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DEVELOPMENT OF A MATHEMATICAL ATTAINMENT SCALE AIMED AT UNIVERSITY STUDENTS*

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ABSTRACT

In this research, it is aimed to develop a "Maths Attainment Scale" which can reveal the level of reaching mathematical achievements of university students. According to this, the study was performed with a total of 159 university students from various departments of Faculty of Engineering, Faculty of Science and Faculty of Economics in Dokuz Eylul University. In order to determine the content validity of the scale, it has benefited from the opinions of 8 specialists who were working in the field of mathematics education and educational sciences. Pre-trial practice of the scale was performed with 30 teacher candidates who were randomly selected from Elementary Mathematics Education Department in Buca Education Faculty of Dokuz Eylul University. An exploratory factor analysis has been made for construct validity of the "Maths Attainment Scale". As a result of the factor analysis, after the items must have been taken from the scale have been removed, a scale which consists of 28 items has been formed. The highest score that can be obtained from the scale will be 140, and the lowest score will be 28. When obtained data were overall examined, it can be said that the "Maths Attainment Scale" prepared by the researcher has high validity and reliability. It is believed that the developed scale can close a serious gap in the related literature by providing important contributions to Maths Education and Educators.
Keywords: *mathematics education, attainment, scale, factor analysis.*

ÜNİVERSİTE ÖĞRENCİLERİNE YÖNELİK BİR MATEMATİK KAZANIM ÖLÇEĞİ GELİŞTİRİLMESİ

ÖZ

Bu araştırmada, üniversite öğrencilerinin matematiksel kazanımlara ulaşma düzeylerini ortaya koyabilecek bir "Matematik Kazanım Ölçeği" geliştirilmesi amaçlanmıştır. Buna göre, araştırma kapsamında Dokuz Eylül Üniversitesi Mühendislik Fakültesi, Fen Fakültesi ve İktisat Fakültesi'nde bulunan çeşitli bölümlerde öğrenim gören toplam 159 üniversite öğrencisi ile çalışılmıştır. Ölçeğin kapsam geçerliğini belirlemek amacıyla matematik eğitimi ve eğitim bilimleri alanlarında görev yapan 8 uzmanın görüşlerinden yararlanılmıştır. Ölçeğin ön deneme uygulaması Dokuz Eylül Üniversitesi Buca Eğitim Fakültesi İlköğretim Matematik Öğretmenliği bölümünden rasgele seçilen 30 öğretmen adayı ile gerçekleştirilmiştir. "Matematik Kazanım Ölçeği"nin yapı geçerliliği için ise açımlayıcı faktör analizi yapılmıştır. Faktör analizi sonucunda ölçekten atılması gereken maddeler çıkarıldığında 28 maddeden oluşan bir ölçek meydana gelmiştir. Ölçekten alınabilecek en yüksek puan 140, en düşük puan 28 olacaktır. Genel olarak elde edilen değerlere bakıldığında araştırmacı tarafından hazırlanan Matematik Kazanım Ölçeği'nin geçerlik ve güvenirliği yüksek bir ölçek

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olduğu söylenebilir. Geliştirilen ölçeğin matematik eğitimine ve eğitimcilerine önemli katkılar sağlayarak ilgili literatürde ciddi bir açığı kapatabileceğine inanılmaktadır.
Anahtar Kelimeler: *matematik eğitimi, kazanım, ölçek, faktör analizi.*

1. INTRODUCTION

The need to use mathematics, which is an indispensable part of our life, in our daily and professional lives has increased in the recent years. Mathematics is a tool used in revealing people's skills, in directing them, in attaining a systematic and logical thinking habit and in all activities of mankind. To react or behave properly, above all, a solid and practical reasoning is needed. Mathematics is a branch of science that gives a reasoning habit to mankind (Başer, 1996). Apart from being an important part of our daily life mathematics is also a major contributor to the development of an individual's thought system. This is the reason why mathematics shows up as a course in every education level from primary education to higher education.

Without mathematics it is misleading to talk of science and technology, socioeconomic progress, qualified products and service. Therefore, like in all developed countries, everyone in our country should strengthen their mathematics, obtain the intellectual culture, share common values and use the communication language actively and widely (Ersoy, 2002). Individuals are expected to gain some mathematical skills and competencies as a result of the mathematics courses they have taken during their education. All these skills and competencies are called mathematical attainments. The concept of attainment is described not only as the individual's directly observable habits, but also as expressions including knowledge, skill, attitude and values (MEB, 2005). Another definition of attainment would be the competencies describing what a student, who has completed his educational process successfully, knows, what he or she can understand, what he or she can do. When the fundamental aims of mathematical education are examined in every educational level along with students learning mathematical topics the development of some fundamental cognitive, affective and psychomotor skills is also aimed. In this context, in mathematical education along with the development of mathematical concepts students are asked to develop their problem solving, communicating, reasoning and associating, creative thinking, critical thinking, entrepreneurship and using the mathematical language correctly and effectively skills.

Therefore, today's world expects mathematics tutors to nurture individuals who can produce effective solutions to real problems, who can use the mathematics they have learned effectively in daily life, who are aware of the tight relation between mathematics and the real world and rather than of being scared of mathematics, enjoy and love it (Doruk & Umay, 2011). During the process of mathematical education, helping students in forming of mathematical concepts via their physical experiences and intuitions and in abstractionism is a purpose. In this process, along with the development of mathematical concepts, the development of some important skills is also aimed at. These skills are problem solving, communicating, reasoning and associating (MEB, 2009). Other than these, it is thought that after the education process students will gain the ability to set up problems, will be able to make inferences regarding logical induction and deduction and develop their scientific thinking skills.

Individuals with these characteristics are thought to having reached mathematical attainments. In order to receive a higher education in mathematics and other fields it is obvious that individuals need to have a sufficient degree of mathematical knowledge and skill, i.e. they need to reach mathematical attainment. It is thought that individuals that have reached mathematical attainment will have understood mathematical concepts, the relations between the concepts, the underlying meaning below the operations and gained operation skills. Moreover, it is believed that these individuals can use these skills effectively in daily life. Individuals obtain their basic mathematical skills starting with the education given in the preschool period and then in primary and high school periods. They use these skills during their college education and their future professional life. Especially the development of mathematical substructure of students in departments where mathematics serves as a basis affects the quality of college level education directly. Moreover, the determination of students levels of reaching mathematical attainment helps in understanding how useful their education was in primary and high school periods. Also, it is thought that this can contribute towards the restructuring of the mathematics courses given in colleges. In this sense, this will render establishing a continuously developing mathematics course educational content possible.

When the relevant literature is examined there are many studies regarding the development of scales regarding students' affective characteristics, like attitude and worry, towards mathematics (Fennema-Sherman, 1976; Sandman, 1980; Erol, 1989; Duatepe & Çilesiz, 1999; Turanlı, Türker ve Keçeli, 2008), however, no scale was encountered regarding the levels of general mathematical attainment reached by college students. Therefore, it is thought that the development of such a scale could cover an important gap in the literature. In this study, the development of a scale that can reveal the levels of mathematical attainment reached by college students is aimed at. The developed scale is thought to provide important contributions towards mathematical education and tutors.

2. METHOD

2.1. Workgroup

In the frame of the study in order to develop the Mathematical Attainment Scale 159 college students attending various departments of Dokuz Eylül University's, Faculty of Engineering, Faculty of Science and Faculty of Economics have been worked with. The departments attended by the students taking part in the study and number of students picked from each department are given in Table 1;

Table 1
The Departments Attended by the Students Who Comprise the Workgroup and Number of Students Picked from Each Department

Departments	Number of Students
Economics	41
Computer Engineering	17
Civil Engineering	10
Environmental Engineering	27
Business Administration	45
Physics	19
TOTAL	**159**

General steps towards developing a measurement tool can be stated as follows (Karasar, 1999; Balcı, 2005):

1. Step of Constituting Scale Items,
2. Step of Referring to Expert Opinions,
3. Step of Pretesting,
4. Step of Validness and Dependability

During the development of the Mathematical Attainment Scale the work done in these steps are summarized below.

1. Step of Constituting Scale Items

In order to develop the Mathematical Attainment Scale, first of all, the students' general mathematical attainments have been tried to determine by combing the relevant field. In this sense, the route taken when designing the scale items is as follows:

- Determining which mathematical attainments students need to reach in their respective level of education,
- Determining which framework to measure within if the students partaking in the study have reached these behaviors or not after the learning process,
- Determining which type the items comprising the scale should be and how the grading system should be designed,
- Designing necessary items in order to measure whether the students partaking in the study have reached these attainments or not.

Following these steps a 5 choice likert type scale containing 39 items was designed. The choices in the designed scale were rated "Strongly Agree", "Agree", "Neither Agree nor Disagree", "Disagree", "Strongly Disagree" and each choice was graded from 5 to 1 in positive items and from 5 to 1 in negative items, respectively. During the designing process of scale items special care was given to make the items clear and understandable and to avoid them containing multiple decisions.

2. Step of Referring to Expert Opinions

Whether the items comprising the scale are a satisfactory indicator of measuring the desired behavior qualitatively and quantitatively or not is content validity (Büyüköztürk, 2002).

Content validity is realized by referring to expert opinions on if the items on the measuring tool are appropriate for it or not and if they represent the variable to be measured or not. To do this, first, a group of experts discuss the measurement aims and if the designed items represent the content required by these aims or not (quoted from Tyler, 1971; Bozdoğan & Öztürk, 2008).

In this sense, in order to determine the content validity of the scale expert opinions have been consulted on. Eight experts on mathematical education and educational sciences have declared that the scale items are adequate in containing general mathematical attainments expected to be reached by college students, in being in conformance with grammar rules and in comprehensibility. As a result of the opinions obtained from the experts it was concluded that the scale was a valid measurement tool regarding content.

3. Step of Pretesting

Erkuş (2012) views the pretesting application as a feedback process in which the legibleness and comprehensibility of the items in the draft of the scale and the spots unclear to the answerers are determined and mistyped expressions are detected before it is performed on the workgroup. The pretesting of the scale was realized with 30 randomly selected teacher candidates from Dokuz Eylül University, Buca Faculty of Education, Department of Primary Education Mathematics Teaching. The pretest lasted for approximately 20 minutes. During the pretest application it was observed that the scale items were legible and comprehensible in general, some items which were difficult to understand were determined and were revised by the researchers.

4. Step of Validness and Dependability

After the pretesting was done the scale was finalized and it was applied to the 159 students in the workgroup. Exploratory factor analysis was performed for structural validity of the "Mathematical Attainment Scale". Factor analysis is a statistical technique that aims to explain measurement with only a few factors by bringing together variables measuring the same structure or quality (Büyüköztürk, 2002). One of the fundamental aims of factor analysis is reducing the number of variables, another is revealing some new structures by making use of relationships between variables (Ersoy, 2012). When factor analysis is performed the meaning and content consistency of items included in every factor, factors with eigenvalues of 1 or greater are generally regarded as important factors, items having high loading values in a single factor, low loading values in other factors and important factors' high common factor variance explained by them in any item is taken into account (Büyüköztürk, 2002).

Before the factor analysis was performed "Mathematical Attainment Scale" was checked if it was a valid measurement tool or not. A prerequisite of a scale being valid is that it should be reliable. The designed scale's Cronbach Alpha Reliability Coefficient was calculated as 0.95. The upper limit for a scale's validity is its reliability coefficient's square root (Ersoy, 2012). Therefore, the validity value of the scale was obtained as 0.97.

The factor analysis might not be suitable for all data structures. To confirm this, first the pilot group the scale was performed upon needs to be checked for suitability for factor analysis. The suitability of the data for factor analysis can be checked via the Kaiser-Meyer-Olkin (KMO) coefficient. It is suggested that the value of the Kaiser-Meyer-Olkin (KMO) coefficient should be greater than or equal to 0.60 (Büyüköztürk, 2002). The designed scale's KMO value was determined as 0.895 as a result of the factor analysis. This value confirms that the scale's sample is valid for factor analysis.

Another aspect that should be taken into account when data suitability is checked in factor analysis is that the data should display a normal distribution. Barlett Sphericity test is one of the statistical techniques to check if the data come from multi variable normal distribution, or not (Ersoy, 2012). Obtaining a meaningful result from the Barlett test is another parameter that shows the validity of the data for factor analysis. The higher the result of the Barlett test, the higher its probability is to be meaningful (Büyüköztürk, 2002). The Barlett test applied to the data obtained from the scale are observed to be meaningful (Approx. Chi-Square = 2062, 536, p = 0,000).

For a choice factor analysis sample adequacy should also be ensured. The sample's adequacy is determined by Anti-Image Correlation Matrix's diagonal values. In order for the sample to be adequate Anti-Image Correlation Matrix's diagonal values should be greater than or equal to 0.60 (quoted from Akgül & Çevik, 2003; Günhan, 2006). The Anti-Image Correlation Matrix's diagonal values pertaining to the scale's items are given in Table 2;

Table 2

Anti-Image Correlation Matrix's Diagonal Values Pertaining to the Mathematical Attainment Scale's Items

Items	**Anti-image Correlation Matrix's Diagonal Values**	**Items**	**Anti-image Correlation Matrix's Diagonal Values**
1	0.842	21	0.864
2	0.874	22	0.918
3	0.807	23	0.908
4	0.896	24	0.880
5	0.636	25	0.915
6	0.629	26	0.922
7	0.794	27	0.948
8	0.908	28	0.947
9	0.918	29	0.911
10	0.905	30	0.846
11	0.931	31	0.932
12	0.929	32	0.940
13	0.894	33	0.916
14	0.940	34	0.965
15	0.913	35	0.911
16	0.937	36	0.927
17	0.887	37	0.937
18	0.935	38	0.917
19	0.899	39	0.891
20	0.928		

Upon examining Table 2 it can be observed that Anti-Image Correlation Matrix's diagonal values are above 0.60 and therefore sample adequacy is ensured.

3. FINDINGS AND COMMENTS

In factor analysis, there are as many eigenvalues as there are factors. Eigenvalues are coefficients taken into account in both calculating the variance as explained by the factor and in determining the number of important factors. In factor analysis, at the start, factors with eigenvalues of 1 or greater are generally regarded as important factors (Büyüköztürk, 2002). After the factor analysis suitability of the data comprising the scale is confirmed, in order to determine the number of factors un-rotated principal component analysis was performed. Obtained results are given in Table 3;

Table 3

Table of Factors' Explaining Total Variance

Factor	Eigenvalues	Percentage of Variance	Total Variance
1	14.362	39.826	36.826
2	2.257	5.787	42.613
3	1.724	4.420	47.033
4	1.662	4.262	51.296
5	1.315	3.372	54.668
6	1.203	3.084	57.751
7	1.167	2.993	60.744
8	1.060	2.718	63.462
9	0.988	2.534	65.996
10	0.936	2.400	68.396
11	0.895	2.294	70.690
12	0.850	2.180	72.870
13	0.750	1.922	74.792
14	0.735	1.885	76.677
15	0.691	1.771	78.448
16	0.663	1.699	80.148
17	0.625	1.602	81.750
18	0.589	1.510	83.260
19	0.563	1.444	84.703
20	0.523	1.340	86.043
21	0.499	1.280	87.323
22	0.457	1.171	88.494
23	0.429	1.099	89.593

24	0.414	1.062	90.655
25	0.391	1.002	91.657
26	0.360	0.923	92.580
27	0.338	0.866	93.446
28	0.319	0.817	94.263
29	0.298	0.764	95.027
30	0.272	0.699	95.726
31	0.255	0.655	96.381
32	0.237	0.607	96.988
33	0.213	0.547	97.534
34	0.208	0.533	98.067
35	0.204	0.522	98.589
36	0.171	0.438	99.027
37	0.156	0.401	99.428
38	0.124	0.318	99.745
39	0.099	0.255	100.000

As a result of the analysis it was observed that the data gathered under eight factors with eigenvalues above 1. After the number of factors in the scale are determined, the number of variables to be included in every factor and the distribution of these variables in the factor are next in line (Nakip, 2006). In the un-rotated principal component analysis, the unsuitability of the scale items' distribution according to the factors was determined. In this case, explanatoriness needs to be increased by reducing the number of factors. The important factors obtained in factor analysis are rotated in order to provide "independence, being open to interpretation and meaningfulness". As a result of the rotation, the items' load increases in a factor, whereas it decreases in others. Thus, factors can find the items they are highly related with and be interpreted with greater ease. In social sciences generally orthogonal rotation is preferred. The most commonly used orthogonal rotation techniques are varimax and quartimax. Both techniques aim to converge the loading values of items to 1.0 in a factor and 0.0 in others (Kırtak, 2015).

As a result of the un-rotated factor analysis most variables ended up in the first factor. However, since other factors could not explain the variables sufficiently varimax rotation was performed upon the scale data. As a result of the rotation the number of important factors in the scale was reduced to seven. The results regarding these factors are given in Table 4;

Table 4

Post-Rotation Factors' Percentage of Explaining Total Variance

Factor	Eigenvalues	Percentage of Variance	Total Variance
1	3.544	12.658	12.658
2	3.466	12.380	25.038
3	2.898	10.349	35.387
4	2.343	8.369	43.756
5	2.315	8.269	52.025
6	2.028	7.243	59.267
7	1.514	5.405	64.673

Another criterion that is taken into account when determining the number of important factors is the line graphic plotted based upon the eigenvalues of the factors. According to Büyüköztürk (2002) in a line graphic fast falls with high acceleration give the number of important factors. Horizontal lines show that the variance explaining contributions are in the same neighborhood (Günhan, 2006). The line graphic obtained from the scale data was investigated. It is given in Figure 1;

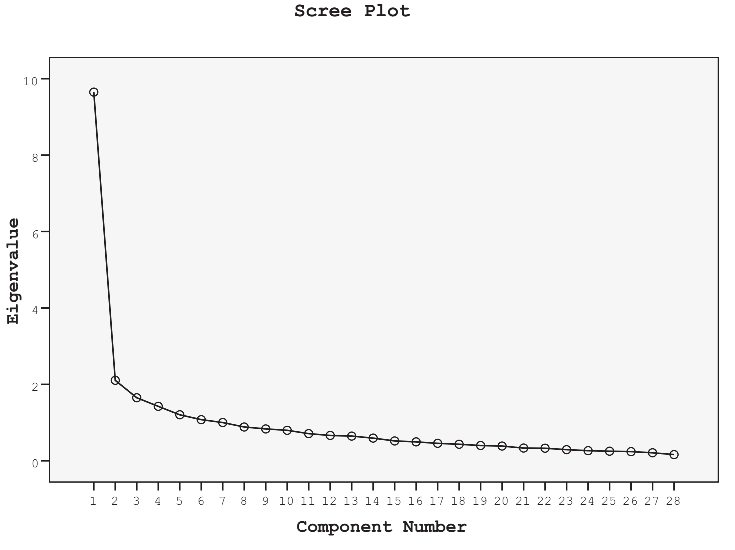

*Figure 1.*The Line Graphic

Upon examining Figure 1 one can observe that there's a steep fall in the data after the first factor. On the other hand, in the other factors up to the eighth there is a less steep, but accelerated fall as well. As for the factors after the eighth the general course of the graphic is horizontal and no important fall tendency is observed. On the other hand, as it can be seen in Table 4, the first four factors can explain 43.756 per cent of the total variance. Since this variance ratio is above the acceptable ratio which is 41 per cent, this can mean that the scale can be interpreted as a four factor scale.

According to the values, obtained as a result of the analyses performed, in order to include an item in a factor, it needs to have a minimum loading factor of 0.3. Also, in order to include an item in two factors, its factor load in the first factor should be at least 0.1 greater than its factor load in the second factor (Büyüköztürk, 2002). 11 items were removed from the scale according to these evaluations. The values belonging to these items are given in Table 5;

Table 5

Values Belonging to the Items Removed from the Scale as a Result of Factor Analysis

Item	**1. Factor**	**2. Factor**	**3. Factor**	**4. Factor**	**5. Factor**	**6. Factor**	**7. Factor**	**8. Factor**
13	0.528		0.487					
14	0.404		0.430					
16			0.351			0.418		
17			0.407		0.384			
19			0.468		0.410			
25	0.379			0.427				
28	0.381	0.447						
29	0.394			0.358				
31	0.471				0.534			
32			0.370	0.463				
33	0.517				0.452			

As seen from Table 5, all items removed from the scale were included in multiple factors and the difference between factor loads were less than 0.1. The factor loads of the items that were allowed to remain in the scale are given in Table 6;

Table 6

Factor Loads Belonging to the Items Allowed to Remain in the Scale as a Result of Factor Analysis

Item	1. Factor	2. Factor	3. Factor	4. Factor
1	0.711			
2				0.579
3		0.646*		
4			0.587	
5				0.891
6				0.888
7	0.780			
8		0.644*		
9		0.587*		
10	0.619			
11			0.590	
12			0.524	
15		0.595*		
18		0.585*		
20			0.766	
21			0.820	
22			0.475	
23		0.721*		
24		0.660*		
26			0.598	
27	0.630			
30		0.644*		
34	0.529			
35	0.650			
36	0.840			
37	0.645			
38			0.726	
39		0.724*		

*These items are negative items and they were graded by reading reversely.

As seen from Table 6 the factor loads of the scale's items vary between 0.475 and 0.891. After the items were removed which needed to be excluded as a result of factor analysis a 28 item scale was obtained. The maximum score attainable from the scale is 140, whereas the lowest score is 28. The designed "Mathematical Attainment Scale" is presented in Appendix 1. The names of the dimensions, the reliability coefficients and item numbers obtained from factor analysis are given in Table 7;

Table 7

Names of the Dimensions, Reliability Coefficients and Item Numbers Obtained from Factor Analysis of the Mathematical Attainment Scale

Dimensions	Items	Cronbach Alpha Reliability Coefficients
Mathematical Thinking Ability	1,7,10,21,23,24,25,26	0.807
Negative Attitudes Towards Mathematics	3,8,9,13,14,18,19,22,28	0.832
Using Mathematical Skills	4,11,12,15,16,17,20,27	0.854
Ability to Use Mathematics in Daily Life	2,5,6	0.712

5. RESULTS, DISCUSSION AND SUGGESTIONS

In the frame of the study, the development of a scale which determines the general mathematical attainments of college students who have completed their primary school and high school educations and reveals how much they improve these attainments during their college education was aimed. When the obtained values are observed the Mathematical Attainment Scale designed by the researcher it can be stated that it is a scale with high validity and reliability. An efficient mathematical education starting from primary school is required to increase the mathematical attainment levels of students. It is believed that education methods that includes the students actively in the education process can increase mathematical attainment levels of students. It is known that in mathematical education given with methods which are referred to as traditional, mathematical knowledge is divided into small parts and is presented and transferred to the students in the form of crumbs as structured and arranged by the teacher and afterwards students are asked to repeat and reflect the presented information almost the way it was presented to them. In this process, teachers are quite active, whereas the students are passive. Even if they do not understand the knowledge bestowed upon them, students are expected to memorize, to renew and reinforce it via exercise, to respond the way they were taught when asked similar question and to not contribute in a major way (Korkmaz & Gül, 2004). In this sense, it is thought that traditional education methods will be inefficient and inadequate in making students reach mathematical attainments. One of the main goals of mathematical education is making students an active contributor in the mathematics performing process. Providing environments in which students can research, discover, solve problems, share and discuss their solutions and approach is of major importance in mathematical education (Ersoy, 2006). Therefore, in order to make students reach sufficient mathematical attainment levels, mathematics tutors are advised to adapt methods and techniques which rely on active learning and to use these methods and techniques effectively.

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