 | 8.7 | 9 | 2.96 | 2 | 13 |

In order to determine if a statistically significant difference between the means of the pre-test and post-test was present, a two-sample paired t-test was conducted. The results of the two-sample paired t-test are shown in Table 2.

Table 2: Summary of Problem Set Two-Sample Paired *t*-test

| N | Mean | St. Dev. | St. Error Mean | *t* | *p* |
|---|---|---|---|---|---|
| 13 | 2.46 | 3.08 | 0.85 | 2.89 | 0.01 |

Since our *p* value is less than 0.05, which is the customary value of $\alpha$, we reject the null hypothesis and accept the alternative hypothesis. Furthermore, since our mean of differences is 2.462, we can also conclude that there exists a positive statistically significant difference. This leads us to believe the introduction of a solution to the Rubik's Cube may enhance a student's problem solving and critical thinking skills.

An unexpected and interesting observation concerns gender. The Two-Sample Paired *t*-test, mentioned above, was performed again, taking gender into consideration. The results are shown in Table 3.

Table 3: Summary of Gender Considered Problem Set Two-Tailed Paired *t*-test

| | N | Mean | St. Dev. | St. Error Mean | *t* | *p* |
|---|---|---|---|---|---|---|
| Boy | 6 | 0.83 | 2.60 | 1.06 | 0.79 | 0.45 |
| Girl | 7 | 3.86 | 3.51 | 1.33 | 2.91 | 0.01 |

Choosing $\alpha$ as we did before, we can see there is no statistically significant difference between the means of the boys' pre-test and post-test scores, but there is a statistically significant difference between the means of the girls' pre-test and post-test scores. Interestingly, the girls scored lower than the boys at the pre-test but higher than the boys at the post-test. Independent measures *t*-tests did not reveal the presence of statistically significant differences between boys and girls for either the pre- or post-test. Even so, evidence exists to suggest that the girls in the study might have experienced greater benefit from their participation. We believe this may be because of the algorithmic nature of the lessons. This coincides with the literature that the use of a step-by-step problem solving methodology may be gender biased in favor of females. (Zambo and Fallman; 1993)

Table 4: Summary of Gender Considered Problem Set Two-Tailed Independent *t*-tests

| | N | Mean | St. Dev. | St. Error Mean | *t* | *p* |
|---|---|---|---|---|---|---|
| Pre-test | | | | | 1.38 | .20 |
| Boy | 6 | 7.33 | 3.45 | 1.41 | | |
| Girl | 7 | 5.29 | 1.80 | .68 | | |
| Post-test | | | | | -.58 | .58 |
| Boy | 6 | 8.17 | 1.60 | .65 | | |
| Girl | 7 | 9.15 | 3.85 | 1.46 | | |

## 4.2 Interest Inventory Results

Another objective of this study was to evaluate if a solution of the Rubik's Cube was associated with an increase in the interest level of students in mathematics. To accomplish this, the statistical results of the pre-interest inventory and the post-interest inventory were analyzed. The results are shown in Table 4.

Table 5: Summary of Interest Inventory Results

| | N | Mean | Median | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| Pre-I.I. | 13 | 85.6 | 90 | 18.95 | 48 | 107 |
| Post-I.I. | 13 | 88.5 | 89 | 16.81 | 56 | 123 |

To determine if a statistically significant difference between the pre-interest inventory and post-interest inventory existed, another two-sample paired *t*-test was conducted. We obtained the difference between the pre and post - interest inventories and performed the statistical test based on that difference. The results are shown in Table 5.

Table 6: Summary of Interest Inventory Two-Sample Paired *t*-test

| N | Mean | St. Dev. | St. Error Mean | *t* | *p* |
|---|---|---|---|---|---|
| 13 | 2.8 | 16.31 | 4.53 | 0.62 | 0.54 |

Since our $p$ value is greater than $\alpha$, we conclude that there is no statistical difference between the means of the pre-interest inventory and the post-interest inventory. A copy of the interest inventory is located in the appendix.

**4.3 Student Interview Results**

At the completion of the lessons, seven students were randomly selected and interviewed. The questions asked were:

- I. Did you have fun learning to do the Rubik's Cube?
- II. At the completion of the lessons, were you able to solve the Rubik's Cube? If so, do you still need your cheat sheet to solve it?
- III. Were you excited about learning to do the Rubik's Cube? When was your interest sparked?
- IV. Was there a time you became disinterested? Why?
- V. Do you think the Rubik's Cube is related to math / problem solving? If so, in what way(s)?
- VI. Do you feel learning the Rubik's Cube was relevant to your studies? If so, why?
- VII. How much time did you spend outside of our lessons, playing with the Rubik's Cube?
- VIII. Do you feel more confident in your problem solving abilities? Why?

Table 6 displays the results of the student interviews:

Table 7: Summary of Student Interview Results

| | QI | QII | QIII | QIV | QV | QVI | QVII | QVIII |
|---|---|---|---|---|---|---|---|---|
| Student #1 (G) | Y | Y; N | Y | N | N | N | None | Y |
| Student #2 (B) | Y | Y; Y | Y | N | Y | N | 2-3 Hours | Y |
| Student #3 (B) | Y | Y; Y | No, When 1st color was made | Y, after falling behind class | Y | N | While watching TV | Y |
| Student #4 (B) | Y | N | Y | Y, after falling behind class | Y | N | None | Y |
| Student #5 (G) | Y | N | Y | N | Y | Y | None | Y |
| Student #6 (B) | Y | N | Y | Y, after falling | Y | N | 45 min. per day | Y |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | behind class | | | | |
| Student #7 (G) | Y | Y; Y | Y | N | Y | Y | Last period of day | Y |

We found that the students had fun while learning a solution to the Rubik's Cube and were excited about the idea of being introduced to a solution. They also felt the Rubik's Cube was related to problem solving, but did not feel the Rubik's Cube was related to their studies. Lastly, we found they felt more confident about their problem solving abilities after being introduced to the Rubik's Cube.

One response that we found interesting was that the students who became disinterested at some point during the lessons, all did so for essentially the same reason. Once students felt that they were falling behind, they became less interested in the solution to the Rubik's Cube. Another interesting aspect of the responses was that regardless of whether a student was able to solve the Rubik's Cube, all of the students felt more confident in their problem solving abilities. We were worried that if a student struggled with the Rubik's Cube, it might have a negative effect on their problem solving self efficacy, but this does not appear to be the case.

## 5. Conclusions

During our intervention, a solution to the Rubik's Cube was introduced to an eighth grade class. The main goal of this study was to enhance both the students' problem solving abilities and self efficacy in problem solving. The study also aimed to increase student interest in mathematics.

To determine if there was an improvement in the problem solving abilities of the students, a pretest and posttest were administered at the initiation and completion of the study. The results of the pretest and posttest indicated that there was a positive statistically significant difference between the means of the pretest and posttest. The individual problems on the pretest and posttest were also examined. Those results determined that there was a statistically significant difference between the means of problem 1, but no statistically significant difference between the means of the other problems. When the boys' and girls' scores were analyzed separately, we found a statistically significant difference between the means of the girls' pretest and posttest scores, but no statistically significant difference between the means of the boys' pretest and posttest scores. This result coincides with the findings of Zambo and Follman (1993). We feel this result may have been a product of the algorithmic approach implemented in the solution of the Rubik's Cube.

The students were also given an interest inventory at the initiation and completion of the study. The results yielded no statistically significant difference between the means of the students' interest inventories. This leads us to believe that a solution to the Rubik's Cube was not associated with an increase in students' interest in mathematics.

Finally, interviews were conducted on the final day of the study. Seven of the thirteen students were randomly chosen and asked a series of questions regarding their thoughts and feelings about the study. This portion of our data was qualitatively analyzed. Overall the students enjoyed their experience with the Rubik's Cube. They had fun during the course of the lessons, and were excited when introduced to the study. The major cause of disinterest towards the lessons occurred when a student began to feel that he or she was falling behind the rest of the class. This may have affected the boys and not the girls in the class because of the competitive nature of boys.

Regardless of their performance during the study, the students unanimously felt more confident in their problem solving abilities at the completion of the study. This leads us to believe that an introduction to the Rubik's Cube has a positive effect on the self-efficacy of students.

**Acknowledgement.** The authors wish to thank Dr. Gary Harris for his careful reading of the manuscript and for his helpful suggestions.

## References

Arizpe, O. (2006). *A problem Solving Application in Mathematics Education*. MS Thesis, Texas Tech University.

Bandura, A. (1995). *Self-Efficacy in Changing Societies*. New York: Cambridge University Press.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Englewood Cliffs, NJ: Prentice Hall.

Bandura, A., Barbaranelli, C., Caprara, G.V., & Pastorelli, C. (1996). "Multifaceted Impact of Self-Efficacy Beliefs on Academic Functioning." Child Development, Vol. 67, No. 3 (1996): 1206-1222.

Bandura, A., Barbaranelli, C., Caprara, G.V., & Pastorelli, C. (2001). "Self-Efficacy Beliefs as Shapers of Children's Aspirations and Career Trajectories", *Child Development*, Vol. 72, No. 1, 187-206.

Blum, H.T., & Yocom, D.J. (1996). "A Fun Alternative: Using Instructional Games to Foster Student Learning." *Teaching Exceptional Children*, Vol. 29 No.2, 60-63.

Brown, D. (1985). "Five Tips on Using Games Effectivly", *The Reading Teacher*, Vol. 39, No. 4, 819-820.

Charles, R. I., & Lester, F. K. Jr. (1984). "An Evaluation of a Process-Oriented Instructional Program in Mathematical Problem Solving in Grades 5 and 7", *Journal for Research in Mathematics Education*, Vol. 15, No. 1, 15-34.

Hanlon, E.H. & Schneider, Y. (1999). *Improving Math Proficiency through Self Efficacy Training*. U.S.; New York: Annual Meeting of the American Educational Research Assoc., ERIC Document Reproduction Service ED433236.

Klein, J.D. & Freitag, E. (1991). "Effects of Using an Instructional Game on Motivation and Performance", *Journal of Educational Research*, Vol. 84, No. 5, 303-308.

Lach, T. & Sakshaug, L. (2004). "The Role of Playing Games in Developing Algebraic Reasoning, Spatial Sense, and Problem-Solving", Focus on Learning Problems in Mathematics, Vol. 26, No.1, 34-42.

Lawson, M. J. (1990). "The Case for Instruction in the Use of General Problem-Solving Strategies in Mathematics Teaching: A Comment on Owens and Sweller", *Journal for Research in Mathematics Education*, Vol. 21, No. 5, 403-410.

Liu, M., Hsieh, P., Cho, Y., & Schaallert, D. (2006). "Middle School Students' Self-Efficacy, Attitudes, and Achievement in a Computer-Enhanced Problem-Based Learning Environment", *Journal of Interactive Learning Research*, Vol. 17, No. 3, 225-242.

Olson, J.L., & Platt, J.M. (1992). *Teaching Children and Adolescence with Special Needs*, New York: Merrill.

Owen, Elizabeth, & Sweller, J. (1989). "Should Problem Solving Be Used as a Learning Device in Mathematics?", *Journal for Research in Mathematical Education*, Vol. 20, No. 3, 322-328.

Ronning, R.R., & McCurdy, D.W. (1982). "The Role of Instruction in the Development of Problem-Solving Skills in Science", *What Research Says to the Science Teacher*, Vol. 4, 31- 41.

Stevens, T., & Olivárez, Jr., A. (2005) "Development of the Mathematics Interest Inventory", *Measurement & Evaluation in Counseling & Development*, Vol. 38, 141-152.

Stevens, T., Olivárez, A., Jr., Lan, W., & Tallent-Runnels, M.K. (2004). "The role of mathematics self-efficacy and motivation in mathematics performance: Issues across ethnicity", *Journal of Educational Research,*Vol. 97, 208-221.

Ufuktepe, U., & Ozel, C.T. (2002) *Avoiding Mathematics Trauma: Alternative Teaching Methods*, Hersonissos, Crete-Greece: 2nd International Conference on the Teaching of Mathematics, ERIC Document Reproduction Service ED477833.

Zambo, R., & Follman, J. (1994). "Gender-Related Differences in the Process of Solving Mathematical Word Problems at the 6th and the 8th Grade Levels", *Focus on Learning Problems in Mathematics*, Vol. 16, No. 2, 20-38.