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Evaluation of numerical analysis course problem-solving processes of engineering students based on different dimensions

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Abstract

In this study, the aim is to evaluate the problem-solving processes in the understanding of problems and to determine and provide strategies, demonstration, expression and problem-writing dimensions in a numerical analysis course for engineering students. The quantitative data and qualitative data were interpreted using exploratory sequential method. The study group consisted of 20 students who took numerical analysis courses in the engineering faculty in a private university in Northern Cyprus. The data of the study were collected by means of an interview form consisting of common question problem solutions and open-ended questions that were asked to these students. The problem-solving processes of the students participating in the research were evaluated along with the solutions they derived for common problems and were analysed on the basis of the four different dimensions mentioned above. As a result of these analyses, it was concluded that the students understood the problems at an intermediate level and did not have sufficient infrastructure in the strategy determination, provision, demonstration and expression dimensions, and the majority could not write problems. In addition, in the light of the findings obtained from the interview form, it was emphasised that the numerical analysis course should be supported in the laboratory.

Keywords: Numerical analysis, mathematics, problem-solving process, engineering students.

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1. Introduction

Teachers ask questions for students to provide explanations and evidence about their work. They use different expressions of mathematical ideas to enable students to gain a better mathematical understanding. These teachers ask their students to explain mathematics. At this point, teachers are expected to solve different problems, apply mathematics to real-life conditions and develop their knowledge. In some cases, they use a calculator, and in others, they use pen and paper (Tezer & Cumhur, 2016; Tezer, Yildiz, Bozkurt & Tangul, 2019).

Although the word 'engineering' has several meanings, it is basically used to imply design geometry, mathematics and science. Engineering education is part of science, technology, engineering and mathematics (STEM) global standards of education that engineering students receive based on the concepts of general and scientific creativity (Demir, 2011).

Mathematics has an important role in the education of students. It is known that knowledge, skills and other learning acquired through the learning of mathematics have an important function in increasing the cognitive development level of individuals and determining their social status. Therefore, in mathematics teaching, efforts to find the best methods and systems are subjected to intensive discussions and research. This issue is also the focus of a process that is occurring on a global scale, which is referred to as change (or reform) movements in mathematics education. Particularly in the past decade, it has been observed that there have been fundamental changes in mathematics education, as a result of both the radical transformations in education. Within this framework, mathematics teaching programs have also been restructured (Baki, 2008; Yurday, 2006).

In the renewed curricula, it is aimed that all students will discover, find and make decisions, make logical inferences and develop as problem solvers by using mathematical methods effectively (Baki, 2008; Yurday, 2006). Therefore, the importance of computational skills is diminishing in the new mathematics programs, whereas 'why' and 'how' questions are gaining importance in learning the subjects and concepts (Cakmak, 1998; Yurday, 2006). As a result, one of the aims of the new programs is to enable students to understand mathematical concepts and systems and to establish relationships between them.

Problem solving is one of the most important elements of mathematics. When students learn to solve problems, it is important that they are able to effectively implement the different stages, such as understanding the problem, generating ideas for the solution, applying these ideas and checking the solution. In this process, understanding the problem and defining and providing strategy, demonstration, expression (communication) and problem writing are all important factors (MEB, 2016). With these elements, it is important to include the necessary teaching practices for the students to become effective in problem solving (Falyali, 2015).

Mathematics is a very difficult course for students. It is one of the courses, in which students have the least amount of success in examinations (Sisman, 2007). According to Baykul (2002), many students develop negative attitudes toward mathematics based on the perception that mathematics, in general, and geometry, in particular, are difficult.

In this study, the four-stage problem-solving process proposed by George Polya (understanding the problem, choosing the strategy about the solution, applying the chosen solution and evaluating the solution) was adapted to the numerical analysis course of the engineering students, where the aim of the course is to evaluate the problem-solving processes in terms of understanding the problem and determining and providing strategy, demonstration, expression and problem writing.

In this study, the numerical analysis course was limited to the following topics: error analysis (error sources and error types), Taylor polynomials and Taylor series, root-finding methods for nonlinear equation systems (bisection method, fixed-point iteration, Newton method, secant method and Regula–Falsi method), iterative methods for systems of linear equations (Jacobi iteration and Gauss–Seidel iteration), interpolation and polynomial approaches (Lagrange interpolation polynomial,

Neville's interpolation polynomial and Newton difference interpolation polynomial), numerical differentiation (forward, backward and central difference formula) and numerical integral (rectangle method, trapezoid method, Simpson's 1/3 method and Simpson's 3/8 method).

2. Method

In the research, the exploratory sequential mixed method was used, which is one of the mixed methods. The interview form was applied to the students, and the data obtained from the common questions were analysed and interpreted with frequency findings. The mixed method involves the collection of qualitative and quantitative data for research questions or hypotheses. In general, the mixed method is preferred because it minimises the limitations of both approaches and has the power to combine qualitative and quantitative research (Creswell, 2013).

2.1. Study group

The study group consisted of 20 students who took the numerical analysis course in the engineering faculty (computer, electrical and electronics, mechanical, petroleum and natural gas and civil and automotive engineering departments) of a private university in Northern Cyprus. Engineering students (n = 20) were interviewed to determine their views on the problem-solving processes of the numerical analysis course. In the semester 2018–2019 Summer, this course is limited to 20 students. These 20 students constituted the sample of the study. In addition, the simple random sampling method was used.

2.2. Data collection tools

The research data were collected with a semi-structured interview form and common problem solutions. For this purpose, an interview form consisting of seven questions that would be asked by the researchers (n = 2) was prepared. During the preparation of the interview form, it was ensured that the questions were prepared in the form of main headings and all interviews with the students were conducted face-to-face by the researcher between 15 July and 31 July 2019. During the interviews, all the obtained data were recorded in written form.

Expert opinions about the reliability and validity of the interview form were obtained, and the interview form was made ready for implementation (n = 4; one professor in the education curricula and teaching department, one assistant professor in the elementary mathematics teaching department and two mathematics lecturers working at the university).

Table 1. Interview form questions

1)	Do you think that it will be more beneficial to study the numerical analysis course in a laboratory environment (when supported by programs such as MATLAB and Fortran)? Why?
2)	Explain what difficulties you have faced in solving the problems of the numerical analysis course.
3)	Are you able to establish a relationship between the subjects learned in the numerical analysis course and the problems you encounter in your department?
4)	How should this course be taught so that the learning at the numerical analysis course can be made permanent? Please explain.
5)	Explain your strengths and weaknesses in learning the content in the numerical analysis course.
6)	Do you think you have sufficient background for the numerical analysis course? If not, where do you think that the problem stems from? (Lack of prerequisite courses, lack of program knowledge, problems using calculators and so on)
7)	Do you think that the numerical analysis course is a necessary course in the Faculty of Engineering? If so, please explain why?

The same questions as shown in Table 1 were also asked to engineering students to determine their understanding of the problem-solving process and determining and providing strategies, demonstration, expression and problem writing in the numerical analysis course.

2.3. Data analysis methods

Content analysis was applied to the qualitative data obtained as a result of the research. Content analysis was conducted by the researchers by coding the data, finding and arranging the themes and, finally, defining and interpreting the findings. Based on the comments obtained in accordance with the findings of the research, the results of the students' numerical analysis course were evaluated in terms of understanding problem solving and determining and providing strategy, demonstration, expression and problem writing.

The graphic given below belongs to the function $y = x^3 - 6x^2 + 9x$. Solve the area of the region shown as the R region using any integral method, assuming *n* = 6. Obtain the result closest to the actual result by specifying why you chose this method.

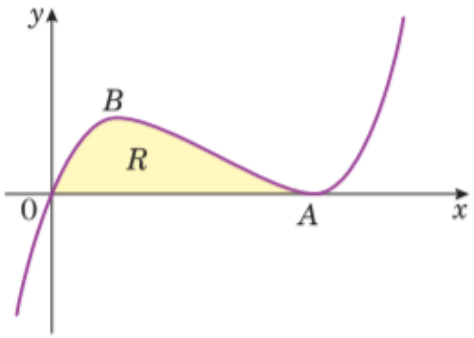

Figure 1. Numerical analysis course problem question-1

The problem-solving process of the numerical analysis course of the students was evaluated based on the following criteria.

a) Understanding the problem:

- Excellent
- Good
- Intermediate degree of understanding of the problem is evaluated.

b) Strategy determination and check:

In this process, elements of information gathering, editing and interpretation, estimation and reasoning, separation into smaller problems, expressing the result and explaining why it is correct were applied. Four kinds of integral methods are taught to solve the given integral. These are as follows:

- Rectangle method
- Trapezoid method
- Simpson 1/3 method
- Simpson 3/8 method

c) Demonstration and expression:

The demonstration and expressions for this question are summarised as follows:

- Finding intersections with the *x*-axis of the integral
- Calculating the required step size which is defined by *h*
- Data table including the part required to calculate the integral on the *x*-axis after being broken into pieces and finding its function values
- Analytical solution of the given integral
- The error term showing the difference between the obtained approximate solution and the analytical solution

d) Problem writing (writing appropriate problem based on a given result):

The problem writing dimension was evaluated by asking the question 'Write a problem related to *your department and solve it in the light of the information you have learned during a semester in the Numerical Analysis course'*.

3. Findings

In this section, findings related to the problem-solving process of students in the numerical analysis course are presented. The frequency and tabulation process of the content analysis, which was conducted at the end of the interviews and in accordance with the data obtained from the common problem solutions asked, is detailed in Table 2.

Table 2. Student opinions about the question 'do you think that it will be more beneficial to study the numerical analysis course in the laboratory environment (when supported by programs such as MATLAB or Fortran)? Why?'

Opinions	Frequency (f)
I think it is useful. I think it would be more useful for us to experience the computer environment.	6
I definitely want it to be in the computer environment. I do not think that knowledge can be learned without implementation.	2
I agree, because I believe that knowledge will be more permanent in this way.	1
I would not want it to be in a computer environment. The system currently being processed is sufficient.	1
I strongly agree with the implementation, because I think that having engineering departments in a laboratory based on practice will help us to produce better quality and more accurate work in the future.	4
I think it is appropriate. Due to the length of the solutions, we learned in the numerical analysis course, and it is better to do it in a computer environment because results close to the exact solution are desired and it will enable us to obtain more accurate results and will allow us to solve more questions.	6
Total	20

As shown in Table 2, most of the students argued that the course should be delivered in the laboratory and they wanted to experience by applying the theoretical knowledge that they learned in the course. In addition to this, although the students argued that it was sufficient to explain this course in the classroom with a traditional approach, the majority of the students expressed the opinion that this course should be supported in the laboratory as in the computer environment, the information is more permanent and it enables long solutions to reach more accurate results in.

The students' opinions explaining the difficulties that they faced in solving the problems of numerical analysis are given in Table 3.

Table 3. Students' opinions about the question 'explain what difficulties you have encountered in solving the problems of the numerical analysis course'

Opinions	Frequency (f)
There are no difficulties other than the length of operations and formulas.	2
I faced with a lack of knowledge while performing analytical solutions on derivative and integral issues.	5
I faced difficulties in not being allowed to use a calculator.	8
I had a hard time working with very small numbers.	2
I liked this course very much and did not encounter any difficulties.	3
Total	20

According to Table 3, it was found that students have difficulties in using calculators while solving numerical analysis course problems, and they emphasised that there is a lack of knowledge about derivatives and integrals. In addition, it is difficult for students to deal with long operations and formulas, as well as very small numbers in numerical analysis. We found that some students liked this course very much and did not encounter any difficulties.

Table 4. Student opinions about the question 'are you able to establish relationships between the subjects learned in the numerical analysis course and the problems you encounter in your department?'

Opinions	Frequency (f)
Yes. I think it is a very relevant course for the department. I am so satisfied to see this lesson.	7
Yes. Unfortunately, in practical terms, they are not often used in real life.	1
No.	7
I think it is very important for engineering students to learn approaches and methods to solve unsolved problems. It is a course that allows us to think about how to approach several problems in the department.	5
Total	20

As shown in Table 4, most of the students stated that there is a relationship between the problems that they encounter in their departments and numerical analysis course and emphasised that it is a necessary and important course. In addition, some students answered 'no' and argued that there was no relationship between the subjects learned in the numerical analysis course and the problems that they encountered in their department. They also thought that it is not often used by technicians in real life, but it is important to learn different methods and approaches to problems that cannot be solved in engineering.

Students' opinions about how a course should be delivered in order to be able to be permanent in the case of numerical analysis are listed in Table 5.

Table 5. Students' opinions about the question 'how should this course be taught in order for the course of numerical analysis to be permanent? Please explain'

Opinions	Frequency (f)
I believe that it would be more efficient to explain the engineering departments with the examples associated with each department and to support the education with more homework and projects instead of being in the same classroom.	9
I believe that it will be more efficient to do research and presentation style assignments with various computer programs in the laboratory.	7
I am pleased with the way it works in a traditional way.	4
Total	20

Table 5 shows that the laboratory environment is necessary and that the numerical analysis course should be supported by various computer programs in the laboratory. In addition, some also thought

that it would be more beneficial if students are separated according to their departments and supported with homework and projects related to their departments in the laboratory environment.

Students' opinions explaining their strengths and weaknesses faced in the process of numerical analysis course are given in Table 6.

Table 6. Students' opinions about the question 'explain your strengths and weaknesses in the learning process of the numerical analysis course'

Opinions	Frequency (f)
Not being able to solve the analytical results due to the lack of basic mathematics lessons we took at the beginning of the school.	8
I did not have any problems with the course.	2
I had trouble due to not knowing how to use the calculator.	5
My strength is that I can use technological devices such as a calculator. My weakness is that I get confused quickly in the calculations made with very small numbers.	5
Total	20

As shown in Table 6, they emphasised that they had a lack of basic knowledge of mathematics in the first place and that they had problems in using the calculator and confused the transactions with small numbers in the second place. Although there were students who stated that they did not have any problems related to the course, the majority stated that they did have some problems with numerical analysis course.

Table 7. Students' opinions about the question 'do you think you have sufficient background information for the numerical analysis course? If not, where do you think that the problem stems from? (Lack of prerequisite courses, lack of program knowledge, problems in using a calculator and so on)'

Opinions	Frequency (f)
Yes. If this course is taken after the chain courses, there will be no difficulty.	10
Due to the fact that we are transfer students, the inadequate and incomplete courses have led to a lack of infrastructure.	6
Since I passed many of the so-called prerequisite courses by memorising, I forgot many parts of the courses when I started on the numerical analysis course. That is why I am having a hard time due to the lack of infrastructure.	4
Total	20

According to Table 7, the engineering students stated that they did not have sufficient infrastructure before the numerical analysis course. One of the reasons for this was that they were transfer students and their lack of necessary and insufficient courses leads to the lack of infrastructure. They also thought that the numerical analysis course should be taken after the prerequisite courses so that they would not face the difficulty of a lack of foundation.

Table 8. Students' opinions about the question 'do you think that the numerical analysis course is a necessary course in the faculty of engineering? If so, please explain why you think that way'

Opinions	Frequency (f)
I certainly agree. More valuable work can be done by associating the department with relevant examples, and these results can be presented to people as proof of the quality of our work.	11
I do not think so.	5
I certainly think that it is necessary for those who want to study academically, but I do not see it necessary for those working in the field.	4
Total	20

As shown in Table 8, the majority of students thought that the numerical analysis course is absolutely necessary. However, the remaining students thought that it is necessary for a person working in academia but not for a person working in the field. They also suggested that the remaining students did not need to give any reasons.

Table 9. The understanding problem dimension of the problem question in Figure 1

Understanding problem dimension	Frequencies (f)
Excellent	3
Good	4
Intermediate	13
Total	20

According to Table 9, we found that the problem shown in Figure 1 is that the majority of the students understand at the 'intermediate' level, half of the remaining students understand at 'good' level and the other half at 'excellent' level. As shown in Table 10, students mostly used the Simpson 1/3 method. The remainder used the trapezoidal method and Simpson 3/8 method, but none of the students used the rectangle method. In addition, some students were unable to determine the method and, therefore, left the problem solution blank.

Table 10. Strategy determination and checking dimension of the problem question in Figure 1

Strategy determination and check	Frequencies (f)
• Rectangle method	0
• Trapezoidal method	2
• Simpson 1/3 method	6
• Simpson 3/8 method	3
• Unable to determine the method and get results	3
• Those who left the question blank	6
• Total	20

The aim is to select and apply the method that will give and answer closest to the exact solution. The most effective method to choose here should be Simpson 3/8 because more data (three points) are used to apply this method than all other methods, and therefore, it is expected to obtain better results with a margin of error closer to the exact solution.

Table 11. Demonstration and expression dimension of the problem question in Figure 1

Demonstration and expression	Frequencies (f)
Finding the cutting points of the integral	11
Calculating the desired step interval (h)	10
Data table through which the part whose integral has to be calculated on the x-axis is separated into its segments and its function values are found.	8
Analytical solution of the given integral	6
The error term showing the difference between the approximate solution obtained and the analytical solution	2
Total	37

As shown in Table 11, the students mostly used finding the cutting points (interceptions) of the integral and calculating the desired step interval (h) in the demonstration and expression dimension. In addition, we found that they used such dimensions as '*data table through which the part whose integral has to be calculated on the x-axis is separated into its segments and its function values are found, and analytical solution of the given integral as well as the error term showing the difference between the approximate solution obtained and the analytical solution'.*

As shown in Table 12, according to the evaluation results of the students' problem writing dimension of the numerical analysis course, it can be seen that the majority of students were able to

write problems (Figure 2), whereas only one student could not write problems, and the remaining students wrote problems that were irrelevant to the topic (Figure 3).

Table 12. Evaluation results in regard to the problem-writing dimension

Problem-writing	Frequencies (f)
Was able to write problem	14
Was not able to write problem	1
The problem written is irrelevant with the topic	5
Total	20

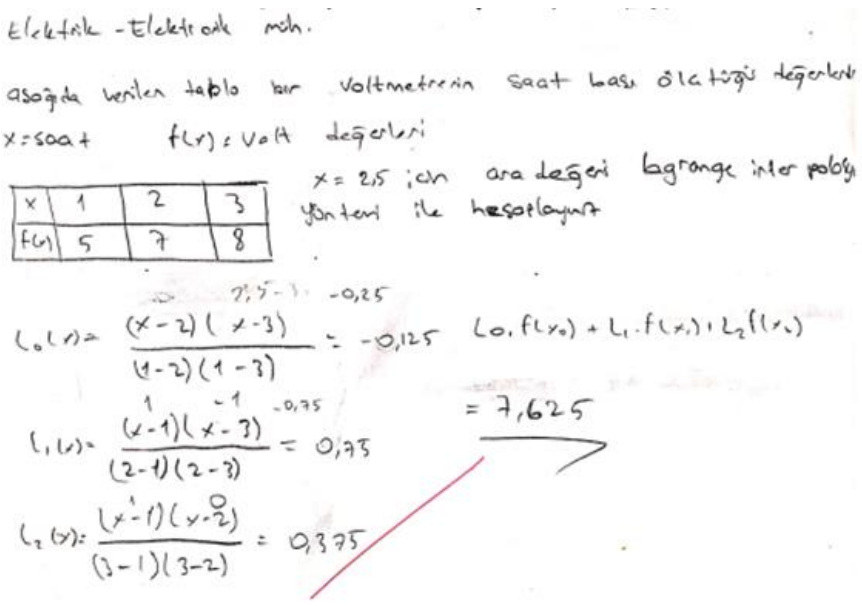

Figure 2. Example of a paper of a student who understood and wrote the question accurately

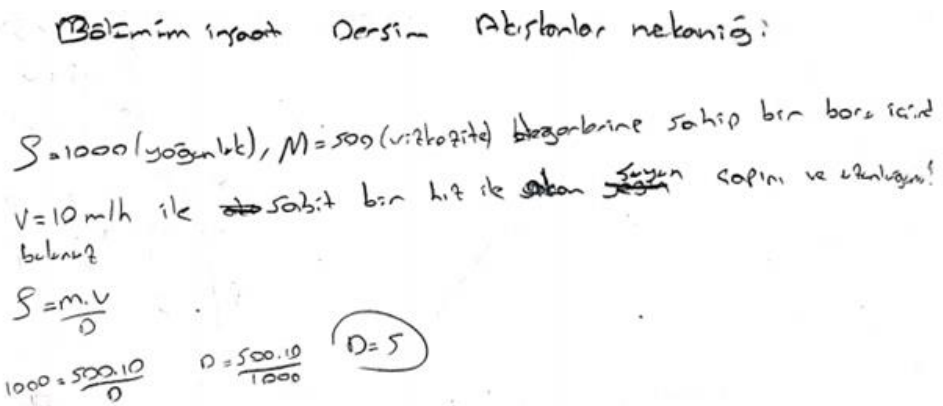

Figure 3. Example of a paper with question irrelevant with the topic

4. Discussion, conclusion and recommendations

4.1. Discussion and conclusion

The importance of mathematics education, which has a significant place in modern society, is increasing day by day and continually gaining value (Altun & Yabas, 2009). In this study, an

investigation has been conducted on engineering students on a numerical analysis course in terms of their understanding of problem solving and determining and providing strategies, demonstration, expression and problem writing.

According to the results, most of the students argued that the course should be conducted in a laboratory, and they wanted to experience the theoretical knowledge that they learned in practice. In this way, they claimed that knowledge would be more permanent and could be applied in their future professions and that their department would be more useful because it is an applied department. This result is in accordance with the findings of Fidan (2012).

We concluded that the students made most of the mistakes in the mathematics course by approaching the question with a rote approach. The most common mistake made by the students in the data group that we considered is that the results of the numerical analysis course should be sensitive to the exact solution. It is aimed that the error term which is among results (error = [exact solution – approximate solution]) is as small as possible. For this reason, due to the small numbers that have to be dealt with, operations are made in the classroom using a calculator.

It was observed that the students had difficulty in using the calculator and found incorrect results. This finding is in line with Baki and Celik (2005) and Ozdemir (2014). The most important problem is 'the information lost because the students learned in the form of memorisation and their deficiencies in the past mathematics classes'. The reason for this is that although the arithmetic expressions that they wrote were correct, the results of the calculation made with the calculator were incorrect. The main reason for this can be explained under the following four main headings:

Not knowing the features of the calculator
Not knowing the sequence of operations
Lack of arithmetic knowledge
Entering the examination with someone else calculator

The majority of engineering students emphasised that the problems they encountered in their departments were related to the subjects learned in the numerical analysis course. For this reason, in the case of daily life related to STEM, science and mathematics fields were described by all participants. However, in relation to technology and engineering, it is possible to say that the participants have limited ideas and experiences (Rockland et al., 2010). The engineering field is the keystone of STEM education (Cavanagh, 2009). In this sense, it is of great importance to support and integrate the engineering knowledge, skills and experience of prospective mathematics teachers who will be the practitioners of STEM education with the other STEM education areas. When the descriptions are examined, it can be seen that the science field is not related to other fields at all, whereas the mathematics field is described by only one person in relation to the other STEM fields (Yildiz & Ucar, 2017).

The weak methods that the students encountered in the learning process of the numerical analysis course are the lack of knowledge of the fundamentals of mathematics. This result shows that we have reached the same result as Harman and Celiker (2012) and Kutluca and Baki (2009). Although most of the students thought that numerical analysis is a compulsory and necessary course, there were also students who disagreed. This result is proved that we reached parallel findings with Dede (2007), Huyut and Keskin (2017) and Yurtbakan, Iskenderoglu and Sesli (2016).

In addition, the majority of students understood the sample problem (Figure 1) at a moderate level, and this result is in line with Aydemir and Kubanc (2014) and Ersoy and Guner (2014). Furthermore, it is possible to say that more than half of the students followed the steps of finding the interception points of the integral, and this result is in line with the results of Tarhan (2015).

4.2. Recommendations

Based on the findings of this study, the engineering students' views on the evaluation of problem-solving processes were analysed based on different dimensions, and the following recommendations can be made:

a) Supporting the course in the laboratory will positively affect the problem-solving abilities of the students,
b) It is necessary to teach the students different program applications (MATLAB, Fortran, GeoGebra, C programming, Graphmatica, Maple, Mathematica and so on) prior to the course, thus allowing them to obtain more precise solutions than the solutions obtained on the calculator, and this will also increase the reliability of the results,
c) The relationship between the subjects taught in the course and the problems that they encounter in their departments should be established, and the course should be enriched with department-based examples,
d) High school scientific calculator usage should be taught,
e) The readiness of the students should be tested before applying the digital analysis course and applying the necessary pre-courses,
f) The number of studies related to problem-solving processes in mathematics education and training needs to be increased,
g) Organising in-service courses that will increase the tendency of mathematics instructors to prefer the problem-solving teaching approach.

References

Altun, S. & Yabas, D. (2009). The effects of differentiated intructional design on students' self-efficacy beliefs, metacognitive skills and academic achievement. *Hacettepe Universitesi Egitim Fakultesi Dergisi, 37*, 201–214.

Aydemir, H. & Kubanc, Y. (2014). *Investigation of the cognitive behavioral problem solving process. Turkish Studies*, *9*(2), 203–219. DOI: 10.4103/jepr.jepr_18_16

Baki, A. & Celik, D. (2005). Opinions of mathematics teachers about adaptation of graphing calculators of mathematics courses. *The Turkish Online Journal of Educational Technology, 4*(4), 1303–6521.

Baki, A. (2008). *Mathematics education from theory to practice.* Ankara, Turkey: Harf Egitim Publishing.

Baykul, Y. (2002). *Secondary mathematics education (Grade 6-8).* Ankara, Turkey: Pegem A Publishing.

Cavanagh, S. (2009). Panel wants engineering integrated into curriculum, (2016, November). Available: http://www.edweek.org/ew/articles/2009/09/08/03engineering.h29.html

Dede, Y. (2007). Teachers' views about ways of teaching mathemantics. *Hacettepe University Journal of Education,* 33, 99–107.

Demir, B. (2011). *Application of problem based learning model in numerical analysis course.* (Master thesis). Balikesir, Turkey: Balikesir University Institude of Science and Technology. Secondary Science and Mathematics Education.

Ersoy, E. & Guner, P. (2014). Mathematics teaching and mathematical thinking. *Journal of Research in Education and Teaching,* 2(13), 2146–9199.

Fidan, M. E. (2012). Differences between the students taking accounting course in the universities with the powerpoint presentation and classical method: Case of Bilecik University. *Journal of Yasar University, 25*(7), 4281–4306.

Harman, G. & Celikler, D. (2012). A review study on the importance of readiness in education. *Journal of Education and Teaching Research, 1*(3), 147–156.

Huyut, M. T. & Keskin, S. (2017). Determination of factors affecting of mathematics success: Individual factors with multiple correspondance analysis. *Turkish Journal of Applied Sciences and Technology, 1*(2), 60–72.

Kutluca, T. & Baki, A. (2009). Investigating of views of students, student teachers and teachers about difficult subjects in 10th grade mathematics class. *Journal of Kastomonu Egitim, 17*(2), 609–624.

MEB, (2016). Basic education program. Introduction to mathematics curriculum. Nicosia, North Cyprus: Okman Printing Ltd.

Ozdemir, E. (2014*). Learning-teaching applications on modeling in mathematics education.* (Master's Phd Thesis). Balikesir, Turkey: Balikesir University Institude of Science and Technology. Secondary Science and Mathematics Education.

Rockland, R., Bloom, D. S., Carpinelli, J., Burr-Alexander, L., Hirsch, L. S. & Kimmel, H. (2010). Advancing the 'E' in K-12 STEM education. *The Journal of Technology Studies*, *36*(1), 53–64.

Sisman, M. (2007). *The effect of teaching factor and identities on elementary 8th grade mathematics course in conformity with constructivist learning approach to student success.* Ankara, Turkey: Gazi University, Institute of Educational Sciences. Primary Mathematics Education Department.

Tarhan, F. (2015). *Determination of problem solving skills levels of students in vocational high schools.* (Master thesis, Near East University), Washington, DC: Institute of Educational Sciences, Department of Curriculum and Instruction.

Tezer, M., & Cumhur, M. (2016). Antropological theory of didactics and the probability of the constructivist approach being a solution to the common mistake made in mathematics lessons. *International Journal of Educational Sciences, 15*(1–2), 148–156. https://doi.org/10.1080/09751122.2016.11890524

Tezer, M., Yildiz, E., Bozkurt, S. & Tangul, H. (2019). The influence of online mathematics learning on prospective teachers mathematics achievement: The role of independent and collaborative learning. *World Journal on Educational Technology: Current Issues*, *11*(4), 257–265. https://doi.org/10.18844/wjet.v11i4.4361

Yildiz, B. & Ucar, E. (2017). STEM applications in mathematics education: Using Scratch and Arduino. In *Turkish Computer and Mathematics Education Symposium-3* (pp. 613–618.). Afyon, Turkey.

Yurday, H. (2006). *Approaches of high school mathematics teachers to the new curriculum.* Unpublished Master's Thesis. Trabzon, Turkey: Karadeniz Technical University, Institute of Science and Technology.

Yurtbakan, E., Iskenderoglu, T. A. & Sesli, E. (2016). The views of the classroom teachers on enchancing the students' success of mathematics. *Ondokuz Mayis University Journal of Faculty of Education, 35*(2), 101–119.