Educational Sciences: Theory & Practice - 12(2) • Spring • 1173-1181

www.edam.com.tr/estp

The Relationship between Secondary School Pre-Service Mathematics Teachers' Skills in Problem Solving Dimensions and their Learning Style Characteristics

Kemal ÖZGEN[a]
Dokuz Eylül University

Hüseyin ALKAN
Dokuz Eylül University

Abstract

The present study examined the potential relationship between 1st and 5th year secondary school pre-service mathematics teachers' skills in understanding, method, modelling, verification, and extension dimensions of problem solving and their learning style characteristics. The data consisted of the skills pre-service teachers demonstrated in the solution process of open-ended problems. For this purpose, a graded scoring rubric was developed specific to each problem. Regarding the relationships between problem solving dimensions and the characteristics of McCarthy's learning styles, it was assumed that type 1 learners' skills were more dominant in the understanding dimension, type 2 learners' skills in the method and modelling dimensions, type 3 learners' skills in the verification dimension, and type 4 learners' skills in the extension dimension. On the basis of this assumption, problem-solving skills and learning style characteristics were associated and interpreted. The results obtained suggested that 5th year pre-service teachers were better in representing the skills pertaining to type 1 and type 2 learning styles, while 1st year pre-service teachers were better in representing the skills pertaining to type 1 learning style only. On the other hand, it was observed that a great majority of the pre-service teachers had a low level of the skills pertaining to type 3 and type 4 learning styles.

Key Words

Problem Solving Skills, Learning Style, Pre-Service Mathematics Teachers.

In order to interpret individual differences and to design educational models around these differences, individual learning styles have become an important consideration. Mutual characteristics of individual differences have been pivotal in the development of learning style models (Silver, Strong, & Perini, 1997). Kolb (1984) argued that individual differences in the learning process emerge in the perception/understanding and processing/transformation dimensions. According to Kolb's model, students are grouped in relation to their preferences for concrete experience or abstract conceptualisation (how students gain and comprehend knowledge) and active experimentation or reflective observation (how students transform and internalise knowledge) (Felder, 1996; Kolb).

According to McCarthy's (1985) learning styles model, dimensions of individual's understanding and processing are presented similar to Kolb's learning styles model; concrete experience (feeling/sensing) – abstract conceptualisation (thinking) and active experimentation (doing) – reflective observation (watching), respectively. McCarthy identified four types of individual learning styles which are determined by a combination of information perception and processing dimensions; type one learners (imaginative learners), type two learners (analytic learners), type three learners (commonsense learners), and type four learners (dynamic learners) (McCarthy, 1990).

The 4MAT learning system, developed by McCarthy based on Kolb's "Experiential Le-

a **Kemal ÖZGEN, Ph.D. Candidate,** is currently a research assistant at the Department of Secondary Sciences and Mathematics Education. His research interests include learning style, problem-based learning and mathematical literacy. Correspondence: Res. Assist. Kemal ÖZGEN, Dokuz Eylül University, Buca Faculty of Education, Department of Secondary Sciences and Mathematics Education, Izmir/Turkey. E-mail: kemal.ozgen@deu.edu.tr Phone: +90 505 5883065.

arning Theory" and Jung's "Personality Types Theory" and findings of brain studies, is a *"learning cycle"* model with 8 instructional events (McCarthy, 1990). Each of McCarthy's four quadrants of learning styles includes right and left mode brain and holistic oriented students. While a combination of alternative right and left mode techniques in all four learning styles enables students to be relaxed in the situations that are in line with their learning styles, it also allows the students to overcome difficulties in situations which are not within their learning style (McCarthy, 1990, pp. 32-33). The 8 instructional events of the 4MAT learning model are respectively: connect, attend, image, inform, practice, extend, refine, perform (McCarthy, Germain, & Lippitt, 2006, pp. 18-22).

Dunn (1983) argued that students could learn via learning methods convenient for themselves and approaches compatible to their learning styles. This widely emphasised approach requires a consideration of individual learning styles in mathematics education. Thus, the individual's learning style should be activated in all activities for learning mathematics. During the process of learning mathematics, a consideration for learning styles also assists teachers in choosing appropriate teaching strategies for whole learning to take place. Moreover, it also enables students' to take more responsibility in the learning process (Knisley, 2002; Leng & Hoo, 1997; Thompson & Mascazine, 1997).

According to Harb, Durrant and Terry (1991), each event in McCarhty's learning cycle also requires the selection of appropriate learning activities for students with dominant learning styles in all quadrants. Furthermore, they also believe that, in fact, there are different and similar learning activities, which would appeal to individual learning styles and could be placed in a certain quadrant intuitively. Learning activities to be designed for mathematics teaching can be arranged in line with the 4MAT learning style model and the National Council of Teachers of Mathematics (NCTM) (Best practices, 2006). Such an approach entails choosing mathematical structures within the real world, discovering and using the power of abstract thinking, experimenting and including interesting mathematical practices, respectively.

Leng and Hoo (1997) emphasised that a consideration of students' learning styles in mathematics learning process would increase student success. Elçi, Bukova-Güzel, and Alkan (2006) also stated that developing and using activities based on a constructivist learning approach and learning styles would provide students with important opportunities and significant advantages in constructing mathematical concepts. In short, emphasising students' learning styles during the mathematics learning process and reflecting them on the process have various benefits. In fact, students who are left to gain information in a format inconsistent with their own learning styles struggle in perceiving information, processing and reacting (Şimşek, 2006, p.114).

At this point, problem solving which is essential in mathematics learning can be discussed in relation to learning styles. McGehee (2001) argued that within a multidisciplinary approach to mathematics education, units could be developed based on the 4MAT system, Polya's problem solving steps and activity processes. McGehee related the first two events of the 4MAT system, connect and attend to the understanding the problem step of Polya's problem solving steps, image and inform to devising a plan, practice and extend to carrying out the plan, and refine and perform to the looking back step. As part of the mathematics learning process, it is essential for the individual to learn problem solving to acquire the necessary mathematical knowledge and skills in the real world because a solution to a problem encountered both at school and in real world involves the steps of *understanding the problem, devising a plan, carrying out the plan* and *looking back* (Polya, 1973). Only through problem solving skills can learners' mathematical knowledge be tested and skills be assessed (Baki, 2006, p. 147). Chapman (2005) asserted that problem solving plays an important role in doing, learning and teaching mathematics. Problem solving in mathematics also assists learners in understanding concepts and facilitates learners in defining a concept using their own words. When learners actively solve problems, they learn mathematics better because the learners do not learn mathematics as a pattern of facts, but they learn using "what" a mathematician does and "how" he/she does it (Northwest Regional Educational Laboratory [NWREL], 2000). Furthermore, according to NCTM (2000) and Ministry of National Education [MEB, 2005), problem solving is central to mathematics education. Accordingly, problem solving is not a topic *per se*, but a learning tool for all stages of learning. Similarly, Toluk and Olkun (2002), unlike the traditional verbal problem solving process, emphasised the necessity of perceiving problem solving as a tool for mathematics learning and teaching. Baykul and Yazıcı (2011) also stated that rather than teaching problem solving as a separate topic, it should be thought as a process comprising of problem solving activities for all concepts. Problem solving is not an end, on the contrary, it can be perceived as a process (Altun, 2000). In fact, during the process of problem solving, the strategy the learner develops and the steps used to obtain the solution are more important than the outcome. Therefore, the students are expected to solve open-ended problems that include all steps for the solution.

Open-ended questions are essential in that they falsify the belief that there can only be a single correct answer and that they provide all students an opportunity to use various learning strategies, deepen their mathematical knowledge and develop mathematical thinking according to their abilities (Klavir & Hershkovitz, 2008). In contrast, "*routine*" problem solving does not contribute to students' mental development (Polya, 1973). If the aim is to develop students' higher order behaviour such as understanding, analysis and discovery, the students should be involved in at least "*non-routine*" problem solving. Programme for International Student Assessment [PISA] studies conducted by Organisation for Economic Co-Operation and Development [OECD] (2003) are in support for such an idea because in non-routine problem solving students' mathematical literacy, performance and especially behaviours during the problem solving process are foregrounded. That is why open-ended problems selected from the real world or are related to the real world are preferred.

An observation of students' process of solving open-ended problems can lead to various meanings, strategies, models and inferences rooted in learning style differences because the student chooses alternatives which are appropriate to his/her own learning style and develops a relevant problem solving process (Leng & Hoo, 1997, p. 125). Likewise, Klavir and Hershkovitz (2008) indicated that "an investigation of open-ended problem solving process reveals individual differences among students and the analyses of these enable teachers to evaluate students' levels of mathematical knowledge and to get to know them better".

Previous studies have reported different approaches that extend Polya's problem solving steps (Gonzales, 1998; Mason, Burton, and Stacey, 1985 (as cited in Passmore, 2007); Verschaffel et al., 1999). A widespread view is that problem posing is not independent of problem solving, but they should be considered together (Cai & Hwang, 2002; Silver, 1994; Silver & Cai, 1996). In the present study, inspired by Polya's problem solving steps, a model of five steps was used. These were understanding, method, modelling, verification and extension, respectively.

Courses related to solving and teaching problems also exist in university mathematics teaching programmes. For example, one of these courses oriented towards problem solving was identified to include headings such as what a mathematical problem is, types of problems, problem solving steps and extending the problem ("Dokuz Eylül Üniversitesi Matematik Öğretmenliği", 2011).

Learning styles, like problem solving, is a popular research topic of mathematics education studies. These studies investigate students' learning styles and their academic success (Bilgin & Durmuş, 2003; Elçi, 2008; Tatar & Dikici, 2009; Uyangör & Dikkartın, 2009), their attitudes towards the mathematics course (Elçi, 2008; Orhun, 2007), their cognitive development levels (Johnson, 1999), their mathematics anxiety (Gresham, 2007; Peker, 2009; Sloan, Daene, & Giesen, 2002), their preferences of brain hemispheres (Ali & Kor, 2007) and their levels of geometric thinking (Özsoy, Yağdıran, & Öztürk, 2004) especially during the process of learning mathematics. However, there is a lack of research that extensively studies problem and problem solving, which is a major component of the process of mathematics learning, and learning style and characteristics. Thus, the findings of the present study, which investigated the skills involved in the problem solving process and students' learning style characteristics mentioned in McCarthy's learning styles model, are believed to fill this important gap.

The aim of this study was to investigate the skills of 1st and 5th year pre-service mathematics teachers in the understanding, method, modelling, verification, and extension dimensions of problem solving and to uncover the relationships between these skills and learning style characteristics.

Method

This study has a comparative research model as part of the descriptive method. The relationships between the variables are important in such research. A prerequisite of using the model is a comparison among situations with at least two variables (Çepni, 2007, p. 48). In order to investigate students' mathematical problem solving processes, writing activities, in other words written answers were investigated using document analysis. Earlier studies had argued for the benefits of writing about the applications of the problem solving process (Bell & Bell, 1985; Beswick & Muir, 2004; Pugalee, 2001; Taylor & McDonald, 2007; Williams, 2003). Ishii (2003) stated that problem solving is a type of writing. For the investigation of the problem solving process, Pugalee (2001) determined that students' writing could be used to explain the cognitive processes and that through their writings it was possible to understand how students learned and thought. Therefore, students' writings were used in this study in order to investigate their skills in the understanding, method, modelling, verification, and extension dimensions of the open-ended problem solving process.

Participants

84 1st and 5th year pre-service mathematics teachers studying the Secondary School Mathematics Education Programme at a state university participated in this study. The participants were selected from different year groups in order to identify pre-service mathematics teachers' levels at the beginning and end of the education and to allow for comparisons to reveal relative development. Among the participants, 56 pre-service teachers (66,7%) were 1st year students and 28 (33,3%) were 5th year students. In terms of gender, 46 participants (54,8%) were male, while 38 (45,2%) were female.

Data Collection Tool

For data collection, three open-ended problems were developed and used. Special care was taken to ensure that the problems would be related to real world situations and mathematical models. Content-wise, the problems included the concepts of functions, limits and continuity and the prerequisites of these concepts. Each problem had more than one solution step and was constructed in line with the principles of McCarthy's learning styles model. The solution process also supported three fundamentals of "*establishing relationships between the mathematical concept and prerequisites, real world and other disciplines*" (Elçi et al., 2006).

In order to investigate the level of skills in the sub dimensions of problem solving in detail, lead-in questions and instructions were used for the understanding, method, modelling, verification and extension dimensions. Hence, it was possible to investigate and compare pre-service teachers' skills in the problem solving dimensions and comment on relevant learning style characteristics.

Process

The data were collected in the spring term of the 2009-2010 academic year. Participating pre-service teachers did not receive any special training or information about problem solving and skills prior to the study. Pre-service teachers were requested to read the lead-in instructions and questions carefully for each problem in the data collection tool and answer accordingly.

In order to assess pre-service teachers' skills in problem solving dimensions a scoring rubric was developed and used. For the understanding dimension of problem solving, the identification of whether the students have completely understood the problem or not was important. For the method dimension, the selection of potentially appropriate methods for the solution of the problem and an emphasis on these methods in practice was in question. For the modelling dimension, constructing a mathematical model for the solution of the problem and demonstrating the accuracy and workability of the model were considered important. For the extension dimension, students were required to summarise the problem solving process and all results and to make deductions based on evidence. For the extension dimension, which foregrounded individuality, the skills of extending and developing the problem using various hypotheses and approaches were investigated. Problem solving performance levels were identified as "100, 75, 50, 25 and 0".

In order to test the reliability of the content analysis used for the analysis of qualitative data, analyses carried out by different people or by the same person at different times could be compared and contrasted (Gökçe, 2006, p. 83). For the assessment of the problems using the rubric, students' answers to the problems were evaluated by the researchers and their correlation coefficients were found to be between 0,72 and 0,86 following a *Pearson Product Moment Correlation* analysis. A correlation coefficient between 0,7-1.00 indicates a strong relationship (Büyüköztürk, 2005, p. 32).

According to McCarthy's learning styles model, type 1 learners would be more successful at meanings, type 2 learners at concepts, type 3 learners at skills and type 4 learners at performance

(McCarthy et al., 2006). The hypothesis for the relationships between problem solving dimensions and learning style characteristics was that type 1 learners' skills would be more dominant in understanding, type 2 learners' in methods and modelling, type 3 learners' in verification and type 4 learners' in extension dimensions. This hypothesis was used in creating relationships between problem solving skills and learning style characteristics and generating interpretations. In order to compare pre-service teachers' problem solving skills, mean score, frequency, percentage and t-test results were calculated for all three problems. Moreover, for the interpretation of mean scores in the dimensions of problem solving, scores between 0–39 were coded as *"low"*, scores between 40–59 as *"moderate"* and scores between 60–100 as *"high level"*.

Results

Pre-service teachers' mean scores in problem solving dimensions differ both among themselves and between the years. For example, the range of the mean scores of 1st year students was narrower than that of 5th year students. In other words, while the mean scores of 1st year students were not much different, the mean score of 5th year students were more varied and there were students at upper and lower levels.

In the understanding dimension 64,3% of 1st year students and 96,4% of 5th year students obtained high scores. However, 35,7% of 1st year students and 89,2% of 5th year students obtained high scores for the method dimension. In the modelling dimension, 3,6% of 1st year students and 50% of 5th year students obtained high scores, while in the verification dimension 5,4% of 1st year students and 39,3% of 5th year students obtained high scores. In the extension dimension, only 5,4% of 1st year students and 25% of 5th year students obtained high scores. In this dimension, an average of 85% of students received low scores.

An analysis of the mean scores indicated that in all dimensions, understanding, method, modelling, verification and extension, mean scores of 5th year students were higher than that of 1st year students. While the mean score of 1st year students for all dimensions was [illegible], that of 5th year students reached [illegible]. For both classes, the mean scores for the problem solving process gradually decreased from understanding to extension. Moreover, mean scores of 1st year students for all dimensions except understanding and mean scores of 5th year students for extension in particular were at low levels. Mean scores of 5th year students were at high levels in understanding and method dimensions, while mean scores of 1st year students were high only in the understanding dimension. However, mean scores of 1st year students were generally moderate in the method dimension and low in other dimensions. Interesting findings include high mean scores of 5th year students and low mean scores of 1st year students in modelling and verification dimensions and low mean scores of students in both years in the extension dimension. Given the lowest and highest mean scores, overall, 1st year students obtained lower mean scores.

The fact that most of 1st and 5th year students' mean scores were high in the understanding dimension could be accepted as an indication that most of the students had type 1 learner characteristics. In the method dimension, most 1st year students' mean scores were moderate, while most 5th year students' mean scores were high. This implied that most 5th year students had a high level of type 2 learner characteristics and 1st year students had a moderate level of type 2 learner characteristics. In the modelling dimension, most 1st year students' mean scores were low, while most 5th year students' mean scores were high. This meant that most 5th year students had a high level of type 2 learner characteristics, while 1st year students had a low level of type 2 learner characteristics. In the verification dimension, most 1st year students' mean scores were low, while most 5th year students' mean scores were moderate. Thus, 5th year students had a moderate level of type 3 learner characteristics and some of 1st year students had a low level of type 3 learner characteristics. Finally, in the extension dimension, the mean scores emphasised that most 5th year students had a moderate level of type 4 learner characteristics and 1st year students had a low level of type 4 learner characteristics.

Pre-service mathematics teachers' scores in the dimensions of problem solving were significantly different in terms of year groups; understanding [$t_{(82)}$=-6,603, p<.05], method [$t_{(82)}$=-8,871, p<.05], modelling [$t_{(82)}$=-7,642, p<.05], verification [$t_{(82)}$=-6,539, p<.05] and extension [$t_{(82)}$=-4,694, p<.05]. The difference was in favour of year 5. The findings implied that there was a significant relationship between year groups and the skills in problem solving dimensions.

Discussion

According to the findings, pre-service teachers' mean scores for the problem solving dimensions were varied. Although this could be perceived as normal due to individual differences, having low scores at the lower limit was significant. In other words, pre-service teachers were not able to completely and accurately use the process and dimensions of problem solving. Especially the dimensions of verification and extension seemed redundant for the pre-service teachers, yet the final year pre-service teachers, who had been through a long-term education were expected to have higher level skills in all sub-dimensions of problem solving. The expectation is for the pre-service teachers to be above a certain standard in order to become effective and qualified teachers. Similar and low mean scores of 1st year students' could be due to their lack of theoretical knowledge and skills in relation to problem solving dimensions. Given that these students might not have solved any problems in the previous years, this outcome is normal. Studies that investigate pre-service mathematics teachers problem solving skills indicated that their skills of using multiple representations in the problem solving process was insufficient (Delice & Sevimli, 2010) and that strategies used in problem solving were limited (Altun & Sezgin-Memnun, 2008; Avcu & Avcu, 2010). These findings suggest that pre-service teachers encounter difficulties in mathematical problem solving.

On the other hand, other research reported that following training for problem solving, positive changes were observed in students' knowledge and views on problem solving and skills (Akay & Boz, 2009; Bukova-Güzel, 2010; Bulut & Tat, 2009; Kandemir & Gür, 2009; Toluk-Uçar, 2009). These findings contradict the outcomes of the present study in relation to 5th year students' problem solving skills because although these students had taken courses and training for problem solving, their low levels of skills especially in some dimensions call for an examination of the education process.

Students reveal their individual differences via their preferences in perceiving and processing knowledge during the learning process (Kolb, 1984; McCarthy, 1997). Therefore, individual differences in problem solving dimensions were expected. However, according to McCarthy and Kolb's learning style models, individuals have a dominant learning style, but individuals also have some skills in all other learning styles. In other words, the individual can use secondary, tertiary or the least preferred learning styles which assist the dominant learning style. Likewise, Gardner (2004), in his theory of multiple intelligences, indicated that individuals have abilities in all intelligence types, but one is more dominant than the others. In particular, McCarthy et al. (2006) stated that learning occurs in a cycle and with the characteristics and skills of all four styles. However, the findings of this study suggested that the students did not feel the need to use their secondary or tertiary preferences. Yet, this could be due to the education system or at least could be interpreted as a constraint of the data collection tools.

The findings of this study indicated that most 5th year students were better at reflecting type 1 and type 2 learners' skills in McCarthy's learning styles model, which means their dominant learning style or secondary dominant learning style could be type 1 or type 2. Moreover, most 5th year students used type 3 and type 4 learner skills relatively less or preferred them as secondary or tertiary. Most 1st year students had moderate scores in method dimension and low scores in modelling dimension and thus, most students seemed to prefer type 2 learning style as tertiary or they preferred it the least. Most 1st year students reflected type 3 and type 4 learner skills less and hence their least preferred styles could be these. In a similar study, Narlı, Özgen, and Alkan (2011) identified learning styles using rough set data analysis in relation to pre-service mathematics teachers' multiple intelligence areas. The findings mathematically identified to what extent pre-service teachers had other learning styles in addition to their dominant learning styles.

Similar results were obtained in earlier studies. For example, research by Elçi (2008), Peker, Mirasyedioğlu, and Aydın (2004) and Orhun (2007) demonstrated that there were different findings in relation to pre-service mathematics teachers learning styles. This could be due to the participants of the studies. However, it is a common fact that the number of type 4 learners is considerably low in most studies. Likewise, Dede and Yaman (2005) and Kar, Özdemir, İpek and Albayrak (2010) stated that pre-service mathematics teachers' problem posing levels were generally low and they had serious difficulties; and Işık and Kar (2011) found that primary school students' skills of number sense and solving non-routine problems were low and that there was a positive relationship between these skills. These results overlap with the findings of this study that most 5th year students did not achieve high levels in reflecting type 3 and type 4 learners' skills and had low levels of skills especially in relation to the extension dimension of problem solving which is related to type 4 learning.

1st year students, on the other hand, did not differ much in the learning cycle and had similar skills. Although most students reflected type 1 learner skills at a high level, it is a significant drawback that they had low scores in relation to skills of other learning types. This outcome is mostly rooted in the learning environment and the methods applied in the learning processes prior to university education. Previous studies conducted in Turkey reported that primary school and secondary school students struggle in problem solving (Altun & Arslan, 2006; Işık & Kar, 2011; Karataş & Güven, 2004; Soylu & Soylu, 2006). Moreover, given 5th year students' behaviour and levels, university learning and teaching approaches might also have fallen short to completely eliminate the difficulty.

Schools embrace learning approaches based on left-brain more and neglect learning activities based on right brain. We believe that this potentially accounts for the current findings. By adding right-brain activities such as intuition, imagination, creativity, synthesis, and researching patterns and relationships to the educational system, students can develop their low level skills. Kitchens, Barber, and Barber (1991) suggested that left – right brain preferences are important in mathematics education and especially in understanding students' mathematical development. Furthermore, they reported that the number of students' with right-brain preferences is considerably high at school that are restrained by learning approaches based on the left-brain. In most mathematical learning processes and especially in the problem solving process, students are expected to have and use both logical and intuitive skills. Therefore, students should be trained using alternative learning activities in relation to both left and right hemispheres of the brain.

The reason why students' scores decrease from the understanding dimension to the extension dimension should be questioned and the reasons why they could not sufficiently reflect type 3 and 4 learning style skills in McCarthy's learning cycle should be examined. What's more, although learning styles are relatively constant, they could change under certain circumstances. Elçi (2008) reported that as a result of learning environments designed according to learning styles, learning styles changed. As presented in the findings of this study, students had low levels of skills especially in relation to type 3 and 4 learning styles. At all levels of education learning environments and activities that would develop these skills should be included and necessary guidance should be provided.

It is typical for pre-service teachers to have a dominant learning style. What is not typical is the fact that they did not use the skills in relation to all learning styles of McCarthy's learning cycle at least to a certain extent. Yet, Bukova-Güzel, Elçi, and Alkan (2006) found that learning activities based on the constructivist learning approach and learning styles significantly contributed to the learning process. Pre-service mathematics teachers should be made aware of the importance of learning styles in their education. Thus, they should be encouraged to acquire knowledge, skills and abilities of different learning styles at least to a certain extent and to design their own learning environments, activities and testing-evaluation processes and reflect these in their applications. Such a teaching approach would pave the way for both the students and pre-service teachers in their future teaching careers to feel relaxed with students who have different learning styles in the learning and teaching process. On the other hand, mathematics teachers at secondary and primary schools should leave teaching approaches geared towards one learning style and facilitate students' learning processes with multiple approaches and a consideration of learning style principles. In order to do so, in-service courses and seminars could be organised for teachers. Moreover, activities and materials appropriate for multiple learning approaches could be prepared in order to develop and advance students' non-dominant learning styles to a certain level in addition to their dominant learning styles.

In order to decrease the limitations of the measures used to identify learning styles and to obtain more extensive information about learning styles, students' skills in problem solving dimensions and learning styles could be interpreted in terms of the mathematics learning process, as in the present study. Future research could investigate various problems with larger samples to prove this hypothesis.

References/Kaynakça

Akay, H., & Boz, N. (2009). Prospective teachers' views about problem poesing activities. *Procedia Social and Behavioral Sciences, 1* (1), 1192-1198.

Ali, R. M., & Kor, L. K. (2007). Association between brain hemisphericity, learning styles and confidence in using graphics calculator for mathematics. *Eurasia Journal of Mathematics, Science & Technology Education*, *3* (2), 127-131.

Altun, M. (2000). İlköğretimde problem çözme öğretimi. *Milli Eğitim Dergisi, 147,* http://yayim.mebgov.tr/dergiler/147/altun.htm adresinden 01.06.2011 tarihinde edinilmiştir.

Altun, M. ve Arslan, Ç. (2006). İlköğretim öğrencilerinin problem çözme stratejilerini öğrenmeleri üzerine bir çalışma. *Uludağ Üniversitesi Eğitim Fakültesi Dergisi, 19* (1), 1-21.

Altun, M. ve Sezgin-Memnun, D. (2008). Matematik öğretmeni adaylarının rutin olmayan matematiksel problemleri çözme becerileri ve bu konudaki düşünceleri. *Eğitimde Kuram ve Uygulama, 4* (2), 213-238.

Avcu, S., & Avcu R. (2010). Pre-service elementary mathematics teachers' use of strategies in mathematical problem solving. *Procedia Social and Behavioral Sciences, 9,* 1282-1286.

Baki, A. (2006). *Kuramdan uygulamaya matematik eğitimi.* Ankara: Derya Kitabevi.

Baykul, Y., & Yazıcı, E. (2011, April). *Problem solving in elementary mathematics curriculum*. Paper presented at the 2nd International Conference on New Trends in Education and Their Implications, Antalya, Turkey.

Bell, E. S., & Bell, R. N. (1985). Writing and problem solving: Arguments in favour of synthesis. *School Science and Mathematics, 85* (3), 210-221.

Best practices. (2006). Retrieved August 28, 2006 from www.aboutlearning.com.

Beswick, M. & Muir, T. (2004). Talking and writing about the problem solving process. In I. Putt, R. Faragher & M. McLean (Eds.), *Mathematics education for the third millennium: Towards 2010: Proceedings of the 27th annual conference of the Mathematics Education Research Group of Australasia* (Vol 1, pp 95-102) Sydney: MERGA. Retrieved June 15, 2011 from http://www.merga.net.au/documents/RP92004.pdf

Bilgin, İ. ve Durmuş, S. (2003). Öğrenme stilleri ile öğrenci başarısı arasındaki ilişki üzerine karşılaştırmalı bir araştırma. *Kuram ve Uygulamada Eğitim Bilimleri, 3* (2), 381-400.

Bukova-Güzel, E. (2010). An examination of pre-service mathematics teachers' approaches to construct and solve mathematical modelling problems. *Teaching Mathematics and Its Applications*, *30* (1), 19-36.

Bukova-Güzel, E., Elçi, A. N. ve Alkan, H. (2006, Eylül). *Çok yönlü etkinlik yaklaşımı ile matematiksel kavram oluşturma*. VII. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi'nde sunulan bildiri, Gazi Üniversitesi Eğitim Fakültesi, Ankara.

Bulut, S. ve Tat, E. T. (2009, Ekim). *Öğretmen adaylarının matematiksel problem çözme performanslarının incelenmesi.* 18. Ulusal Eğitim Bilimleri Kurultayı'nda sunulan bildiri, Ege Üniversitesi Eğitim Fakültesi, İzmir.

Büyüköztürk, Ş. (2005). *Sosyal bilimler için veri analizi el kitabı* (5. bs). Ankara: PegemA Yayıncılık.

Cai, J., & Hwang, S. (2002). Generalized and generative thinking in U.S. and Chinese students' mathematical problem solving and problem posing. *Journal of Mathematical Behavior, 2* (1), 401-421.

Chapman, O. (2005). Constructing, pedagogical knowledge of problem solving: pre-service mathematics teachers. In H. L. Chick, & S. L. Vincent (Eds.), *Proceedings of the 29th Conference of the International Group for the Psychology of Mathematics Education* (Vol.2, pp. 225-232). Melbourne: International Group for the Psychology of Mathematics Education.

Çepni, S. (2007). *Araştırma ve proje çalışmalarına giriş* (3. bs). Trabzon: Celepler Matbaacılık.

Dede, Y. ve Yaman, S. (2005). Matematik öğretmen adaylarının matematiksel problem kurma ve problem çözme becerilerinin incelenmesi. *Eğitim Araştırmaları*, *18,* 236-252.

Delice, A. ve Sevimli, E. (2010). Öğretmen adaylarının çoklu temsil kullanma becerilerinin problem çözme başarıları yönüyle incelenmesi: belirli integral örneği. *Kuram ve Uygulamada Eğitim Bilimleri, 10* (1), 137-149.

Dokuz Eylül Üniversitesi Matematik Öğretmenliği Ders İçerikleri. (2011). http://www.deu.edu.tr/DEUWeb/Icerik/Icerik.php?KOD=7802 adresinden 01.06.2011 tarihinde edinilmiştir.

Dunn, R. (1983). Can students identify their own learning style? *Educational Leadership*, *40* (5), 60-62.

Elçi, A. N. (2008). *Öğrenme stillerine uygun olarak seçilen öğrenme yöntemlerinin öğrenci başarısına, matematiğe yönelik tutumuna ve kaygısına etkileri*. Yayımlanmamış doktora tezi, Dokuz Eylül Üniversitesi, Eğitim Bilimleri Enstitüsü, İzmir.

Elçi, A. N., Bukova-Güzel, E., ve Alkan, H. (2006, Nisan). *Yapılandırmacı öğrenme yaklaşımına uygun çalışma yaprakları*. Eğitimde Çağdaş Yönelimler-III: "Yapılandırmacılık ve Eğitimde Yansımaları" Sempozyumu'nda sunulan bildiri, Tevfik Fikret Okulları, İzmir.

Felder, R. M. (1996). Matters of style. *ASEE Prism*, *6* (4), 18-23.

Gardner, H. (2004). *Zihin çerçeveleri çoklu zeka kuramı* (çev. E. Kılıç). İstanbul: Alfa.

Gonzales, N.A. (1998). A blueprint for problem posing. *School Science and Mathematics, 98* (8), 448-465.

Gökçe, O. (2006). *İçerik analizi. Kuramsal ve pratik bilgiler.* Ankara: Siyasal Kitabevi.

Gresham, G. (2007). An invitation into the investigation of the relationship between mathematics anxiety and learning styles in elementary preservice teachers. *Journal of Invitational Theory and Practice*, *13*, 24-33.

Harb, J. N., Durrant, S. O., & Terry, R. E. (1991, September). *Use of the 4MAT system in engineering education*. Paper presented at the 21st Annual Frontiers in Education Conference, Purdue, IN.

Ishii, D.K. (2003). First-time teacher-researchers use writing in middle school mathematics instruction. *The Mathematics Educator, 13* (2), 38-46.

Işık, C. ve Kar, T. (2011). İlköğretim 6, 7 ve 8. Sınıf öğrencilerinin sayı algılama ve rutin olmayan problem çözme becerilerinin incelenmesi. *Ahi Evran Üniversitesi Eğitim Fakültesi Dergisi, 12* (1), 57-72.

Johnson, S. L. S. (1999). *The relationship among the cognitive development level, learning style and retention of preservice elementary teachers in a content course in mathematics*. Unpublished doctoral dissertation, The University of Oklahoma, Graduate College, Norman, Oklahoma.

Kandemir, M. A., & Gür, H. (2009). The use of creative problem solving scenarios in mathematics educatiın: views of some prospective teachers. *Procedia Social and Behavioral Sciences, 1* (1), 1628-1635.

Kar, Ö., Özdemir, E., İpek, A. S., & Albayrak, M. (2010). The relation betweeen tje problem posing and problem solving skills of prospective elementary mathematics teachers. *Procedia Social and Behavioral Sciences, 2* (2), 1577-1583.

Karataş, İ. ve Güven, B. (2004). 8.sınıf öğrencilerinin problem çözme becerilerinin belirlenmesi: Bir özel durum çalışması. *Milli Eğitim Dergisi, 163,* 132-143.

Kitchens, A. N., Barber, W. D., & Barber, D. B. (1991). Left brain / right brain theory: Implications for developmental math instruction. *Review of Research in Developmental Education, 8* (3), (ERIC ED 354 963).

Klavir, R., & Hershkovitz, S. (2008). Teaching and evaluating "open-ended" problems. *International Journal for Mathematics Teaching and Learning*. May 20th. Retrieved May 10, 2010 from http://www.cimt.plymouth.ac.uk/journal/default.htm

Knisley, J. (2002). A four-stage model of mathematical learning. *The Mathematics Educator*, *12* (1), 11-16.

Kolb, D. A. (1984). *Experiential learning: experience as the source of learning and development*. New Jersey: Prentice Hall.

Leng, Y. L., & Hoo, C. T. (1997). Exploring the thinking, learning styles and cognition constructs. *The Mathematics Educator, 2* (1), 113-127.

McCarthy, B. (1985). What 4MAT training teaches us about staff development. *Educational Leadership*, *42* (7), 61-68.

McCarthy, B. (1990). Using 4MAT system to bring learning styles to schools. *Educational Leadership*, *48* (1), 31-37.

McCarthy, B. (1997). A tale of four learners: 4MAT's learning styles. *Educational Leadership*, *54* (6), 46-51.

McCarthy, B., Germain, C. S., & Lippitt, L. (2006). *The 4MAT research guide, reviews of literature on individual differences and hemispheric specialization and their influence on learning*. Illinois: About Learning Incorporated.

McGehee, J.J. (2001). Developing interdisciplinary units: A strategy based on problem solving. *School Science and Mathematics, 101* (7), 380-389.

Milli Eğitim Bakanlığı (MEB). (2005). *Matematik dersi öğretim programı ve kılavuzu (9-12.Sınıflar)*. Ankara: Yazar.

Narlı, S., Özgen, K., & Alkan, H. (2011). In the context of multiple intelligences theory, intelligent data analysis of learning styles based on rough set theory. *Learning and Individual Differences*, *21* (5), 613-618.

National Council of Teachers of Mathematics (NCTM). (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

Northwest Regional Educational Laboratory (NWREL). (2000). *Mathematics problem solving.* Northwest Regional Educational Laboratory Mathematics and Science Education Center. Retrieved November 24, 2006 from http://www.nwrel.org/msec

Organisation for Economic Co-Operation and Development (OECD). (2003). *The PISA 2003 assessment framework – mathematics, reading, science and problem solving knowledge and skills*. Paris: OECD.

Orhun, N. (2007). An investigation into the mathematics achievement and attitude towards mathematics with respect to learning style according to gender. *International Journal of Mathematical Education in Science and Technology*, *38* (3), 321-333.

Özsoy, N., Yağdıran, E., ve Öztürk, G. (2004). Onuncu sınıf öğrencilerinin öğrenme stilleri ve geometrik düşünme düzeyleri. *Eğitim Araştırmaları, 16,* 35-48.

Peker, M. (2009). Pre-service teachers' teaching anxiety about mathematics and their learning styles. *Eurasia Journal of Mathematics, Science and Technology Education*, *5* (4), 335-345.

Peker, M., Mirasyedioğlu, Ş. ve Aydın, B. (2004). Matematik öğretmenlerinin dikkate alabilecekleri öğrenme stilleri: McCarthy modeli. *Milli Eğitim Dergisi*, *163,* 72-81.

Passmore, T. (2007). Polya's leagacy: Fully forgotten or getting a new perspective in theory and practice? *Australian Senior Mathetmatics Journal, 21* (2), 44-53.

Polya, G. (1973). *How to solve it – a new aspect of mathematical method*. New Jersey: Princeton University Press.

Pugalee, D. K. (2001). Writing, mathematics, and metacognition: Looking for connections thorugh students' work in mathematical problem solving. *School Science and Mathematics, 101* (5), 236-245.

Silver, E. A. (1994). On mathematical problem posing. *For the Learning of Mathematics, 14* (1), 19-28.

Silver, E. A., & Cai, J. (1996). An analysis of arithmetic problem posing by middle school students. *Journal for Research in Mathematics Education, 27* (5), 521-539.

Silver, H., Strong, R., & Perini, M. (1997). Integrating learning styles and multiple intelligences. *Educational Leadership*, *55* (1), 22-27.

Sloan, T., Daene, C. J., & Giesen, J. (2002). Mathematics anxiety and learning styles: What is the relationship in elementary preservice teachers? *School Science and Mathematics*, *102* (2), 84-87.

Soylu, Y. ve Soylu, C. (2006). Matematik derslerinde başarıya giden yolda problem çözmenin rolü. *İnönü Üniversitesi Eğitim Fakültesi Dergisi, 7* (11), 97-111.

Şimşek, A. (2006). Öğrenme biçimi. Y. Kuzgun, ve D. Deryakulu (Ed.), *Eğitimde bireysel farklılıklar* içinde (s. 97-138). Ankara: Nobel Yayın Dağıtım.

Tatar, E., & Dikici, R. (2009). The effect of the 4MAT method (learning styles and brain hemisphere) of instruction on achievement in mathematics. *International Journal of Mathematical Education in Science and Technology*, *40* (8), 1027-1036.

Taylor, J. A., & McDonald, C. (2007). Writing in groups as a tool for non-routine problem solving in first year university mathematices. *International Journal of Mathematics Education in Science and Technology, 38* (5), 639-655.

Thomson, B. S., & Mascazine, J. R. (1997). *Attending to learning styles in mathematics and science classrooms* (ERIC ED 432440).

Toluk, Z. ve Olkun, S. (2002). Türkiye'de matematik eğitiminde problem çözme: İlköğretim 1. ve 5. sınıflar ders kitapları. *Kuram ve Uygulamada Eğitim Bilimleri, 2* (2), 579-582.

Toluk-Uçar, Z. (2009). Developing pre-service teachers understanding of fractions through problem posing. *Teaching and Teacher Education, 25* (1), 166-175.

Uyangör, S. M. ve Dikkartın, F. T. (2009). 4MAT öğretim modellerinin öğrencilerin erişileri ve öğrenme stillerine etkisi. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi*, *3* (2), 178-194. http://www.nef.balikesir.edu.tr/~dergi adresinden 17 Mayıs 2010 tarihinde edinilmiştir.

Verschaffel, L., De Corte, E., Lasure, S., Van Vaerenbergh, G., Bogaerts, H., & Ratinckx, E. (1999). Learning to solve mathematical application problems: A design experiment with fifth graders. *Mathematical Thinking and Learning, 1* (3), 195-229.

Williams, K. (2003). Writing about the problem solving process to improve solving performance. *The Mathematics Teacher, 96* (3), 185-187.