



Developing Instruments to Measure Montessori Instructional Practices

Technical Appendix (TA)

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Analysis

Pearson Correlation Analysis

We examined the item-total correlations for current data gathered in 2018 as well as data gathered data from a pilot version of the questionnaire in 2017. We discovered that results were much improved after eliminating problematic items and revising the original pilot instrument. Table TA1 shows the maximum, minimum, and median item-total correlation for each hypothesized construct based on the 2017 pilot and the current data set. Conducting confirmatory factor analysis (CFA) was the next step in the analysis.

Table TA1
Item-Total Correlations from 2017 and 2018 Pilot Data Sets

Data	Construct	Min		Max		Median	
		2017	2018	2017	2018	2017	2018
EC	Structure	0.18	0.44	0.64	0.65	0.41	0.49
	Curriculum	0.31	0.37	0.60	0.64	0.49	0.56
	Freedom	0.21	0.50	0.58	0.61	0.38	0.55
	All	0.10	0.28	0.56	0.64	0.33	0.49
EL	Structure	0.48	0.32	0.61	0.68	0.51	0.49
	Curriculum	-0.23	0.30	0.62	0.69	0.50	0.59
	Freedom	-0.25	0.50	0.66	0.60	0.52	0.58
	All	-0.32	0.23	0.62	0.64	0.44	0.51

CFA

Neither the EC nor EL data set is normally distributed because the majority of the participants agreed on most items and selected response option 3 or 4, making most of the individual items left skewed. Furthermore, the null hypothesis that the variables come from a multivariate normal distribution was rejected with $p < .001$ for Henze-Zirkler (HZ) test (Henze & Zirkler, 1990). However, the use of maximum likelihood with robust estimation method (MLR) corrected the nonnormality. Rhemtulla, Brosseau-Liard, and Savalei (2012) concluded that, although robust categorical methodology (i.e., categorical least squares, or cat-LS, methodology) is best when observed variables have fewer than five categories, factor correlations and model fit were assessed equally well with ML as with cat-LS when categories are fewer than five. Further, we used robust full information maximum likelihood (RFIML) to treat missing ordinal data as if they were continuous (Jia & Wu, 2019). RFIML is superior to the weighted least squares (WLS) method in handling missing data because missing data need to be imputed when WLS is used (Asparouhov & Muthén, 2010). However, data for these analyses showed very few missing responses. Finally, we chose to set the variance of items to 1 and freely estimate all items (Brown, 2006).

Results

Descriptives

Item univariate skewness and kurtosis analysis results are available in Tables TA2-1 through TA2-3 for EC and Tables TA3-1 to TA3-3 for EL.

Table TA2-1
Early Childhood Univariate Skewness and Kurtosis: Structure

	Q4_02	Q4_06	Q4_08	Q6_01	Q6_02	Q6_03	Q6_04	Q7_07
<i>N</i> valid	241	242	242	240	241	240	241	241
<i>N</i> missing	1	0	0	2	1	2	1	1
Skewness	-2.41	-1.32	-0.02	-1.53	-1.25	-0.78	-0.99	-0.91
SE of skewness	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Kurtosis	4.39	1.40	-1.69	2.23	0.88	-0.30	0.32	-0.39
SE of kurtosis	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31

Table TA2-2
Early Childhood Univariate Skewness and Kurtosis: Curriculum

	Q4_01	Q4_05	Q4_07	Q6_05	Q6_06	Q6_07	Q6_08	Q7_03	Q7_04	Q7_08	Q7_09	Q7_10
<i>N</i> valid	241	242	241	239	241	241	240	241	238	240	239	240
<i>N</i> missing	1	0	1	3	1	1	2	1	4	2	3	2
Skewness	-2.23	-2.30	-1.56	-3.44	-1.25	-0.79	-1.66	-1.92	-0.66	-0.99	0.37	-0.86
SE of skewness	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Kurtosis	4.64	5.09	1.31	12.49	1.32	-0.57	1.72	3.24	-1.15	-0.22	-1.37	-0.63
SE of kurtosis	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31

Table TA2-3
Early Childhood Univariate Skewness and Kurtosis: Freedom

	Q4_03	Q4_04	Q7_01	Q7_02	Q7_05	Q7_06
<i>N</i> valid	241	241	24	238	240	240
<i>N</i> missing	1	1	2	4	2	2
Skewness	-0.40	-2.22	-1.60	-1.71	-1.56	-2.03
SE of skewness	0.16	0.16	0.16	0.16	0.16	0.16
Kurtosis	-0.84	3.76	1.65	2.10	1.52	4.89
SE of kurtosis	0.31	0.31	0.31	0.31	0.31	0.31

Table TA3-1
Elementary Univariate Skewness and Kurtosis: Structure

	Q4_01	Q4_03	Q4_06	Q4_07	Q4_08	Q6_02	Q6_05	Q6_06	Q6_07	Q6_08
<i>N</i> valid	170	169	170	169	170	169	169	169	169	169
<i>N</i> missing	0	1	0	1	0	1	1	1	1	1
Skewness	-2.88	-2.45	-0.81	-1.34	-0.67	-0.96	-1.79	-1.63	-0.71	-1.07
SE of skewness	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Kurtosis	7.03	5.51	0.33	1.68	-0.63	0.88	2.20	2.11	0.39	0.76
SE of kurtosis	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37

Table TA3-2
Elementary Univariate Skewness and Kurtosis: Curriculum

	Q4_04	Q4_10	Q4_11	Q4_12	Q6_01	Q6_03	Q6_09	Q6_10	Q7_07	Q7_08	Q7_09	Q7_10	Q7_11
<i>N</i> valid	168	170	169	170	169	168	168	169	168	168	168	168	168
<i>N</i> missing	2	0	1	0	1	2	2	1	2	2	2	2	2
Skewness	-1.26	-1.32	-0.55	-1.17	-1.60	-0.94	-1.87	-0.39	-0.68	-0.25	-0.60	-2.34	-0.80
SE of skewness	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Kurtosis	1.43	0.81	0.26	0.09	1.77	0.12	3.62	-1.21	-0.32	-0.65	-0.60	6.38	0.12
SE of kurtosis	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37

Table TA3-3
Elementary Univariate Skewness and Kurtosis: Freedom

	Q4_02	Q4_05	Q4_09	Q6_04	Q7_01	Q7_02	Q7_03	Q7_04	Q7_05	Q7_06
<i>N</i> valid	170	167	170	169	168	167	168	167	168	168
<i>N</i> missing	0	3	0	1	2	3	2	3	2	2
Skewness	-1.73	-0.23	-2.43	-1.15	-1.19	-0.91	-0.46	-1.16	-1.70	-2.51
SE of skewness	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Kurtosis	1.78	-1.45	6.12	1.30	1.40	0.89	-0.24	1.64	3.13	7.42
SE of kurtosis	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37

Initial CFA

Factor loadings for the initial CFA models that incorporated all items from the study are reported in Table TA4 for EC and TA5 for EL.

Table TA4

EC Item Loadings on Each Factor in the Initial CFA Model

Variables	Unstandardized loadings	Std. err	Z-value	Sig	Standardized loadings
Factor 1. Structure					
Q4_02	0.28	0.12	2.31	.02	0.33
Q4_06	0.28	0.10	2.93	<.001	0.35
Q4_08	0.24	0.11	2.22	.03	0.19
Q6_01	0.28	0.09	3.24	<.001	0.37
Q6_02	0.27	0.09	3.10	<.001	0.31
Q6_03	0.34	0.12	2.79	.01	0.37
Q6_04	0.29	0.09	3.09	<.001	0.36
Q7_07	0.30	0.10	2.85	<.001	0.30
Factor 2. Curriculum					
Q4_01	0.44	0.08	5.82	<.001	0.64
Q4_05	0.32	0.09	3.76	<.001	0.50
Q4_07	0.60	0.10	6.15	<.001	0.65
Q6_05	0.33	0.10	3.30	<.001	0.66
Q6_06	0.32	0.09	3.70	<.001	0.45
Q6_07	0.77	0.19	4.12	<.001	0.76
Q6_08	0.38	0.10	3.92	<.001	0.42
Q7_03	0.40	0.12	3.37	<.001	0.52
Q7_04	0.62	0.20	3.08	<.001	0.52
Q7_08	0.67	0.23	2.91	<.001	0.66
Q7_09	0.57	0.17	3.32	<.001	0.49
Q7_10	0.42	0.16	2.58	<.001	0.39
Factor 3. Freedom					
Q4_03	0.67	0.20	3.30	<.001	0.68
Q4_04	0.62	0.18	3.51	<.001	0.75
Q7_01	0.23	0.08	2.67	<.001	0.42
Q7_02	0.29	0.11	2.54	<.001	0.57
Q7_05	0.24	0.07	3.49	<.001	0.49
Q7_06	0.16	0.08	2.07	.04	0.27

Table TA5

EL Item Loadings on Each Factor in the Initial CFA Model

Variables	Unstandardized loadings	Std. err	Z-value	Sig	Standardized loadings
Factor 1. Structure					
Q4_01	0.23	0.13	1.75	.08	0.30
Q4_03	0.18	0.12	1.43	.15	0.24
Q4_06	0.29	0.09	3.13	.00	0.35
Q4_07	0.27	0.10	2.75	.01	0.39
Q4_08	0.63	0.10	6.64	.00	0.65
Q6_02	0.49	0.05	9.02	<.001	0.74
Q6_05	0.45	0.12	3.90	<.001	0.53
Q6_06	0.51	0.09	5.50	<.001	0.63
Q6_07	0.43	0.07	6.04	<.001	0.64
Q6_08	0.44	0.10	4.30	<.001	0.57
Factor 2. Curriculum					
Q4_04	0.47	0.11	4.45	<.001	0.58
Q4_10	0.41	0.11	3.86	<.001	0.47
Q4_11	0.42	0.09	4.60	<.001	0.59
Q4_12	0.22	0.09	2.46	.01	0.22
Q6_01	0.43	0.10	4.25	<.001	0.52
Q6_03	0.53	0.07	7.91	<.001	0.59
Q6_09	0.38	0.11	3.46	<.001	0.59
Q7_07	0.56	0.07	8.58	<.001	0.63
Q7_08	0.61	0.12	5.23	<.001	0.70
Q7_09	0.56	0.07	7.53	<.001	0.64
Q7_10	0.31	0.09	3.54	<.001	0.53
Q7_11	0.45	0.10	4.69	<.001	0.55
Factor 3. Freedom					
Q4_02	0.51	0.11	4.84	<.001	0.57
Q4_05	0.77	0.08	9.56	<.001	0.66
Q4_09	0.38	0.08	4.73	<.001	0.57
Q6_04	0.51	0.07	6.81	<.001	0.70
Q6_10	0.37	0.07	5.66	<.001	0.63
Q7_01	0.36	0.07	5.27	<.001	0.62
Q7_02	0.39	0.09	4.55	<.001	0.48
Q7_03	0.26	0.08	3.35	<.001	0.42
Q7_04	0.28	0.08	3.44	<.001	0.46
Q7_05	0.26	0.08	3.13	<.001	0.48
Q7_06	0.51	0.11	4.84	<.001	0.57

IRT Analysis

Model fit for the IRT analysis after removing problematic items is provided in Table TA6 for EC and TA7 for EL. Item characteristic curves (ICC) for each construct are provided in Figures TA1 through TA6.

Table TA6

EC IRT Model Fit

	Marginal reliability	2loglikelihood	AIC	BIC	Number of freely estimated parameters
Structure	0.63	3,480.77	3,528.77	3,612.51	24
Curriculum	0.76	4,632.73	4,704.73	4,830.33	36
Freedom	0.62	1,951.24	1,987.24	2,050.04	18

Table TA7

EL IRT Model Fit

	Marginal reliability	2loglikelihood	AIC	BIC	Number of freely estimated parameters
Structure	0.66	2,075.65	2,117.65	2,183.50	21
Curriculum	0.79	2,629.01	2,683.01	2,767.67	27
Freedom	0.66	1,451.39	1,487.39	1,543.83	18

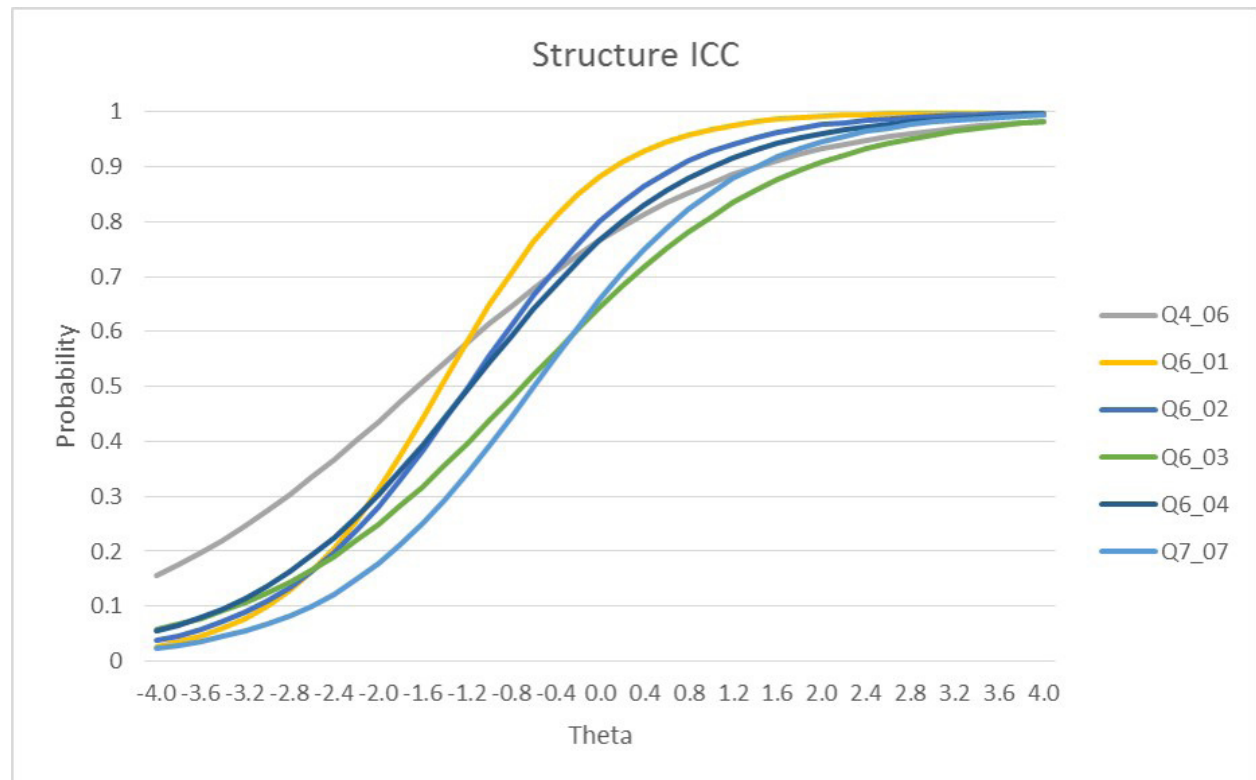


Figure 1. Item characteristics curve: EC items in structure construct.

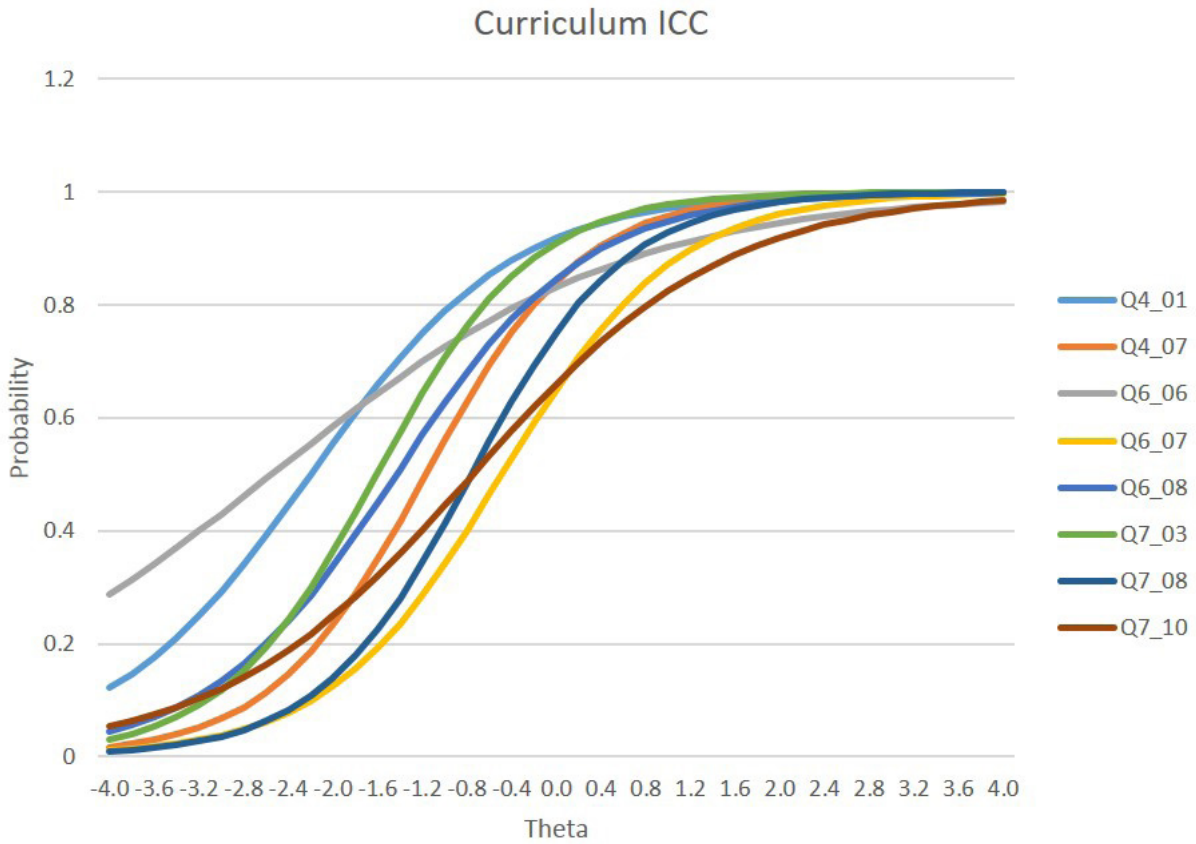


Figure 2. Item characteristics curve: EC items in curriculum construct.

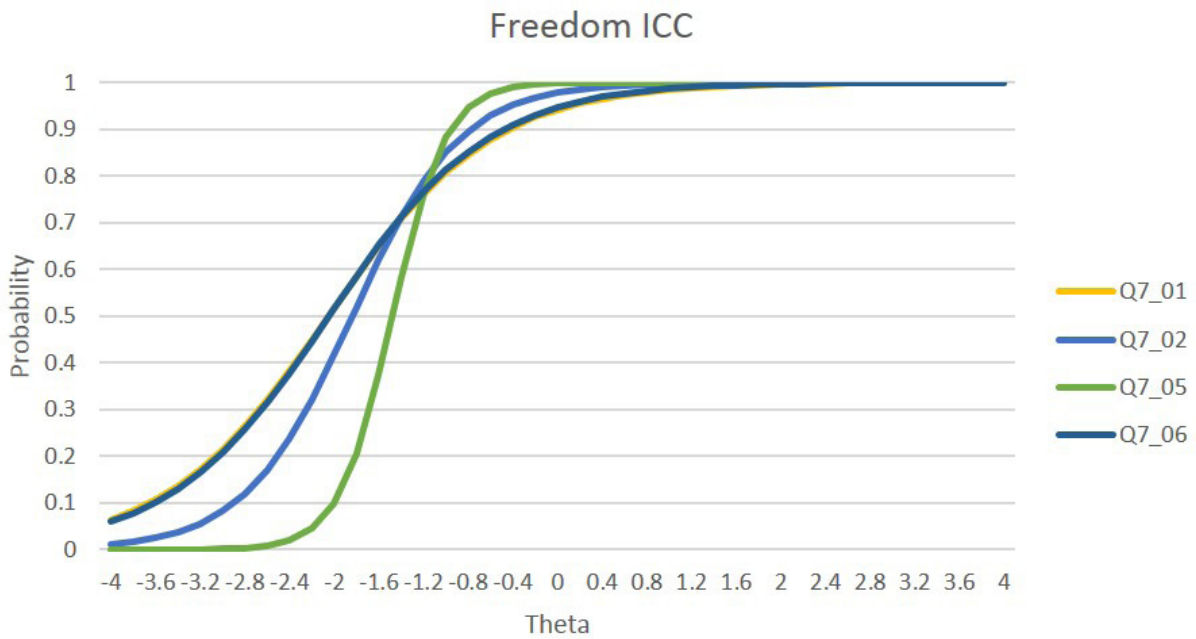


Figure 3. Item characteristics curve: EC items in freedom construct.

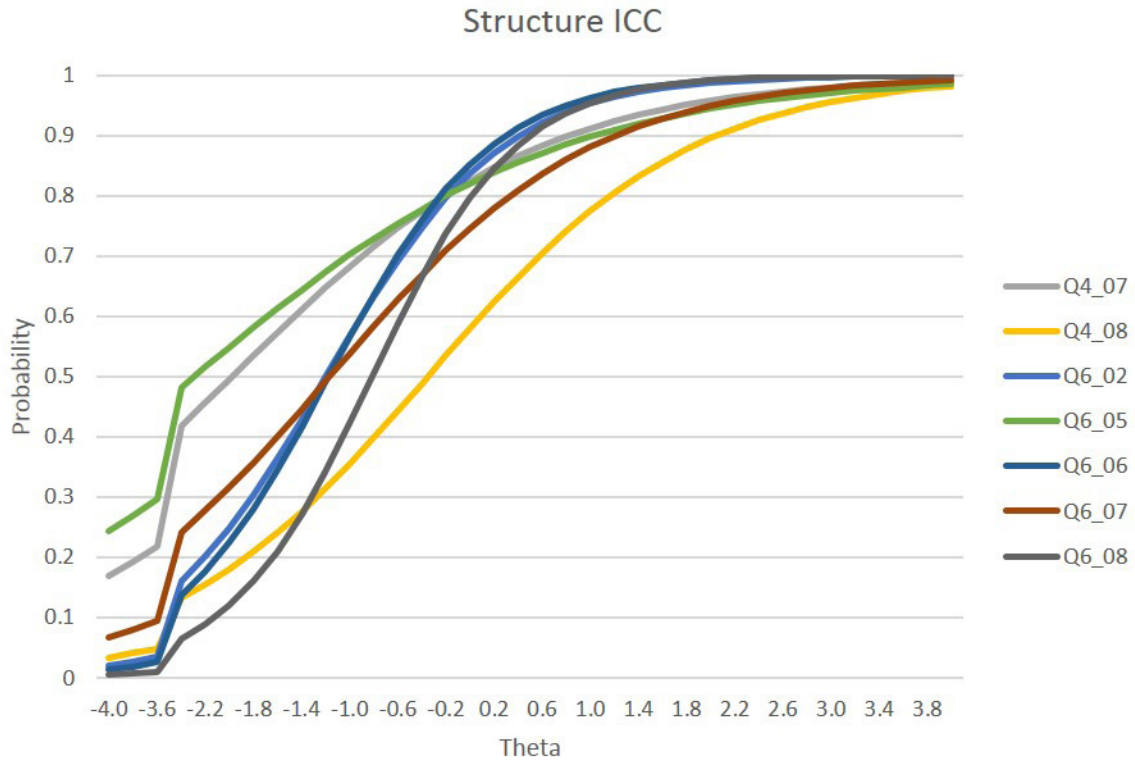


Figure 4. Item characteristics curve: EL items in structure construct.

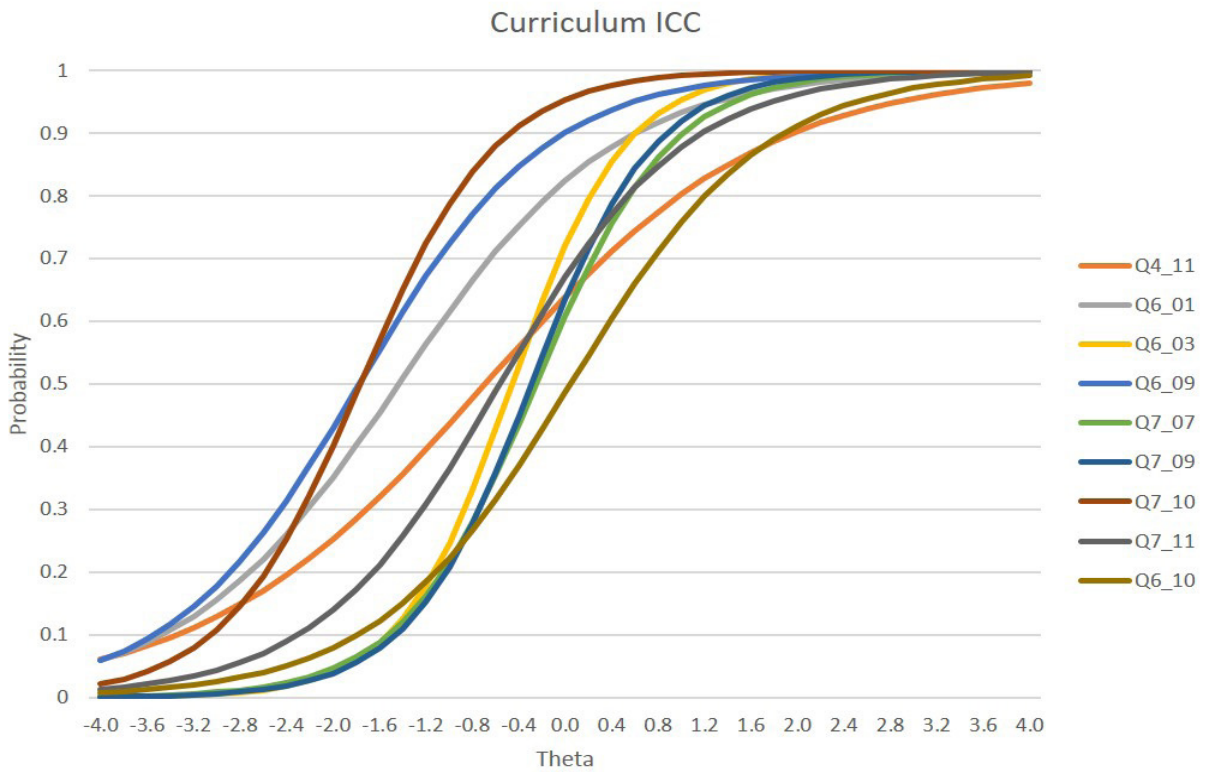


Figure 5. Item characteristics curve: EL items in curriculum construct.

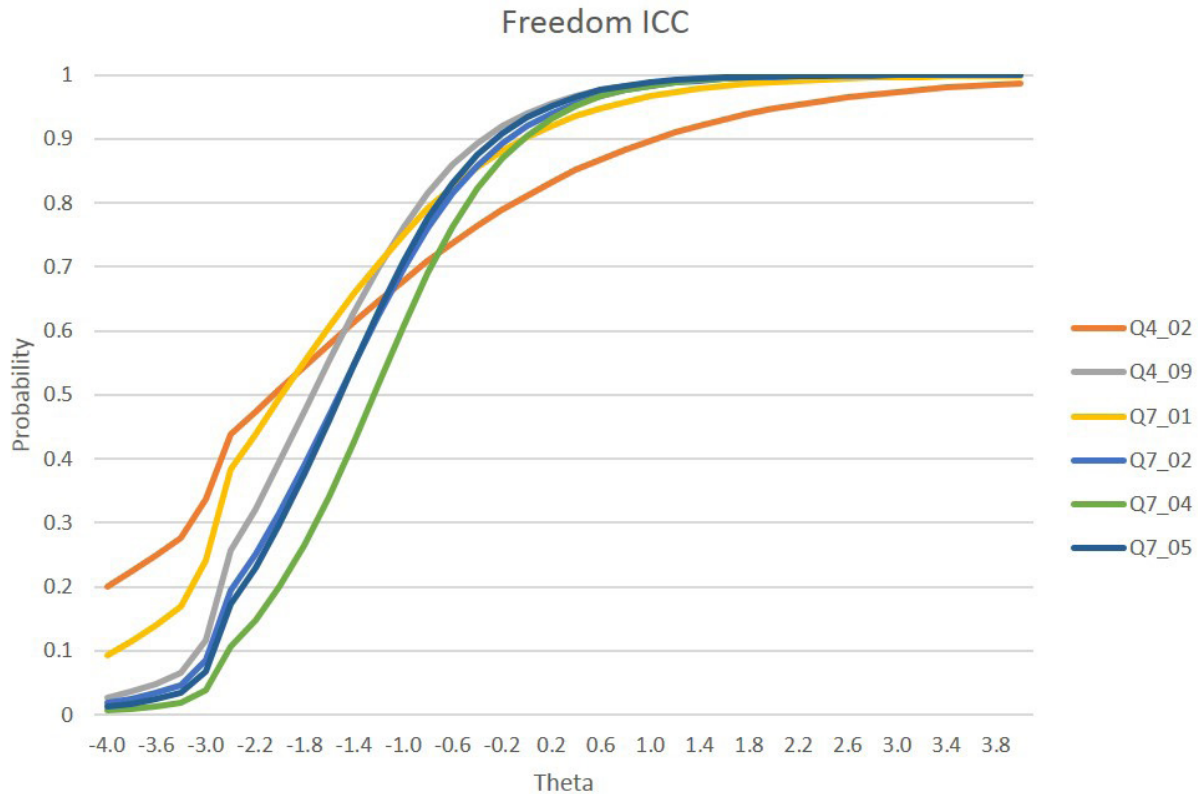


Figure 6. Item characteristics curve: EL items in freedom construct.

Improved CFA

Tables TA8-1 to TA9-3 outline the correlations among the items in the improved CFA within each of the three constructs for both the EC and EL levels. Tables TA10 and TA11 provide item loadings and standard errors for the improved EC and EL CFA models. All the structure paths in the improved model are significant for both EC and EL. Only one curriculum path in the improved EC model is significant, and all the curriculum paths in the improved EL model are nonsignificant. All the freedom paths in the improved EC model are significant. All but one freedom paths in the improved EL model are significant.

Table TA8-1

Improved EC CFA Model: Correlations Among Items in Structure Construct

Items in structure construct	1	2	3	4	5	6
1. Children give lessons to one another.	–	.24***	.03	.17**	.12	.20**
2. Observation is used for daily lesson planning.		–	.40***	.26***	.22***	.24***
3. Children’s activities are recorded each day.			–	.24***	.27***	.21**
4. There is a 3-hour uninterrupted work period.				–	.23***	.24***
5. Lessons are mostly given to individuals.					–	.22***
6. Are evenly spread across at least a 3-yr age span.						–
<i>M</i>	3.35	3.48	3.35	3.13	3.32	3.15
<i>SD</i>	0.82	0.74	0.84	0.92	0.80	1.01

** $p < .01$; *** $p < .001$.

Table TA8-2

Improved EC CFA Model: Correlations Among Items in Curriculum Construct

Items in curriculum construct	1	2	3	4	5	6	7	8
1. A full set of Montessori materials is available.	–	.41***	.23***	.33***	.45***	.17**	.26***	.21**
2. A polishing activity is available.		–	.08	.32***	.39***	.28***	.26***	.22***
3. Classroom books feature realistic stories.			–	.21***	.26***	.25***	.28***	.18**
4. Children regularly prepare food.				–	.20**	.35***	.37***	.34***
5. Older children do golden bead addition.					–	.26***	.21**	.27***
6. Care for classroom plants.						–	.34***	.34***
7. Walk on the line carrying objects.							–	.30***
8. Garden in a designated area.								–
<i>M</i>	3.66	3.42	3.45	3.09	3.47	3.56	3.17	3.08
<i>SD</i>	0.69	0.93	0.72	1.01	0.90	0.78	1.01	1.09

** $p < .01$; *** $p < .001$.

Table TA8-3

Improved EC CFA Model: Correlations Among Items in Freedom Construct

Items in freedom construct	1	2	3	4
1. May choose to work alone or with others.	–	.33***	.39***	.25***
2. Decide where they will work.		–	.48***	.25***
3. Choose their work/activities.			–	.43***
4. Determine how long to work with an activity.				–
<i>M</i>	3.70	3.73	3.73	3.68
<i>SD</i>	0.53	0.51	0.49	0.58

*** $p < .001$.

Table TA9-1
Improved EL CFA model: Correlations among items within Structure construct

Items in Structure construct	1	2	3	4	5	6	7
1. Problem solving for off-task behavior.	–	.29**	.21**	.21**	.15	.10	.33***
2. 1-on-1 meetings at least every 2 weeks.		–	.43***	.17*	.24**	.19**	.16*
3. Observation used for daily lesson planning.			–	.18*	.37***	.30**	.31***
4. Children record activities in work journals.				–	.09	.19*	.28**
5. There is a 3-hour uninterrupted work period.					–	.26**	.48**
6. Children give lessons to one another.						–	.29***
7. Most lessons given in groups of 2-5 children.							–
M	3.49	3.03	3.42	3.53	3.48	3.31	3.34
SD	0.69	0.98	0.66	0.85	0.81	0.67	0.77

* $p < .05$; ** $p < .01$; *** $p < .001$.

Table TA9-2
Improved EL CFA model: Correlations among items within Curriculum construct

Items in Curriculum construct	1	2	3	4	5	6	7	8	9
1. Children correct their own work.	–	.17*	.20*	.29***	.30***	.26***	.29***	.28***	.33***
2. Great Lessons/Stories are given each fall.		–	.41***	.45***	.31***	.23**	.18*	.15	.22*
3. Use human fundamental needs charts.			–	.36***	.45***	.48***	.41***	.35***	.35***
4. Most instruction with Montessori materials.				–	.27***	.27***	.34***	.22***	.33***
5. Make history timelines.					–	.51***	.36***	.32***	.38***
6. Repeat Montessori science experiments.						–	.35***	.44***	.40***
7. Have access to full set Montessori materials.							–	.33***	.23**
8. Take part in community service projects.								–	.37***
9. Children regularly prepare food.									1
M	3.16	3.47	3.17	3.62	3.07	3.11	3.70	3.18	2.81
SD	0.70	0.85	0.90	0.65	0.90	0.88	0.60	0.82	1.11

* $p < .05$; ** $p < .01$; *** $p < .001$.

Table TA9-3
Improved EL CFA model: Correlations among items within Freedom construct

Items in Freedom construct	1	2	3	4	5	6
1. Children decide when to have snack.	–	.28***	.19**	.13	.19*	.20*
2. Children make classroom rules/ guidelines.		–	.34***	.29***	.28***	.25***
3. Do research based on interests.			–	.32***	.23**	.32***
4. Choose their work/activities.				–	.40***	.34***
5. Determine how long to work with activity.					–	.47***
6. Decide where they will work.						–
M	3.51	3.68	3.57	3.51	3.50	3.62
SD	0.90	0.67	0.58	0.58	0.63	0.62

* $p < .05$; ** $p < .01$; *** $p < .001$.

Table TA10
EC Item Loadings on Each Factor in the Improved CFA Model

Variables	Unstandardized loadings	Std. err	Z-value	Sig	Standardized loadings
Factor 1. Structure					
Q4_06	0.43	0.13	3.34	<.001	0.53
Q6_01	0.49	0.12	4.03	<.001	0.66
Q6_02	0.52	0.13	4.06	<.001	0.62
Q6_03	0.51	0.20	2.48	.01	0.55
Q6_04	0.44	0.11	3.90	<.001	0.55
Q7_07	0.46	0.11	4.31	<.001	0.45
Factor 2. Curriculum					
Q4_01	0.40	0.19	2.09	.04	0.58
Q4_07	0.52	0.30	1.76	.08	0.56
Q6_06	0.32	0.21	1.54	.13	0.45
Q6_07	0.73	0.50	1.47	.14	0.72
Q6_08	0.34	0.18	1.95	.05	0.39
Q7_03	0.33	0.23	1.41	.16	0.42
Q7_08	0.80	0.48	1.67	.09	0.80
Q7_10	0.48	0.32	1.49	.14	0.44
Factor 3. Freedom					
Q7_01	0.32	0.07	4.82	<.001	0.59
Q7_02	0.40	0.09	4.44	<.001	0.79
Q7_05	0.39	0.10	3.85	<.001	0.79
Q7_06	0.33	0.10	3.35	<.001	0.57

Table TA11

EL Item Loadings on Each Factor in the Improved CFA Model

Variables	Unstandardized loadings	Std. err	Z-value	Sig	Standardized loadings
Factor 1. Structure					
Q4_07	0.24	0.10	2.26	.02	0.34
Q4_08	0.63	0.12	5.12	<.001	0.65
Q6_02	0.48	0.08	6.00	<.001	0.72
Q6_05	0.45	0.13	3.49	<.001	0.53
Q6_06	0.49	0.07	6.58	<.001	0.61
Q6_07	0.42	0.08	5.00	<.001	0.62
Q6_08	0.42	0.08	5.10	<.001	0.54
Factor 2. Curriculum					
Q4_11	0.43	0.47	0.91	.36	0.61
Q6_01	0.49	0.50	0.97	.33	0.57
Q6_03	0.53	0.48	1.10	.27	0.59
Q6_09	0.44	0.50	0.88	.38	0.66
Q7_07	0.60	0.58	1.03	.30	0.67
Q7_09	0.57	0.55	1.04	.30	0.65
Q7_10	0.33	0.37	0.87	.38	0.55
Q7_11	0.47	0.45	1.06	.29	0.58
Q6_10	0.71	0.67	1.05	.29	0.64
Factor 2. Freedom					
Q4_02	0.62	0.11	5.75	<.001	0.69
Q4_09	0.45	0.13	3.55	<.001	0.68
Q7_01	0.41	0.15	2.77	.01	0.71
Q7_02	0.42	0.13	3.10	<.001	0.72
Q7_04	0.29	0.15	1.93	.05	0.46
Q7_05	0.30	0.15	2.00	.05	0.49