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Comparison of Mathematical Problem Posing Skills of University Students in the Context of Critical Thinking Dispositions

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ABSTRACT

The purpose of this study is to question the existence of a relationship between the tendency to think critically and the ability to form mathematical problems. In other words, questioning the ability of mathematical problem-setting to be a sign of the existence of critical thinking. Participants of the research are 120 first-year university students of architecture faculty. In the study, the "if not" strategy was used for the mathematical problem-setting activity. Students are asked to solve this problem by giving an integral calculation problem, to create new problems from this problem and to solve the problems they have created. The problem chosen is one of the most fundamental integral problems in any analysis book. In addition, the California Critical Thinking Tendency Inventory was applied for all 120 learners. The corrational survey model was used in this study. One of the conclusions is that the subscale scores of the students who pose 3 or more types of problems are higher than the others.

Keywords: Mathematical problem posing, what-if-not strategy, critical thinking.

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Eleştirel Düşünme Bağlamında Üniversite Öğrencilerinin Matematiksel Problem Kurma Becerilerinin Karşılaştırılması

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ÖZET

Bu çalışmanın amacı, eleştirel düşünme eğilimi ve matematiksel problem kurma becerisi arasındaki ilişkinin varlığını sorgulamaktır. Başka bir deyişle, matematiksel problem kurma becerisinin eleştirel düşünme bağlamında sorgulamaktır. Bu çalışmada tarama modeli kullanılmıştır. Araştırmanın katılımcıları 120 kişiden oluşan mimarlık fakültesi birinci sınıf üniversite öğrencisidir. Çalışmada, matematiksel problem kurma aktivitesi için "eğer yoksa" stratejisi kullanılmıştır. Öğrencilere integral bir hesaplama problemi verilerek bu problemi çözmeleri, bu problemden yeni problemler oluşturmaları ve yine bu oluşturdukları problemleri çözmeleri istenmiştir. Seçilen problem herhangi bir analiz kitabında yer alan en temel integral problemlerden biridir. Ayrıca, 120 öğrencinin tamamı için California Eleştirel Düşünme Eğilimi Envanteri uygulanmıştır. Sonuçlardan biri verilen problemden yeni problem üreten öğrencileriden; sınırları değiştirme, fonksiyonu değiştirme, integrandı değiştirme ve isteneni değiştirme kategorilerinden üç ve üzeri sınıflamaya giren öğrencilerin eleştirel düşünme alt ölçek puanları diğerlerine nazaran daha yüksektir.

Anahtar Kelimeler: Matematiksel problem kurma, what-if-not stratejisi, eleştirel düşünme.

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Introduction

Problem posing is producing problems from any situation or event (Stickles, 2006). It means approaching problem solving from a different point of view (Altun, 2005). This is because the learners check whether the solution of the problem that they solved is correct. Learners should have opportunities to pose problems about subjects that are being covered in the lessons and they should be encouraged to do this during her learning experience. Thus, how the learners understand and what they wonder about the subject will (Hiebert and Wearne, 1996). Classroom environment and teachers are important factors in order to have an efficient problem posing activity and classroom environment. Students need a classroom environment which is authentic, interrogative and which does not blame learners for their productions. This environment has to be provided by teachers (Moses, Bjork and Goldenberg, 1993). Thanks to problem posing students' critical thinking skills are improved because problem solving is an activity including critical thinking as well. (Freire, 1970). Learners try to produce original ideas to find better in each problem posing activity and in conclusion their creativity is consolidated. While converting a situation into a problem, they start focusing on logical correlations and forming it as a question. While questioning whether the posed problem has a solution, their problem solving skills becomes stronger (Silver, 1997; English, 1997; Cai, 1998). It is seen that most of the problem posing studies in literature carried out in a classical way. Problem posing can be defined as producing a problem from a situation or an event or it can also be defined as producing new problems from a current problem. Problem posing gives learners opportunities to discuss a standard subject from a different point of view. However, it does not mean creativity on its own, but it can be a step leading for creativity. NCTM (2000) emphasizes the following:

Teachers and families should encourage their children to write problems with their own words, teachers have important roles in preparing necessary environment for improving students' problem solving and posing skills. In such an environment learners are encouraged to search, take risks and share their mistakes and achievements. Thus, learners feel relaxed and become eager to search and share by getting rid of their anxieties. Learners start writing challenging questions with the development of self-confidence (p. 53).

Kılıç (2014) stated in her study, primary teachers indicated that they had the same meaning as problem solving when they pointed out the benefits of problem solving. Kar and Işık (2014) found in their study that secondary school mathematics teachers are able to create problems with addition or subtraction of fractions while some teachers show mistakes in established problems.

Mathematical problem posing can be predictor in terms of the flexibility and fluency components of problem posing (Sophocleous and Pitta-Pantazi, 2017)

Problem Posing Strategies

Stoyanova and Ellerton (1996) looked at theoretical frames used by researchers to analyze problem posing and they tried to propose a theoretical frame which can be used to carry out problem posing with students in lessons. This theoretical frame was classified as free problem posing, semi-structural problem posing and structured problem posing. Students received instructions like 'write a question for a maths contest', 'write a difficult question', 'write a question for your friends', 'write a question which you like to solve' to let them use their experiences for free problem posing. In semi-structured problem posing case, students were asked to pose problems suitable for the given criteria. For example, students were asked to pose suitable problems for a given image, equation, operation or operations or a table. For instance, 'Last night, there was a party. The bell rang ten times. When the bell rang for the first time, one person for the second time two people, for the third time 3 people came.' After giving this situation, students were asked to pose suitable problems for this situation.

Stickles (2006) searched what teachers and prospective teachers pay attention while posing problems in his doctoral thesis. In his study, four main purposes were classified as in the following: to determine the type of the problem that learners posed for an open-ended problem situation, to determine the type of the problem that learners posed for a similar problem, to determine whether teachers' experiences or past activities have an effect on their problem posing and to determine whether there are differences in the characteristics of the problems that they posed.

Brown and Walter (1990) were used "what-if-not" strategy which enables producing a new problem by changing the rule of current problem. According to this, the first that you should do is to determine the characteristics of the problem, then to change some or one of these characteristics or conditions, thirdly to write a new problem and finally to analyse the new problem. In this way, it becomes possible to produce new problems.

Let us produce a new problem by using this strategy on the problem given below. Problem: "4 friends sitting in a café shared 3 middle sized pizza by cutting them into equal slices. Since each of them ate pizzas in equal amounts, how many slices of pizza did each one eat?" New problem generated by using What-if-not strategy: "4 friends bought 6 balloons while walking on the beach. When they shared their balloons equally, how many balloons did each one get ?"(If we look closely, in the first problem we can share a pizza equally but when it comes to share a balloon, it changes because if you try to share a balloon equally, it blows so each one can only get one balloon. Remaining two balloons cannot be shared) (Arıkan, 2014). This study was carried out quantitatively to compare mathematical problem posing skills of university students in the context of critical thinking.

Method

The Research Model

The research model of this study is correlational survey model from descriptive research models. Karasar said that the purpose of the scanning model is to describe the situation as it is without making any changes or interventions (Karasar, 1999).

Study Group

The universe of the sample is composed of freshman students studying at architecture and interior architecture departments of a private university in Istanbul. The sample of the study was decided as convenient sampling from random sampling methods in terms of accessing and implementing easily (Büyüköztürk et al., 2017). 173 freshman students taking general Mathematics II lesson coded as

Math 152 and studying at architecture and interior architecture department at a private university in Istanbul attended this study. However, 53 students who could not pose problems by using what-if-not strategy or submitted a blank page excluded from the study and the study was carried out with the pages of 120 students.

Data Collection Instruments

Two different instruments were used in this study in order to find the answers of the following questions: 'Does critical thinking disposition mean anything for problem posing? And, is there really a close relationship between critical thinking and problem posing as it is stated in the literature?'

First instrument was to generate as many problems as possible from a given problem. Second instrument was California Critical Thinking Disposition inventory. Facione, Facione and Giancarlo had developed California Critical Thinking Disposition İnventory in 1998. Afterwards, Kökdemir adapted the İnventory to Turkish language in 2003 (Kökdemir, 2003).

The Critical Thinking Disposition Inventory

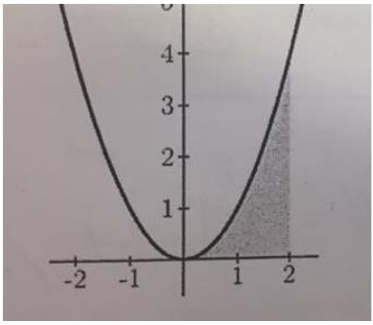
Critical Thinking disposition is an internal motivation necessary for problem solving and decision making (Facione et al, 1994). When we analyze literature, we can see that there are studies claiming that there is a positive correlation between critical thinking skills and critical thinking disposition (Profetto-McGrath, 2003; Shin, Jung, Shin and Kim, 2006).

Kökdemir (2003) adapted California Critical Thinking Disposition Inventory (CCTDI) containing 51 items into Turkish. The titles of the sub-scales were adapted as truth seeking (looking for the truth, questioning and being impartial between competing point of views) open mindedness, (considering different point of views), analyticity (reasoning, anticipating possible problems and to be able to produce alternative solutions), systematicity (studying carefully and being organized) self-confidence and inquisitiveness. The inventory which was adapted to Turkish is composed of 6- sub-scales and 51 items in 6 point likert scale. For the reliability study, CCTDI was conducted to 425 students at Teaching English, Psychological

Counselling and Guidance and Art Departments in the Educational Faculty and the Cronbach Alfa coefficient which was calculated to check the internal consistency of the scale was found as 0.78. It is stated that individuals who have 240 points and over from the scale have critical thinking disposition.

Problem Posing Case

The other testing instrument used in the study is a question that students need to make calculations by using a structured integral. First of all students were asked to solve this question and then they were expected to produce as many problems as they can by using what-if-not strategy.



Please calculate the area of the region occurred between $y = x^2$ function, $x = 0$ and $x = 2$ in the figure on the left. Later on create and solve your own problems by changing the conditions.

Figure 1. Testing Instrument Prepared for Problem Posing

The question, which is prepared for What-if-not strategy, is a standard area calculation question. The posed problems were classified according to content analysis. I have a professional colleague in the field of problem posing and I get his opinion. The classes I have specified were: changing boundaries, changing functions, changing integrands, and changing what is asked.

Data Analysis

After the data were collected, the students were coded as S1 S2 S3 .... S120. After the problems produced by the students were examined, the problems are classified according to the frequency of the changed places. These classifications were named as: changing the function in the integral, changing the boundaries in the integral, calculating the same field by changing the integrand, and changing

the asked one by giving the same graph. After the approval of my colleague, I started analysing the data.

Posed problems were ticked in SPSS 23 software both as total score and category. Students who generated and solved problems in 2 categories or only in 1 category were coded as 1 and students who generated and solved problems in 3 and 4 categories were coded as 2. This coding was named as general problem posing coding.

The points obtained from the analyticity, open mindedness, inquisitiveness and systematicity sub-scales of the critical thinking disposition inventory were coded to the SPSS 23 software.

After coding, a comparative analysis were carried out by determining problem posing score code as dependent variable and critical thinking disposition sub—scale scores as independent variable for non-parametric Mann_Whitney U test. Moreover, another analysis were made for the categories which created some differences from problem posing categories and this coding was called as special problem posing coding.

Findings

After making a comparison with the test of critical thinking tendency, analyticity, open mindedness, inquisitiveness and systematicity scores from the sub-scales of the critical thinking disposition inventory, which can be analyzed with what-if-not strategy, were used in the study.

Table 1. Findings regarding the four sub-scales of the Critical Thinking Disposition Inventory

	N	Minimum	Maximum	Mean
Inquisitiveness	120	26,00	54,00	41,3250
Analyticity	120	48,00	60,00	57,7000
OpenMindedness	120	16,00	72,00	49,1000

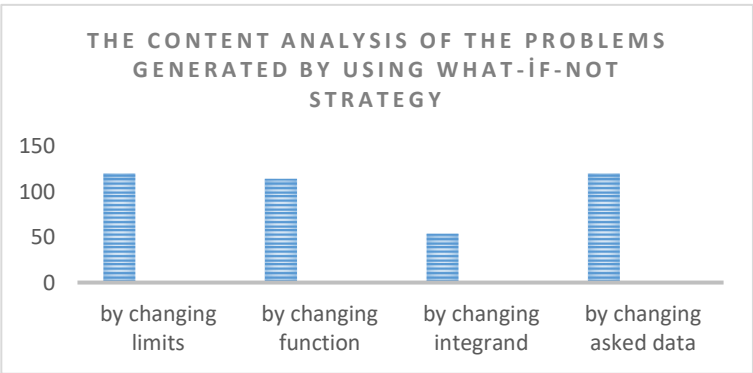
Systematicity	120	13,00	36,00	19,5500

In the problem posing case students were asked to generate questions by using what-if-not strategy. According to the content analysis of the posed problems; findings were four classified as changing boundaries, changing function, changing integrand and changing the requested of question. All the participants generated questions by changing boundaries and requested of question. No all the students could generate new questions by changing function and integrand. It was determined that there 54 students who generated and solved problems by changing integrand and 114 students who generated and solved problems by changing function. Therefore, the biggest difference was to generate and solve problem by changing the integrand.

Problem Posing Content Analysis

In the calculation of the scanned area, 111 students asked an area question by changing x=0 and x=2 numbers in the limits with x=3 and x=4 and then solved the question. 9 students changed the limits as exponential numbers.

Table 2. The Distribution of Problem Categories



The sample generated by using exponential numbers;

Some students who generated and solved the question by saying how would be the question if the limits in the question were $x = e$ and $x = e^2$ instead of $x = 0$ and $x = 2$.

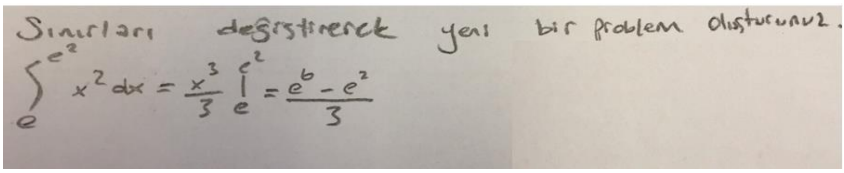


Figure 1. Problem created by simply changing the boundaries

The distribution of the functions used by students who generated problems by changing the function was as in the following from the most to the least; polynomial, exponential, trigonometric and natural logarithmic function.

In the case of changing the asked data, all the students generated and solved the question by asking cubage instead of calculating the area.

Some students who generated and solved the problem by changing the condition; if the function were $y = cosx$ or $y = e^x$ instead of $y = x^2$

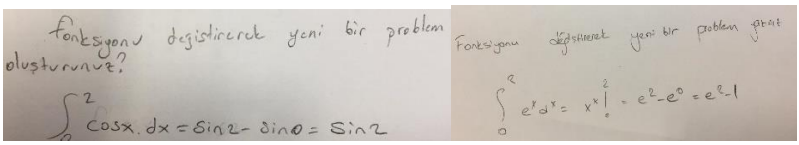


Figure 2. 2. students created problems by changing the functions

While all the students succeeded at the same level in generating problem by changing limits and asked data, 114 students could generate and solve the question in by changing the function category and 54 students in by changing the integrand category. Therefore, there is a difference in changing the function and integrand categories so these categories were particularly discussed for comparative analysis.

Some students who tried to change and solve the problem by saying "What would happen if we calculated the area according to y-axis?";

Some students who re-formulated and solved the problem as if we wanted to find the volume of the object occurred by rotating it 360 degrees around the x-axis rather than the area of the region;

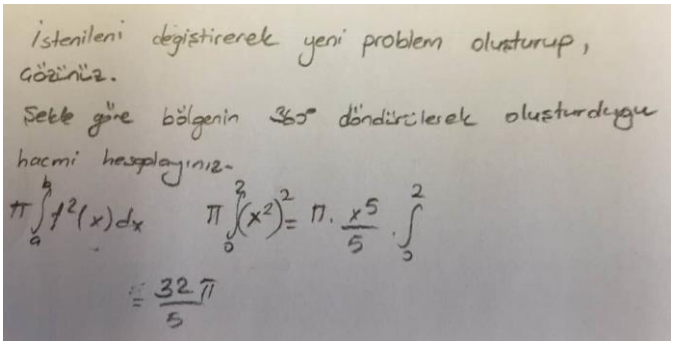


Figure 3. Problem created by changing the asked

As it can be seen above, students identified the features of the initial problem and generated new problems by changing these features. The number of students who could realize and change all of these features was 54 because students who could reformulate and solve the problems by changing the integrand could also solve the problem by changing the other features.

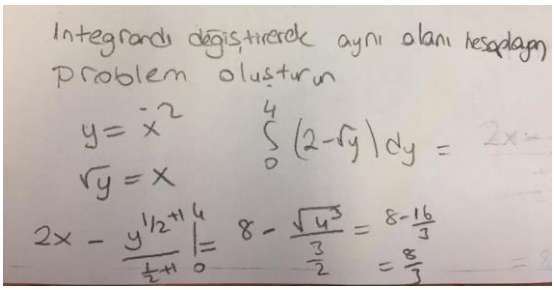


Figure 4. Problem created by changing the integrand

The integrand comparison and the function comparison were performed with the critical thinking disposition inventory and are described in Table 3.

Table 3. The integrand comparison and the function comparison according to the critical thinking disposition inventory

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of integrand is the same across categories of win_group.	Independent-Samples Mann-Whitney U Test	,000	Reject the null hypothesis.
2	The distribution of function is the same across categories of win_group.	Independent-Samples Mann-Whitney U Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

It is seen that the students with a tendency of critical thinking of 240 and above change the integrand and the function to create a problem.

The Analysis of the Relationship between Critical Thinking Disposition Inventory Sub-Scales and Problem Posing:

The analyticity, open mindedness, inquisitiveness and systematicity subscales of the critical thinking disposition inventory were compared with general and specific codes of the posed problems and presented in Table 4.

Table 4. Quantitative Analysis of Problem Posing Categories

According to Integrand Changing- Comparative of Sub-scores

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of analicity is the same across categories of integrand.	Independent-Samples Mann-Whitney U Test	,032	Reject the null hypothesis.
2	The distribution of inquisitiveness is the same across categories of integrand.	Independent-Samples Mann-Whitney U Test	,016	Reject the null hypothesis.
3	The distribution of systematicity is the same across categories of integrand.	Independent-Samples Mann-Whitney U Test	,121	Retain the null hypothesis.
4	The distribution of openmindness is the same across categories of integrand.	Independent-Samples Mann-Whitney U Test	,116	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

According to Function Changing- Comparative of Sub-scores

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of analicity is the same across categories of function.	Independent-Samples Mann-Whitney U Test	,092	Retain the null hypothesis.
2	The distribution of inquisitiveness is the same across categories of function.	Independent-Samples Mann-Whitney U Test	,005	Reject the null hypothesis.
3	The distribution of systematicity is the same across categories of function.	Independent-Samples Mann-Whitney U Test	,253	Retain the null hypothesis.
4	The distribution of openmindness is the same across categories of function.	Independent-Samples Mann-Whitney U Test	,057	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

When the analytical, curiosity, systematic and open-mindedness scores for the integrand variable were compared, significant

differences were determined in terms of analyticity and inquisitiveness scores at the .05 level. When the analytical, curiosity, systematic and open-mindedness scores for the function variable were compared, significant difference was determined in terms of inquisitiveness scores at the .05 level.

Conclusion and Discussion

There are some risks in problem posing like being superficial and not using creativity. Many people prefer writing known problems without using their creativity. And this is also same for this study. The integral question used in this study is a standard area calculation question and the questions occurred as result of changing conditions are ordinary questions.

It was determined that there are quantitative differences in comparison between subscales of critical thinking disposition scale for students who thought more multiple changes (for integrand and function conditions) according to yes sample. When we look at Table 7 for comparative analysis of critical thinking dispositions, it was identified that there is a significant difference for analyticity subscale for those who changed function and for those who change integrand there is a significant difference for both analyticity and inquisitiveness subscales. In conclusion, in the comparative analysis of critical thinking dispositions, a significant difference was found between the ones who changed 1 or 2 conditions and the ones who changed 3 or 4 conditions in terms of analyticity and inquisitiveness subscales.

Seo (1997) stated in his published article about what if not strategy that there are some differences while implementing. For instance, while it is enough to generate and solve a problem from a given problem or situation by changing conditions for Tejima (1992), for Shiota (1991), win strategy has not been completed only by solving the posed problem but it can only be completed by explaining how the solution is differentiated by making what type of change and in which conditions it was made. My study suits Tejima's implementation but Shiota's study enables making deep analysis. Therefore, I want to use Shiota's implementation in my future studies.

To tell the truth, I think that I really had an important progress in my problem posing studies with this study because it became clear that each generated problem should be questioned whether it is a problem or not. It is the same case in problem solving. In other words, is every question you solve a problem? Or, are they standard exercises? The same question should also be asked in problem posing. Are these generated questions problems or standard exercises?

In fact, by looking at the problems that students have posed, it can be said that the subject is superficial and does not deepen. Clearly speaking, the fact that students only need to change the function, boundaries, integrand or ask in the question, and not to mention on paper what this change means, should be deeper in this regard. For this reason, we teachers have a lot of work. Because students may not be able to see how deep they can become in a subject, and as such, we need to guide them as teachers. We can achieve this deepening through problem posing.

Unfortunately, this study did not include deepening due to the nature of the screening study. However, in future studies, it should be mentioned about deepening.

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