Journal of Turkish Science Education, 2024, *21*(2), 196-211.
DOI no: 10.36681/tused.2024.011

Journal of Turkish Science Education
http://www.tused.org
© ISSN: 1304-6020

Devising an early childhood engineering habits of mind scale

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ABSTRACT
Engineering education aims to equip children with the skills to solve and apply complex problems. Problem-solving processes in engineering require high-level thinking and mind habits. Habit is a term used to describe various aspects of intelligence. Engineering habits of mind are the values, attitudes, and thinking skills associated with engineering. This research aimed to develop a scale to assess the engineering habits of mind of children ages 5-8. The study involved 417 children in two provinces in the southwest and northwest of Türkiye. We performed Explanatory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) for the scale's construct validity. The scale consisted of 35 items and six factors and explained 59.2% of the total variance. We called the factors "system thinking," "creativity," "optimism," "collaboration," "communication," and "attention to ethical considerations." According to the CFA result, the construct we obtain is reasonable ($\chi 2/sd= 1.97$, RMSEA= 0.068, CFI= 0.93, TLI= 0.91, SRMR= 0.062). The item total correlations range from 0.43 to 0.66. We determined the Cronbach Alpha coefficient of the scale to be 0.94 and the test re-test reliability to be 0.87. According to the results, it can be said that the scale obtained can be used validly and reliably to determine the engineering habits of mind children according to teacher reports. The study contributes to the ever-increasing engineering habits of mind literature.

RESEARCH ARTICLE

ARTICLE INFORMATION
Received:
24.03.2024
Accepted:
12.03.2024

KEYWORDS:
Engineering education engineering habits of mind (ehom), early childhood, scale.

To cite this article: Erol, A., & Erol, M. (2024). Devising an early childhood engineering habits of mind scale. *Journal of Turkish Science Education*, *21*(2), 196-211. DOI no: 10.36681/tused.2024.011

Introduction

Children are prone to explore the world and ask questions with their innate curiosity their innate curiosity (Piaget, 1952). This encourages children's active participation and focuses on exploring, questioning, and developing problem-solving skills. In this way, it aims to deepen their learning experiences and enable them to construct their own knowledge actively (Murphy et al., 2019; Simoncini, 2017). Therefore, enriching children's learning environments based on their natural curiosity will create meaningful experiences for them. Many understandings have been developed to support children's natural curiosity in early childhood classrooms. STEM education has been evaluated as an approach that serves children's natural curiosity (Erol, 2021; Erol et al., 2023). Due to the rise of STEM education in early childhood education, researchers have recently focused on integrating engineering into preschool classrooms and supporting children's engineering habits of mind (Bagiati & Evangelou, 2016; Lippard et al., 2018; Van Meeteren & Zan, 2010). Engineering design is the organisation, development, testing, production, and operation of products or processes that perform a desired function within defined criteria and limitations, planned through scientific and mathematical principles (Apiola & Sutinen, 2021; Lange et al., 2019; NAE & NRC, 2009).

Children encounter problem-solving and engineering design in their daily activities. To solve their problems in their early years, children stack objects on top of one another, attempt to combine them, create relationships between the materials, and break what they have assembled again (Cunningham, 2018; Lange et al., 2019). Children develop early engineering skills by building models, trying new ideas, and building (Lange et al., 2019). In this process, they experience space, shapes, dimensions, and gravity (Texley & Ruud, 2018; Stone-MacDonald et al., 2015). The engineering design process contributes to developing children's creativity (Lasky & Yoon, 2011; Pérez-Ferra et al., 2020; Ramanathan et al., 2023). Children find opportunities for systems thinking, visualising, improving, adaptation, creative problem-solving, optimism, collaboration, and communication (Katehi et al., 2009; Lippard et al., 2019; Lucas et al., 2014; Stone-MacDonald et al., 2015). These opportunities are expressed as engineering habits of mind (EHoM).

The Engineering Habits of Mind (EHoM)

In problem-solving and creativity, children use a set of mind habits (Schucker et al., 2022; Öztürk et al., 2023; Van Meeteren, 2018). Mind habits that can be developed through reading, writing, and critical analysis are related to creativity, openness, curiosity, resilience, flexibility, responsibility, and meta-knowledge (O'Neill et al., 2012). Engineering problem-solving procedures call for advanced thinking and mental habits. The term "habits" is used to describe the components of intelligence (Resnick, 1999). In this context, EHoM is defined in the literature (EHoM) as a set of "engineering-related values, attitudes, and thinking skills" (Katehi et al., 2009). Specifically, the six EHoM are focused on systems thinking, optimism, communication, collaboration, creativity, and attention to ethical considerations (Han et al., 2023; Lippard et al., 2019; Katehi et al., 2009; Van Meeteren, 2018). System thinking is about identifying and exploring the interrelationships between materials and parts of systems (NAE & NRC, 2009). Lammi and Becker (2013) stated that integrating the engineering design process into educational environments would encourage systems thinking skills. Creativity is using imagination to solve engineering problems (Loveland & Dunn, 2014). Optimism reflects a perspective in which opportunities and possibilities can be found in every difficulty. It includes recognising that every technology has room for improvement (National Academy of Engineering, 2010). Collaboration is the process of integrating the skills and strengths of each group member into the problem-solving procedure to achieve a superior outcome (NAE & NRC, 2009). Communication is a core skill for problem-solving, learning, and academic success. Teachers can evaluate how children understand and integrate new information by expressing their thoughts while learning. Attention to ethical considerations involves the idea that any solution to a problem will affect others around you (Lippard et al., 2018; NAE & NRC, 2009; Yang et al., 2024).

Another EHoM model was suggested by Lucas et al. (2014) in a report published by the Royal Academy of Engineering. Accordingly, there are six EHoM: system thinking, adapting, problem finding, creative problem solving, visualizing, and improving. Figure 1 (Lucas et al., 2014) illustrates the model.

Figure 1

The engineering habits of mind

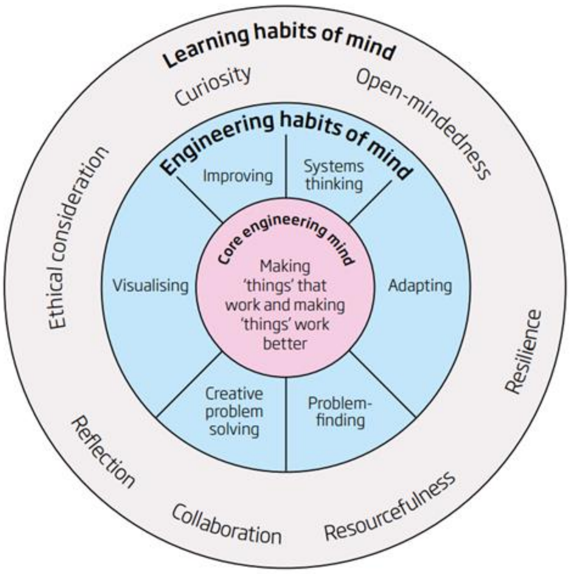

Table According to the model above, 1) System thinking is seeing the relationships between all systems and parts, finding patterns, and synthesising them. 2) Problem finding, clarifying requirements, evaluating existing solutions, conducting research, and confirming contexts. 3) Visualizing is the capacity to transition from the abstract to the concrete, manipulate materials, cognitively test physical space, and create practical design solutions. 4) Improving is attempting to improve everything by experimenting, designing, sketching, predicting, conducting mental experiments, and insisting on developing prototypes. 5) Creative problem solving, utilising various techniques, generating ideas and solutions in collaboration, delivering rigorous criticism, and viewing engineering as a team sport. 6) Adapting adjustment is testing, analysing, reflecting, rethinking, and changing physically and mentally.

Current Study

Researchers have developed measurement tools that attempt to determine EHoM in early childhood classrooms (Lippard et al., 2019; Yang et al., 2024). A classroom observation protocol (COP) was created by Lippard et al. (2019). COP is an observation measure capturing behaviors that show the EHoM in early childhood classes. COP offers a robust structure with observation-based data delivery. Collecting the observation data and obtaining parental permission to observe each child may present difficulties. Developing measurement tools that demonstrate children's demonstration of these skills is accordingly important. There are some difficulties in using a measurement tool. A study involving a scale in the literature aimed to evaluate children's STEM habits of mind with a teacher-completed form (Yang et al., 2024). The scale is three-dimensional. Three dimensions with high internal reliability, such as Science Process Skills, Coding and Decoding Skills, and Engineering and Mathematics Skills, are essential factors in the Children's STEM Habits of Mind Questionnaire (CSHMQ). The CSHMQ is an essential tool for early childhood researchers and practitioners because it provides evidence for assessing children's STEM process skills and planning and adapting instructional practices to develop these skills. This measurement tool is valuable for better understanding children's interests and abilities in STEM fields and optimising educational programmes accordingly.

More practical measurement tools are needed to develop EHoM literature in early childhood Li et al., 2021; Wan et al., 2021). The relevant literature reveals that most EHoM-related research uses qualitative research designs, with observation as the primary data collection method (Lippard et al., 2019). Work on scale development and work in broader sample groups will contribute to the increasingly sought-after EHoM literature. Therefore, this study aimed to develop a measurement tool to evaluate the EHoM of children aged 5-8 from the teacher's perspective.

Methods

Participants

The study involved 417 children studying in two provinces in the southwest and northwest of Türkiye. We used convenience sampling methods to identify participants. The convenience sampling method minimises time, labour, and cost, and adds speed and practicality to research (Patton, 2015). The re-test reliability test was performed with 37 children from the first study group. Participants, 21 were girls, and 16 were boy. We have shown detailed information about the participants involved in the working groups in Table 1.

Table 1

Participants' demographics

		EFA Group (N=204)*		CFA Gourp (N=213)**	
Variables	Demographic İnformation	%	*f*	%	*f*
Gender	Girl	50.98	104	49.77	106
	Boy	49.02	100	50.23	107
Mother's level of education	Primary	17.65	36	17.37	37
	Middle school	21.57	44	21.13	45
	High school	31.37	64	29.58	63
	Tertiary	29.41	60	31.92	68
Fathers' level of education	Primary	18.63	38	18.31	39
	Middle school	11.76	24	12.21	26
	High school	36.76	75	36.62	78
	Tertiary	32.84	67	32.86	70
Family monthly income	Below mean	66.67	136	66.20	141
	Above mean	33.33	68	33.80	72

Note. *EFA average family income per month ($\bar{X}$ = 9847 TL), **CFA average family income per month ($\bar{X}$ = 8869 TL)

The ages ranged from 5 to 8 years. The average age of the EFA group is 6.12 years. The average age of the CFA study group is 6.57 years.

Data Collection Tools

Early Childhood Engineering Habits of Mind Scale (EC-EHoM)

Measurement tools related to each sub-dimension of EHoM (Lippard et al., 2019; Oğuz & Köksal-Akyol. 2015; Yıldız-Çiçekler et al., 2020) were examined. EHoM models have been studied (Lippard et al., 2019; Lucas et al., 2014). There were 78 items in the first draft scale. Experts in the field were consulted regarding each item's clarity, the scale's purpose, and its suitability for children. Expert opinion was sought for the draft scale to ensure content validity and eliminate spelling errors. The draft scale was presented to five instructors/teachers who are experts in their fields. The scale was then conveyed to a statistician. Twenty-seven feedbacks given by the expert were examined, and necessary arrangements were made considering 24 feedbacks. Finally, opinions were obtained from two field experts working as associate professors in science education. After all expert opinions, 23 items were removed from the 78-item scale, and it was decided that the scale would consist of 55 items before the application. The content validity index of the scale was calculated as 0.96.

The scale is 5-point Likert (strongly agree, agree, moderately agree, disagree, strongly disagree). The Likert scale indicates that two, three, four, six, and seven can be used, but the five scale is the most convenient option (Köklü, 1995; Ray, 1980; Fink, 1995). The scale has been developed in Turkish, and it is recommended to do re-validity reliability analyses to adapt it to other languages or cultures. The form is in the appendix section.

Data Collection Process

We collected research data from early childhood and primary school teachers. We obtained permission from the (Ministry of Education, School Directorate, children's families, class teachers, and the children themselves). The data from the first study group was collected face-to-face, while the data from the second study group was collected online. We handed the scale loaded in the Google form for the second working group to the teachers. We provided teachers with explanatory information online about the purpose, scope, and how to fill out the scale. We also held an informing meeting for teachers on the purpose, scope, content, time of filling, and how the scale is filled. Teachers filled out the scale on behalf of the children in their classes. Incomplete or incorrect forms were excluded from the process by examining the collected data.

Data Analysis

The data were analyzed using SPSS 25, JAMOVI 2.1.13, and Mplus 7.5 package versions. The procedures for data analysis are as follows:

Normality

Before the EFA and CFA analyses, the assumption of normality was examined by Shapiro-Wilk analysis, and it was determined that the assumption was met (for the first study group: $p = 0.083$; for the second study group: $p = 0.117$; $p > 0.005$). In addition, kurtosis and skewness values were also examined. It was determined that kurtosis and skewness took a value between +/-1 (Çokluk et al., 2010; Tabachnick & Fidell., 2007).

Validity Analysis

For validity analysis, EFA was conducted with data obtained from the first study group and CFA with data from the second study group. KMO (Kaiser Meyer Olkin) analysis was also carried out to determine the conformity of the data to the EFA, and the qualification of the sample for EFA was determined. The scale's validity has been examined in two stages: content and construct. We received expert opinions on content validity. EFA and CFA were used to determine the validity of the construction. We used the JAMOVI program for EFA and CFA.

We used the direct noblemen rotation technique, which is one of the oblique rotation techniques based on the assumption of normality. Maximum Likelihood (ML) with continuous indicators, and the assumption that factors are related (Çokluk et al., 2010). We used ≥ 0.50 criteria for item factor loads (Hair et al., 1998). We evaluated the item according to the factor loadings of the items and the common factor variance (h^2) they explained. We used DFA to confirm the resulting construct in EFA. Accordingly, it is recommended to use CFI (Comparative Fit Index), TLI (Tucker–Lewis Index), RMSEA (Root Mean Square Error of Approximation), and SRMR (Standardized Root Mean Square Residual) fit criteria to evaluate model fit in DFA (Xu & Tracey, 2017). In addition to these values. Kline (2011) states that the relative chi-square (χ^2/df) (2022) is an essential criterion for model fit. In the evaluation of DFA fit indices. CFI and TLI values above 0.95, RMSEA and SRMR values below 0.05, and χ^2/df values less than two indicate a good fit (Kline, 2011).

Reliability Analysis

Reliability analyses were made with the data obtained in the first study group. In determining the reliability of the prepared scale, first split reliability methods, then Cronbach's and McDonald's reliability methods were used to determine internal consistency. At another point, ANOVA Tukey's Nonadditivity, Hotelling's T-Squared, and intraclass correlation coefficient (ICC) analyses were also performed to determine reliability. Test-retest reliability was also calculated in this study. The scale's stability depends on the fact that the structures evaluated in various periods have a significant correlation value close to 1 in the test-retest reliability analysis (Gravesande et al., 2019).

Convergent validity was determined with Mplus. This study used the composite reliability coefficient to test reality. For convergent validity, all CR values of the scale (CR >.70) must be greater than AVE (Average Variance Extracted) values, and the AVE value must be greater than 0.50. To discern convergent validity, the square root of the AVE of each construct must be greater than the correlation of that construct with any of the other constructs. CR and AVE should be greater than .70 and .50. respectively (Fornell & Larcker, 1981).

Ethical Considerations

The study was approved by the social and human sciences ethics committee of the university where the researchers are employed. In addition, necessary permissions were obtained from the principals of the schools where the application was made. At another point, the participants were informed that they participated in the research entirely voluntarily and could leave the study at any time while filling out the scale. Written consent was obtained from the parents of the children. Teachers who agreed to participate in the study were selected for the study. It has been communicated to the participants that the data will not be shared with third parties and institutions.

Findings

Validity Analysis

Six-Dimensional Solution/Explanatory Factor Analysis (EFA)

To determine the number of scale factors and the distribution of items to scale factors, the parallel analysis method was considered. Detailed information on factors and factor loads is presented in Table 2.

Table 2

Factor loadings

Dimensions	Made	1	2	3	4	5	6	Uniqueness
Creativity	CR5_15	0.774						0.364
	CR7_17	0.705						0.313
	CR3_13	0.679						0.456
	CR6_16	0.667						0.402
	CR2_12	0.663						0.490
	CR11_21	0.623						0.415
	CR8_18	0.621						0.431
	CR9_19	0.527						0.439
Collaboration	CO2_33		0.900					0.180
	CO1_32		0.732					0.404
	CO6_37		0.699					0.385
	CO3_34		0.697					0.413

	CO5_36		0.607					0.366
	CO8_39		0.562					0.458
System Thinking	ST3_3			0.704				0.398
	ST 2_2			0.671				0.526
	ST 4_4			0.652				0.520
	ST 7_7			0.616				0.445
	ST 5_5			0.607				0.482
	ST 1_1			0.567				0.622
Communication	COM4_43				0.738			0.368
	COM7_46				0.636			0.374
	COM9_48				0.597			0.452
	COM1_40				0.535			0.480
	COM8_47				0.525			0.340
	COM5_44				0.525			0.595
Attention to Ethical Considerations	AEC3_52					0.763		0.404
	AEC4_53					0.754		0.286
	AEC5_54					0.684		0.325
	AEC2_51					0.620		0.408
Optimism	OP3_25						0.749	0.278
	OP6_28						0.669	0.303
	OP4_26						0.620	0.315
	OP2_24						0.554	0.448
	OP5_27						0.496	0.381

The load factor values of the scale vary from 0.50 to 0.75. Table 3 shows the number of factors and the variance ratio described.

Table 3

Number of factors and variance rate

Factor	SS Loadings	% of Variance	Cumulative %
1.Creativity	4.55	13.01	13.0
2.Collaboration	3.91	11.18	24.2
3.System Thinking	3.27	9.33	33.5
4.Communication	3.20	9.16	42.7
5.Attention to Ethical Considerations	2.88	8.22	50.9
6. Optimism	2.92	8.34	59.2

Table 3 shows the variation ratio explained by the six factors that comprise the scale. The factors together explain 59.2% of the total variance. The Table 4 shows correlations between six factors.

Table 4

Inter-factor correlations

	1	2	3	4	5	6
1.Creativity	—	0.228	0.517	0.110	0.160	0.510
2.Collaboration		—	0.195	0.462	0.309	0.238
3.System Thinking			—	0.205	0.285	0.386
4.Communication				—	0.360	0.184
5.Attention to Ethical Considerations					—	0.311
6. Optimism						—

As shown in Table 4, there are positive and meaningful relationships between the lower dimensions of the scale.

Confirmatory Factor Analysis (CFA)

CFA analysis was performed to re-test the model obtained because of EFA and verify the resulting six-factor construct. We conducted this analysis with 217 children not included in EFA. We examined the fit indices to evaluate the CFA results. At this point, conformity indices χ2/df, RMSEA (Root Mean Square Error of Approximation), CFI (Comparative Fit Index), and SRMR (Standardized Root Mean Square Residual) were calculated. We did not need any modifications in the CFA process. We have interpreted the specified conformity indices by reference to the value ranges specified by Çokluk et al. (2015), statistical data on compliance indices are shown in Table 5.

Table 5

Fit indexes

	Good fit	Acceptable fit	EHOM	Compatibility level
χ2/sd	0 ≤ χ2/sd ≤ 2	2 ≤ χ2/sd ≤ 3	1.97	Perfectly fit
RMSEA	.00 ≤ RMSEA ≤ .05	.05 ≤ RMSEA ≤ .08	.068	Well fit
CFI	.95 ≤ CFI ≤ 1.00	.90 ≤ CFI ≤ .95	.93	Well fit
TLI	.95 ≤ TLI ≤ 1.00	.90 ≤ TLI ≤ .95	.91	Well fit
SRMR	.00 ≤ SRMR ≤ .05	.05 ≤ SRMR ≤ .10	.062	Well fit

As seen in Table 5, when the fit indices obtained as a result of CFA are evaluated together, it can be stated that the six-factor construct of the scale with 35 items shows an acceptable level of fit. Therefore, the factorial validity of the scale is provided.

Reliability Analysis

We examined the reliability of the six-factor solution of the scale with Cronbach's α and McDonald's ω and showed the results in Table 6.

Table 6

Scale reliability statistics

Factor	Mean	SD	Item	Cronbach's α	McDonald's ω
Creativity	4.10	0.579	9	0.908	0.909
Collaboration	4.09	0.620	6	0.897	0.899
System Thinking	3.91	0.538	6	0.842	0.845
Communication	3.99	0.614	6	0.869	0.872
Attention to Ethical Considerations	4.03	0.627	4	0.871	0.871
Optimism	4.03	0.643	5	0.886	0.888
Total	4.03	0.436	35	0.942	0.943

As shown in Table 6, the internal coherence coefficient of the measuring instrument ranges between 0.94 and 0.84 and 0.91. A split-half reliability analysis was performed, another reliability measure to determine the internal consistency of the scale. The test split-half reliability is 0.87. According to the Guttman Lambda (Li) method, the reliability coefficient varies between 0.84 and 0.93. The test-retest results showed a reliability score of 0.87. Furthermore, the CR value was calculated as 0.86 for creativity, 0.87 for collaboration, 0.86 for system thinking, 0.79 for communication, 0.76 for attention to ethical consideration, and 0.83 for optimism. AVE was calculated as 0.57 for creativity, 0.61 for collaboration, 0.60 for system thinking, 0.59 for communication, 0.58 for attention to ethical considerations, and 0.59 for optimism. For all components, CR values are more significant than 0.70. AVE values greater than 0.50 are lower than CR. Data on the item-rest correlation values are presented in Table 7.

Table 7

Item reliability statistics

				If item dropped	
Made	Mean	SD	Item-rest correlation	Cronbach's α	McDonald's ω
CR5_15	4.20	0.713	0.544	0.941	0.941
CR6_16	4.31	0.656	0.578	0.941	0.941
CR7_17	4.06	0.763	0.587	0.941	0.941
CR8_18	4.22	0.739	0.534	0.941	0.941
CR9_19	4.03	0.748	0.597	0.940	0.941
CR11_21	4.00	0.742	0.599	0.940	0.941
CR3_13	4.00	0.795	0.529	0.941	0.942
CR2_12	3.97	0.778	0.525	0.941	0.942
CR4_14	3.89	0.802	0.564	0.941	0.941
CO1_32	4.04	0.733	0.504	0.941	0.942
CO2_33	4.14	0.729	0.587	0.941	0.941
CO3_34	4.17	0.714	0.537	0.941	0.942
CO6_37	4.11	0.722	0.504	0.941	0.942
CO5_36	4.00	0.827	0.570	0.941	0.941
CO8_39	4.07	0.847	0.477	0.942	0.942
ST1_1	3.70	0.732	0.435	0.942	0.942
ST2_2	3.98	0.670	0.426	0.942	0.942
ST3_3	3.60	0.812	0.532	0.941	0.942
ST4_4	4.05	0.693	0.481	0.941	0.942
ST5_5	4.27	0.594	0.553	0.941	0.941
SD7_7	3.84	0.790	0.553	0.941	0.941
COM1_40	3.92	0.732	0.476	0.941	0.942
COM4_43	4.03	0.847	0.537	0.941	0.942
COM5_44	4.18	0.764	0.468	0.942	0.942
COM8_47	3.90	0.776	0.537	0.941	0.942
COM7_46	4.02	0.728	0.531	0.941	0.942
COM9_48	3.90	0.881	0.556	0.941	0.941
AEC2_51	4.11	0.719	0.583	0.941	0.941
AEC3_52	4.14	0.723	0.442	0.942	0.942
AEC4_53	3.89	0.741	0.522	0.941	0.942
AEC5_54	3.99	0.768	0.552	0.941	0.941
OP3_25	4.04	0.775	0.631	0.940	0.941
OP5_27	4.25	0.721	0.655	0.940	0.940
OP6_28	4.11	0.769	0.582	0.941	0.941
OP2_24	3.80	0.801	0.621	0.940	0.941
OP4_26	3.99	0.809	0.652	0.940	0.940

Table 7 shows that the lowest value for item-rest correlation values is 0.43, and the highest value is 0.66. There are no items with values below 0.30 according to the result of the item–rest correlation.

Anova Tukey's Nonadditivity

Anova Tukey's Nonadditivity analysis has been carried out to determine whether the items in the scale have similar structures, collection properties. and homogeneity. The results are shown in Table 8.

Table 8

ANOVA with tukey's test for nonadditivity

			Sum of Squares	df	Mean Square	F	p
Between People			1583.796	234	6.768		
Within People	Between Items		189.735	35	5.421	13.851	.000
	Residual	Nonadditivity	1.136	1	1.136	2.904	.088
		Balance	3204.157	8189	.391		
		Total	3205.293	8190	.391		
	Total		3395.028	8225	.413		
Total			4978.824	8459	.589		

Table 8 illustrates this, and it can be concluded that the scale's components have a uniform structure and are connected to one another (p< .001). Furthermore, the Tukey Nonadditivity value is p= 0.088. According to Özdamar (2013), the scale in this situation exhibits a Likert-type additive scale characteristic.

Intraclass Correlation Coefficient (ICC)

According to the Intraclass Correlation Coefficient (ICC) analysis, the items that make up the scale provide valid and reliable information regarding structure. The results are shown in Table 9.

Table 9

ICC test

	Intraclass Correlation	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	p
Single Measures	.312	.273	.357	17.294	234	8190	.000
Average Measures	.942	.931	.952	17.294	234	8190	.000

In accordance with ICC standards, the variations and total variations of the scale halves are comparable (p< 0.05). Regarding the ordering and structure characteristics of questions, this scale is valid and reliable in this context. Single measurements and average measurements demonstrate the test's structural validity (Özdamar, 2013).

Hotelling's T-Squared

We examined the results of Hotelling's T-Squared test, which helped determine the degree of effective measurement of the phenomenon of EHoM in early childhood by the developed scale. The Hotelling T value appears to be at a significant level (p<.001). According to the values obtained, the scale can be considered a robust and original scale of questions in a homogeneous structure (T = 480.63; $F_{(35)}$ = 11.74. p<.01).

Conclusion and Discussion

In this study, an instrument was developed to assess the EHoM of children aged 5-8. To determine the content and face validity of the scale prepared items were evaluated by experts. Following the expert's assessment, it is determined that the coverage validity index is adequate (.96). As a result of factor analysis to determine the structural validity of the scale, it was determined that the scale consists of six factors, which were determined by examining the items using a parallel method of analysis to the factors. These factors explain 59.2% of the total variance of the scale. The load values of the factors that make up the scale vary from 0.50 to 0.75. The factor load of the items should be over 0.30, and items over 0.50 are considered quite good (Kalaycı, 2016; Sharma, 2016).

When the values obtained as a result of factor analysis are assessed together, it is possible to say that the scale has a construct six-factor validity of 35 items.

The scale (0.94) internal coherence (Cronbach Alpha), Guttman Lambda (0.83 to 0.94), and test split-half (0.87) reliability coefficients were determined to be good. According to Kalaycı (2016), the scale is exceptionally reliable if the reliability ratio is between 0.60 and 0.80; if it is from 0.80 to 1.00, it is highly reliable. When the study's findings are examined in terms of these criteria, it can be said that this developed scale is in a reasonably reliable range. In addition, when the CR and AVE values were examined for the convergent validity of the scale, it was found that the CR. AVE, and CR values were within an acceptable range. Fornell and Larcker (1981) and Lam (2012) can meet the convergent validity criteria for EHoM by acting on their views that when the CR value is more significant than 0.60, close to validity is achieved.

The item-rest correlation values of the scale range from 0.43 to 0.66. Büyüköztürk (2013) suggested a value of 0.30. According to the item-rest correlation results in the scale, no item with a value below 0.30 has been determined. According to the findings, the EHoM scale is a valid and reliable for determining children's EHoM.

Limitations and Future Directions

Among the study's limitations is that the data obtained on children's EHoM skills is based on teachers' opinions and not directly from children. The study was limited to 417 children. There are studies in relevant literature where the dimensions of EHoM are studied separately (such as creativity, communication, and collaboration). This scale can be used to study early childhood children's EHoM skills. Finally, using the scale developed in this study to reveal the relationship of EHoM behavior in children with different variables is recommended.

Conclusion

This study has made several contributions to the literature assessing EHoM in early childhood education. First, the teacher form we developed provides a tool to objectively measure children's EHoM in this age group. This can enable teachers to understand children's engineering skills better and support them where necessary. Additionally, our study raises awareness in this field by highlighting the importance of children's EHoM in early childhood. This will enable educators, families, and policymakers to allocate more resources and develop strategies to promote the development of these skills. The findings of the study also point to potential areas for further research. For example, the developed scale can be tested more broadly for validity and reliability in different cultural contexts and age groups. Additionally, long-term follow-up studies can be conducted to understand more deeply the effects of EHoM on the developmental process in early childhood. Further research such as these can help us better understand the importance of EHoM in early childhood education and develop effective interventions.

Declarations

Acknowledgements

Not applicable

Authors' Contributions

The individual contributions of authors to the manuscript should be specified in this section. Please use initials to refer to each author's contribution in this section

Competing Interests

The authors declare that they have no competing interests.

Funding

No funds were used in this study.

Ethics Approval and Consent To Participate

The aim of this study and the data collection tools were examined by the "Pamukkale University Social and Human Sciences Research and Publication Ethics Committee" and it was stated that no unethical situation was found.

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Appendix

1) English version

Early Childhood Engineering Habits of Mind Scale

Instruction: This survey contains statements for teachers to evaluate the engineering habits of mind of the children in their classes. Here, the engineering mind-set includes the skills that children demonstrate in the process of an activity, design, or activity. Please indicate to what extent you agree or disagree with each statement below for each child in your class by ticking the appropriate section to the right of each statement**.**			**Never**	**Rarely**	**Sometimes**	**Mostly**	**Always**
System Thinking	1	Has an idea of how individual parts work.					
	2	Makes various designs using parts (such as making a tower with interlocking parts).					
	3	For a design, it analyzes the parts of the design one by one.					
	4	Establishes a cause and effect relationship between events.					
	5	Completes a whole by starting from parts (such as successfully completing interlocking pieces and puzzles).					
	6	Analyzes the parts of a whole.					
Creativity	7	Makes original designs.					
	8	She/He likes to take risks, do different things, try new things.					
	9	She/He is inquisitive about many things.					
	10	She/He is curious about many things.					
	11	She/He performs activities in his own unique style and makes what he does subjective.					
	12	She/He uses his imagination and likes to dream.					
	13	It produces many solutions to a problem.					
	14	It creates original designs by taking into account the criteria set forth.					
İyimserlik	15	She/He struggles with difficulties.					
	16	She/He continues an activity until he succeeds.					
	17	She/He thinks that he can achieve every design and activity.					
	18	She/He is self-confident in activities.					
	19	Self-directed and internally motivated.					
Collaboration	20	She/He acts with his friends in events.					
	21	Participates in team work at events.					
	22	Plays with peers during free play.					
	23	Complies with task sharing in events.					
	24	Collaborates with friends at the event.					
	25	Willing to be part of the team at events.					
Communication	26	Makes an effort to understand the wants and needs of others.					
	27	She/He solves his problems by talking to his friends.					
	28	Expresses himself in front of the crowd.					
	29	She/He listens to his friend's suggestions about the activity.					
	30	She/He takes his friend's suggestions about the activity into consideration.					
	31	She/He asks his friends questions about how they solve problems.					
Attention to Ethical Considerationsk	32	She/He thinks about the consequences of his behavior.					
	33	She/He is aware of the effects of his design on people and the environment (such as not disrupting his friend's game while building a tower with blocks).					
	34	It prevents/predicts possible undesirable consequences of a design it has made.					
	35	It determines the possible undesirable consequences of the materials used during the activity (such as being aware that it will pollute the environment while playing with sand).					

2) Turkish version:

Erken Çocuklukta Mühendislik Zihin Alışkanlıkları Ölçeği

Yönerge: Bu anket, öğretmenlerin sınıflarında bulunan çocukların mühendislik zihin alışkanlıklarını değerlendirmelerine yönelik ifadeler içermektedir. Burada, mühendislik zihin alışkanlığı, çocukların bir etkinlik, tasarım veya aktivite sürecinde sergiledikleri becerileri içermektedir. Lütfen aşağıdaki her bir ifadeye sınıfınızda buluna her bir çocuk için ayrı ayrı ne derece katılıp katılmadığınızı her bir ifadenin sağındaki uygun kısmı işaretleyerek belirtiniz.			**Hiçbir Zaman**	**Nadiren**	**Bazen**	**Çoğunlukla**	**Her Zaman**
Sistem Düşüncesi	1	Ayrı parçaların nasıl çalıştığı hakkında fikir sahibidir.					
	2	Parçaları kullanarak çeşitli tasarımlar yapar (Geçmeli parçalarla kule yapması gibi).					
	3	Bir tasarım için, tasarımın parçalarını tek tek analiz eder.					
	4	Olaylar arasında neden sonuç ilişkisi kurar.					
	5	Parçalardan yola çıkarak bir bütünü tamamlar (Geçmeli parçaları, yapbozları başarı ile tamamlaması gibi).					
	6	Bir bütünün parçalarını analiz eder.					
Yaratıcılık	7	Özgün tasarımlar yapar.					
	8	Risk almayı, farklı şeyler yapmayı, yeni şeyler denemeyi sever.					
	9	Birçok şey hakkında sorgulayıcıdır.					
	10	Birçok şey hakkında meraklıdır.					
	11	Etkinlikleri kendine has bir tarzda yapar, yaptığını öznelleştirir.					
	12	Hayal gücünü kullanır, hayal kurmayı sever.					
	13	Bir probleme birçok çözüm üretir.					
	14	Ortaya konan kriterleri dikkate alarak özgün tasarımlar yapar.					
İyimserlik	15	Zorluklarla mücadele eder.					
	16	Yaptığı bir etkinliği, başarana kadar sürdürür.					
	17	Her tasarımı, etkinliği başarabileceğini düşünür.					
	18	Etkinliklerde kendine güvenir.					
	19	Kendini yönlendirir, içsel motivasyona sahiptir.					
İşbilriği	20	Etkinliklerde arkadaşlarıyla birlikte hareket eder.					
	21	Etkinliklerde takım çalışmalarına katılır.					
	22	Serbest oyun sırasında akranlarıyla birlikte oynar.					
	23	Etkinliklerde görev paylaşımına uyar.					
	24	Etkinlikte arkadaşlarıyla Collaboration yapar.					
	25	Etkinliklerde ekibin bir parçası olmaya isteklidir.					
İletişim	26	Başkalarının istek ve ihtiyaçlarını anlamak için çaba sarf eder.					
	27	Arkadaşları ile sorunlarını konuşarak çözer.					
	28	Kalabalık karşısında kendini ifade eder.					
	29	Arkadaşının etkinlik hakkındaki önerilerini dinler.					
	30	Arkadaşının etkinlik hakkındaki önerilerini dikkate alır.					
	31	Arkadaşlarına problemleri nasıl çözdüklerine yönelik sorular sorar.					
Etik Hususlara Dikkat	32	Yaptığı bir davranışın sonuçları hakkında düşünür.					
	33	Yaptığı tasarımın insanlar ve çevre üzerindeki etkilerinin farkındadır (Bloklar ile kule yaparken arkadaşının oyununu bozmaması gibi).					
	34	Yapmış olduğu bir tasarımın olası istenmeyen sonuçlarını engeller/öngörür.					
	35	Etkinlik sürecinde kullandığı materyallerin olası istenmeyen sonuçların belirler (Kum ile oynarken çevreyi kirleteceğinin farkında olması gibi).					