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The Measurement of Preparing Recycling Materials with Many-Faceted Rasch Model*

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ABSTRACT

The study contributes to raising environmental awareness, particularly of recycling among 5th-grade students, by designing recycled materials. This study focuses on the answer of the question: How can recycling materials be evaluated objectively by science teachers? Many-Faceted Rasch Model (MFRM) can be an answer. This model is used to assess the performance judged. It also analyzes jury bias and specifies the most uncomplicated and complicated criteria, which will provide opportunities to improve students' skills. The study was conducted in the 2021-2022 academic year spring semester. The model's surfaces are 14 recycling materials (RM), 10 criteria, and 11 juries: science teachers. The FACETS program was used to analyze data. The findings of the study revealed that recycling project coded as RM 8 is more successful, student-level compatibility criterium was the simplest, and creativity was the hardest. The jury coded as ST8 is the most lenient, and the jury coded as ST7 is the severest.

Keywords: Science education, environmental education, recycling, many-facet Rasch measurement model

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1. INTRODUCTION

Many environmental issues caused by exploiting nature ruthlessly as industrialization progresses are faced. The increasing municipal waste, also called garbage or trash, is a big problem creating social and economic challenges (Erten, 2003; El-Hoz, 2007). Waste collected and processed by or for municipalities is known as municipal waste, such as waste from households, office buildings, and institutions (OECD, 2022). To decrease municipal solid waste and eliminate other environmental problems, attitudes towards the environment must be changed. Environmental education, which helps individuals develop positive attitudes into behaviors, plays an essential role in raising environmental awareness (Erten, 2000; Erten, 2005; Eurostat, 2017; Unterbruner, 1991; Yuzuak & Erten, 2018).

The main causes of the surge in municipal waste are consumer society, extravagance, inadequate waste assessment, and lack of education. Excessive use of natural resources and raw materials to generate energy gives rise to the depletion of resources. The ineffective use of underground and surface water creates pollution, makes soil poorer, pollutes the air, and increases the prevalence of epidemics. These environmental problems threaten both people and the ecology. One solution is to transform ordinary thoughts and behaviors. Recycling can protect lives from hazardous materials such as lead, mercury, gases, and chemicals. Waste can be minimized by reducing the use of resources, recycling, or composting, recovering energy, performing a treatment, and disposal works. 3R: Reduction, Reuse, and Recycling are keys to minimizing waste. Recycling plays a vital role in environmental awareness which keeps improving in Turkiye (EPA, 2020; Erten, 2003; Hiğde & Aktamış, 2021; Larney & Aardt, 2009; Miller, 2010).

Turkiye's total municipal waste (kilograms per capita) is lower than the average of OECD countries. Its total municipal waste was 419.7 kilograms per capita, and in OECD, it was 538.3 kilograms/capita back in 2019. Turkiye's manufacturing sector, mining operations, thermal power plants, organized industrial zones, medical facilities, and homes generated 104.8 million tons of municipal garbage, including 30.9 million tons of hazardous waste (2020). The total waste has increased by 10.5% compared to 2018 (OECD, 2022; Turkish Statistical Institute [TÜİK], 2020). The waste produced in Turkiye is 1.16 kilograms a day per person (TÜİK, 2019). Services for waste disposal were in place in 1387 of the 1389 municipalities. Of 32.3 million tons of waste collected in the municipalities, 69.4% was sent to regular storage facilities, 17% to municipal landfills, and 13.2% to recovery facilities. 0.4% of collected waste was disposed of by burning, burying, or dumping into streams or land. The average

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* Ethical permission of the study was approved (Bartın University, Protocol Number = 2022-SBB-0079 Decision Date: 10.03.2022 Meeting Number: 5)

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daily waste per person in municipalities was 1.13 kg. 127.4 million tons of waste were processed in the waste disposal and recovery facilities, 78.3 million tons were disposed of, and 49.1 million tons were recovered. The total amount of processed waste increased by 22% compared to 2018. (TÜİK, 2020). By recycling waste, the adverse effects on the environment, health and economy are reduced, and pollution and destruction of natural resources can be eliminated (Spiegelman & Sheehan, 2004). Turkiye aims to reach net-zero emissions by 2053. With the Zero Waste Project launch in Turkiye, the recycling rate has increased to 22.4% from 13% (Anadolu Agency, 2021).

Everyone is responsible for environmental protection (Erten, 2006), and public participation is crucial for recycling (Pakpour et al., 2004). People should seek to find solutions for environmental problems i.e., waste problems; this is also important for sustainability. Even though laws and technology play an important role to decrease environmental problems, they are not adequate. The correct tool is environmental education. Environmental awareness of individuals can be raised, with the help of environmental education which is a lifelong process (Erten, 2012). Environmental education's components are awareness and sensitivity, knowledge and understanding, attitudes, skills, and participation (Stapp et al., 1969). Environmental education at schools is crucial for developing environmentally friendly behaviour, such as recycling. Environmental education enables individuals to explore environmental issues, engage in problem-solving, and take action to conserve the environment (Hiğde, Öztekin & Şahin, 2017). Past researchers have concentrated on the effect of environmental education on environmental awareness (Kayaer and Çiftçi, 2022), whether the environmental awareness of the students studying at university affects their environmental attitudes and behaviours (Sancak, 2022), middle school students' attitudes towards the environmental problems and their suggestions (Kırılmazkaya, 2022). Numerous studies have examined environmental awareness (Çetin & Nişancı, 2010; Littledyke, 2008; Marpa, 2020; Türkoğlu, 2019). As mentioned before, recycling plays an important role in environmental awareness. In the literature, there are also studies related to recycling. Demirel and Özcan (2022) investigated the effects of teaching the subject of domestic waste and recycling. Keleş and Keleş (2018) determined how the concept of recycling was perceived by 3rd and 4th grade students. Gönüllü, Doğan, and Çelik (2015) examined recycling of packaging waste in the primary education curriculum in detail recycling applications of different schools which had different socioeconomic levels. On the other hand, as part of study, 5th-grade students designed materials from waste materials to understand the significance of recycling. At this very point, one question is: how can recycled materials be evaluated objectively? This is the main focus of this study. One answer to this question comes with the use of the MFR, based on Item Response Theory (Semerci, 2011a; Semerci, 2011b; Semerci, 2012; Yüzüak, Erten & Kara, 2019; Yüzüak, Yüzüak & Kaptan, 2015). The reliability and separation indices are two credible statistics provided by MFRM. The reliability index is comparable to KR-20 or Cronbach's Alpha test reliability, i.e., the ratio of "True Variance" to "Observed variance". Persons and items with high reliability (near 1.0) are favoured (Linacre, 2010: 160). MFRM is an extension of Rasch measurement models (Rasch, 1980; Wright & Masters, 1979). The equation of the Many-facet Rasch (F_k) is that:

$$\log \frac{Pnijk}{Pnijk-1} = B_n - D_i - C_j - F_k$$

In the equation,

P_{nijk} is the probability of examinee n being awarded on item i by judge j a rating of k,

P_{nijk-1} is the probability of examinee n being awarded on item i by judge j a rating of k-1,

Bn is the ability of examinee n, D_i is the difficulty of item I, C_j is the severity of judge j,

F_k is the extra difficulty overcome in being observed at the level of category k, relative to category k-1 (Linacre, 1989).

"Authentic measurement frequently requires examinee performances to be rated by judges" (Linacre et al., 1994: 570). MFRM is a key for this. This study aims to evaluate the ability of preparing recycling materials with MFRM. In parallel with this aim: Recycling materials performance, criterion hardness, severity/leniency of science teachers and their bias were analyzed.

2. METHODOLOGY

2.1. Research Model

The survey method was used in this study. By the ethical research rules (Bartın University Protocol Number = 2022-SBB-0079, Decision Date: 10.03.2022 Meeting Number: 5), the recycling materials were coded as RM1, RM2 ... RM14 and the science teachers (jury) were coded as ST1, ST2, ... ST11, and criteria were coded as originality, ergonomics, etc.

2.2. Participants

The study was conducted in the spring semester of the 2021-2022 academic year. 5th grade students (14) laid out 14 recycling materials, and 11 science teachers evaluated them. Both 5th grade students (14) and 11 science teachers participated the study voluntarily. The students who prepared recycling materials were informed about municipal waste, statistics related to municipal wasted in the literature to get attention. Science teachers have at least ten years' experience in government schools. Also, all science teachers were enrolled in a master's degree science education program.

2.3. Research Data and Analysis

The FACETS program (Linacre, 2014) was used to analyze the quantitative data, and a material evaluation form to set out the criteria (ISTMEM, 2020). The form includes 10 items: 1 = originality, 2 = ergonomics, 3 = objective compatibility, 4 = usage of inert material, 5 = appealing to the senses, 6 = creativity, 7 = student-level compatibility, 8 = security, 9 = facilitating learning, 10 = aesthetics. The criteria form was of a 5-pointed Likert type: 1 = not appropriate to 5 = entirely appropriate. Two science education experts checked the form. The form was found appropriate for this study. The reliability coefficient for recycling analysis was .96. The research process is indicated in Figure 1.

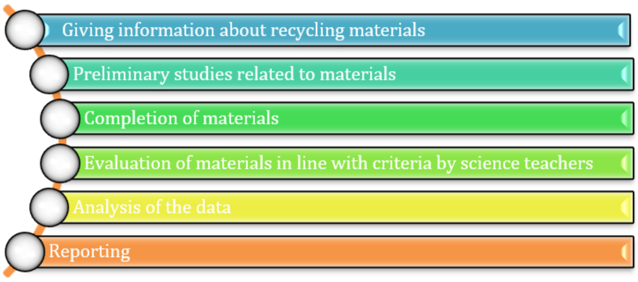

Figure 1. Research process

3. FINDINGS

The study facets are recycling materials, criteria, and jury: science teachers. The related calibration map is indicated in Table 1.

Table 1.
Calibration Map Related to Recycling Projects

Measr	+Recycling materials	+Criteria	+Jury		RATIN
+ 3					5
	RM8				
	RM3				
	RM11				

	RM1 RM14				
+ 2	RM9			+	
	RM12				
					4
	RM10 RM6				
	RM2 RM7				
	RM13 RM4				
+ 1		Security Student level compatibility		+	
			ST8		
			ST3		
			ST9		
	RM5		ST11		
		Aesthetics Usage of recycling material	ST10 ST5		
* 0 *			ST1	*	3 *
		Objective compatibility			
		Ergonomics			
		Facilitating learning Originality			
		Appealing to the senses			
		Creativity			---

Measr	+Recycling projects	+Criteria	+Jury	RATIN
				+
- 1				
			ST7	2
- 2				+ (1)
Measr	+Recycling projects	+Criteria	+Jury	RATIN

The “measr” on the left side of Table 2 shows that the science teachers have scored all recycling projects above the intermediate level. Related logit values are indicated in Table 2.

Table 2.
Logit Values for Three Facets: Recycling Projects, Criteria, and Jury

Recycling Projects	Logit	Criteria	Logit	Jury	Logit
RM8	2.77	Student level compatibility	1.04	ST8	.77
RM3	2.60	Security	1.02	ST3	.60
RM11	2.49	Usage of inert material	.13	ST9	.55
RM14	2.07	Aesthetics	.08	ST11	.29
RM1	2.05	Objective compatibility	-.06	ST5	.13
RM9	1.98	Ergonomics	-.19	ST10	.09
RM12	1.85	Facilitating learning	-.38	ST1	.02
RM6	1.42	Originality	-.42	ST4	-.23
RM10	1.36	Appealing to the senses	-.56	ST2	-.36
RM2	1.35	Creativity	-.67	ST6	-.46
RM7	1.32			ST7	-1.39
RM4	1.06				
RM13	1.06				
RM5	.32				

Table 2 indicates that the recycling project coded as RM 8 (logit value = 2.77) is more successful. The recycling project coded as RM5 (logit value = .32) is less successful. The most challenging criterium is creativity (logit value = -.67), and the least one is student-level compatibility (logit value: 1.04). The science teacher coded as ST8 is the most lenient jury (logit value = .77) and the science teacher coded as ST7 the severest one.

3.1. Recycling Materials Performance Analysis

Details about the performance analysis of recycling projects are shown in Table 3, including logit value, total score, and observed average.

Table 3.
Recycling Materials Performance Analysis

Recycling Materials	Nu	Measure	Model S.E	Infit	ZStd	Outfit	ZStd	Total Score	Obsvd Average
RM8	8	2.77	.17	.96	-.2	.85	-.6	507	4.61
RM3	3	2.60	.16	1.41	2.3	1.62	2.7	501	4.55
RM11	11	2.49	.16	.74	-1.7	.68	-1.8	499	4.54
RM14	14	2.07	.14	1.62	3.8	2.46	6.7	477	4.34
RM1	1	2.05	.14	1.34	2.2	1.49	2.8	476	4.33
RM9	9	1.98	.14	.92	-.5	.97	-.1	472	4.29
RM12	12	1.85	.13	.74	-2.1	.81	-1.3	465	4.23
RM6	6	1.42	.12	.85	-1.1	.80	-1.5	439	3.99
RM10	10	1.36	.12	.87	-1.0	.89	-.8	435	3.95
RM2	2	1.35	.12	1.37	2.6	1.29	2.0	434	3.95
RM7	7	1.32	.12	.57	-3.9	.57	-3.8	432	3.93
RM4	4	1.06	.12	.83	-1.3	.81	-1.5	414	3.76
RM13	13	1.06	.12	.96	-.2	.94	-.3	414	3.76
RM5	5	.32	.11	.92	-.6	.91	-.7	358	3.25

RMSE (Model) = .14 x^2=355.1 df = 13 p= .00 Reliability = .96

Table 3 indicates that RMSE (Model) is .14 and the reliability coefficient is .96. There is a measurable difference between the recycling materials. This hypothesis belongs to the fixed effect with a separation index of 4.99. The reliability coefficient .96 was tested with chi-square test (x^2 = 355.1; df = 13; p= .00). The null hypothesis was rejected. It means that there are significant statistical differences between the projects. The qualification sequence tasks are orderly followed as RM8, RM3, RM11, RM14, RM1, RM9, RM12, RM6, RM10, RM2, RM7, RM4, RM13 and RM5.

3.2. Criteria Analysis

The separation index is 5.18, and the reliability coefficient is .96. There are significant differences in the criteria used to evaluate recycling projects. This hypothesis was tested with chi-square (x^2= 204.9; df = 9; p= .00). The null hypothesis was rejected. According to these results, there are significant statistical differences between the criteria used to assess recycling materials. Details about the criteria measurement analysis are shown in Table 4, including logit value, total score and observed average.

Table. 4.
Criteria Measurement Report

Criteria	Meas.	S.E	Infit	ZStd	Outfit	ZStd	Total.score	Obs. Aver.
Student level compatibility	1.04	.14	1.01	.1	1.14	.8	706	4.58
Security	1.02	.14	1.19	1.3	1.55	2.8	705	4.58
Usage of recycled material	.13	.11	1.29	2.3	1.38	2.7	648	4.21
Aesthetics	.08	.11	1.07	.6	.98	-.1	644	4.18
Objective compatibility	-.06	.11	.93	-.5	.96	-.3	632	4.10
Ergonomics	-.19	.11	.86	-1.2	.88	-1.0	621	4.03
Facilitating learning	-.38	.10	.86	-1.2	.91	-.7	604	3.92
Originality	-.42	.10	.95	-.4	.97	-.2	600	3.90
Appealing to the senses	-.56	.10	.80	-1.9	.85	-1.3	587	3.81
Creativity	-.67	.10	1.08	.7	1.17	1.5	576	3.74
RMSE (Model) = .11 x^2= 204.9 df = 9 p= .00 Reliability = .96								

Table 4 indicates that the simplest criterium is student-level compatibility. The criteria are listed from the simplest to the hardest: Student level compatibility, security, recycled material usage, aesthetics, objective compatibility, ergonomics, facilitating learning, originality, appealing to the senses, and creativity.

3.3. Jury Analysis

Details about the analysis of a jury consisting of science teachers are shown in Table 5, including logit value, total score, and observed average.

Table 5.
Jury Analysis Report

Jury	Nu	Measure	Model S.E	Infit	ZStd	Outfit	ZStd	Total Score	Obsvd Average
ST8	8	.77	.14	.73	-2.2	.62	-2.5	629	4.49
ST3	3	.60	.13	.62	-3.4	.83	-1.0	619	4.42
ST9	9	.55	.13	2.33	7.6	3.04	8.9	616	4.40
ST11	11	.29	.12	.71	-2.7	.92	-.5	646	4.31
ST5	5	.13	.12	.73	-2.4	.75	-2.0	588	4.20
ST10	10	.09	.12	.75	-2.2	.75	-2.0	585	4.18
ST1	1	.02	.12	1.14	1.1	1.04	.3	580	4.14
ST4	4	-.23	.11	.62	-3.6	.63	-3.4	560	4.00
ST2	2	-.36	.11	1.55	3.9	1.47	3.3	506	3.89
ST6	6	-.46	.11	1.08	.7	1.04	.3	541	3.86
ST7	7	-1.39	.10	.76	-2.2	.81	-1.7	453	3.24
RMSE (Model) = .12 x^2= 298.9 df = 10 p= .00 Reliability = .96									

The reliability coefficient is calculated as .96. The jury separation index is 5.06. The null hypothesis was rejected when the hypothesis that reads “there is a difference between severity/leniency of the jury” was tested with a chi-square test (x^2=298.9; df=10; p= .00). According to Table 5, the jury coded as ST8 is the most lenient, and the jury coded as ST7 is the severest. Juries are rated from the most lenient to the severest in ST8, ST3, ST9, ST11, ST5, ST10, ST1, ST4, ST2, ST6 and ST7, respectively.

3.4. Jury Bias Analysis

The bias/interaction report is given in Table 6, including the juries, logit values, observed scores and expected scores.

Table 6.
Bias/Interaction Report

Obs. Score	Exp. Score	Obs. Count	Obs-Exp Avarage	Ju	measr	RM	Proj Measr+
30	45.96	10	-1.60	J9	.55	14	2.07
34	47.49	10	-.1.35	J9	.55	3	2.60
31	39.77	10	-.88	J1	.02	2	1.35
39	44.99	10	-.60	J11	.29	14	2.07
20	27.77	10	-.78	J7	-1.39	4	1.06
33	39.80	10	-.68	J7	-.139	8	2.77
31	37.91	10	-.69	J1	.02	13	1.06
38	43.85	10	-.59	J5	.13	9	1.98
31	37.34	10	-.63	J2	-.36	2	1.35
39	44.01	10	-.50	J8	.77	10	1.36
40	44.76	10	-.48	J6	-.46	8	2.77
27	32.76	10	-.58	J1	.02	5	.32
33	38.24	10	-.52	J4	-.23	10	1.36
49	47.34	10	.17	J3	.60	11	2.49
49	46.34	10	.27	J5	.13	3	2.60
49	46.13	10	.29	J3	.60	14	2.07
48	44.04	10	.40	J6	-.46	3	2.60
49	44.29	10	.47	J5	.13	14	2.07
47	41.98	10	.50	J4	-.23	9	1.98
49	43.79	10	.52	J1	.02	14	2.07
40	34.63	10	.54	J6	-.46	4	1.06
48	42.89	10	.51	J9	.55	10	1.36
45	39.59	10	.54	J1	.02	7	1.32
44	37.85	10	.62	J2	-.36	6	1.42
43	36.63	10	.64	J6	-.46	2	1.35
46	39.66	10	.63	J11	.29	13	1.06
45	38.36	10	.66	J10	.09	4	1.06
49	41.22	10	.78	J9	.55	4	1.06
41	29.94	10	1.11	J7	-1.39	2	1.35
50	46.51	10	.35	J1	.02	8	2.77
50	47.94	10	.21	J3	.60	8	2.77
50	46.83	10	.32	J5	.13	8	2.77
50	48.26	10	.17	J8	.77	8	2.77
50	43.33	10	.67	J1	.02	9	1.98
50	46.40	10	.36	J8	.77	9	1.98
50	47.74	10	.23	J8	.77	11	2.49
50	41.22	10	.88	J9	.55	13	1.06
50	46.69	10	.33	J8	.77	14	2.07
41.3	41.30	10.1	.00		Mean (Count: 153)		
7.5	6.49	.8	.38		S. D. (Population)		
7.6	6.51	.8	.38		S. D. (Sample)		
Fixed (all = 0) chi-square = 378.0 d.f. = 153 significance (probability) = .00							

According to Table 6, some juries may be extremely severe or lenient towards recycling materials. For example, J9 (coded as RM14) scored 30 points for the recycling project, while the expected score was 45.96. J9 (coded as RM3) scored 34 points for the recycling project, and the expected score was 47.49 points. J8 (coded as RM14) scored 50 points for the recycling project, and the expected score was 46.69 points.

4. RESULTS, DISCUSSION AND RECOMMENDATIONS

This study contributes significant contributions to the literature on expertise. Past researchers have concentrated on the effect of instructions and the views related to the recycling process. This study examined the student recycling materials and expertise. The study used an objective measurement system to analyze the ability for creating recycling materials that were used in daily life. Jury analysis is also an important feature of this study.

Recycling is not a straightforward procedure that can be simply implemented (Demirel & Özcan, 2022). The research was carried out with 5th-grade students and science teachers to boost environmental awareness of recycling and evaluating the recycling of materials objectively through the Many Facet Rasch Model. This research has concluded that MFRM indicates reliable coefficients and can be used to measure individuals' performance in environmental education. The research was conducted to bring the attention of 5th grade students who participated in the study voluntarily. This study is a quantitative study but Linacre (1993) stated that no generalization should be made from the sample's data results.

Objectivity and stability are two main advantages of the Rasch model (Linacre 1994; Linacre, 2006). The Rasch model does not include error variance in the item and rater variance (Linacre, 1993). The surfaces used in the study: Recycling materials, criteria, and jury. It was thought that the recycling materials were evaluated objectively. The recycling material coded as RM8 was found the most successful, and the recycling material coded as RM5 was the least successful concerning the ten criteria.

It was stated that when the coefficient number is close to 1.00, the reliability grows as traditional methods foresee (Linacre, 2010). Therefore, it is not wrong to say that the criteria form can evaluate the recycling of materials. According to the criteria measurement report, students should focus more on the following criteria: Creativity, appealing to the senses, facilitating learning, originality, ergonomics, and objective compatibility. Student-level compatibility criterium was the simplest, and creativity was the hardest. According to Craft (2003), creativity can be defined as the capacity of an individual to use intelligence and imagination. Ministry of National Education (MoNE) (2018) aimed to expand student creativity in the science education curriculum. Teachers are expected to support, encourage and be a role model for creativity (Sternberg & Lubart, 1995; Sternberg & Williams, 1996). Teachers were informed of four elements to design materials-COLA: Contrast, Orientation, Lettering, and Artwork (Rotter, 2006). Dikici (2006) has stressed the importance of art education at this point.

Many Facet Rasch Model provides useful information on facets (Batdi, 2017; Batdi & Elaldi, 2016; Semerci, 2011a; Yılmaz, 2016). One facet is the jury. The jury coded as ST8 was the most lenient in the research, and ST7 was the severest. According to the bias/interaction report, as jury members, some science teachers were extremely severe or lenient to recycling materials. Some studies also resulted in different rating processes (Dogan & Tekin, 2021; Saritas Akyol & Karakaya, 2021). Rater severity means the tendency of raters to consistently give higher or lower ratings to the performances (Engelhard, 1994). Kassim (2011) stated that differences in rater severity occur in the presence of different standards expectations.

In the light of results, detailed studies with quantitative data were recommended to improve students' creativity related to preparing recycling materials. Some science teachers displayed biased behaviors as judges; science teachers should be unbiased when evaluating students' performances. Also, for the next studies, criteria should be well defined to decrease the unbiased ratio.

Research and Publication Ethics Statement

The research complies with research and publication ethics.

Contribution Rates of Authors to the Article

This is a single-authored paper.

Statement of Interest

The researcher declares that there is no conflict of interest.

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