An Item Response Theory Analysis of The Biology Freshman Survey Administered at California State University, Long Beach in 2020 and 2021

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Significance

Research Questions

The Biology Freshman Survey was administered to incoming freshman at California State University, Long Beach (CSULB) in 2020 and 2021 whose initial major was Biological Sciences. The survey is designed to measure multiple latent traits associated with student success in Biological Sciences. There are three research questions associated with this project: (RQ 1) determine if there is any significant difference between the latent trait estimates of students who were admitted as Biological Sciences Majors to CSULB in 2020 as compared to students admitted in 2021. (RQ 2) Determine if there is a significant difference in latent trait estimates between male and female students, and (RQ 3) determine if there are any significant correlations between latent trait estimates.

Item Response Theory or Classical Test Theory

The choice to use Item Response Theory (IRT) methodology instead of Classical Test Theory (CTT) methodology for this study was due to the nature of the data collected. The data for this survey consisted of Rating Scale responses to 46 questions designed to measure multiple constructs in higher education. Previous research suggests that IRT models can provide more meaningful information that CTT models when using surveys with Rating Scale answers to measure constructs in higher education. This type of data would be best analyzed using a polytomous IRT model, specifically a Graded Response Model. (Sharkness & DeAngelo, 2010)

Method

Data

The data for this project were provided by CSULB and is not publicly available. The data consists of students who were accepted and enrolled in either Fall 2020 or Fall 2021 as Biological Sciences Majors. The sample consists of 138 students, out of a total enrollment of 680, and 188 students, out of a total enrollment of 649, from the 2020 and 2021 cohorts respectively. Students were invited to participate in the study after enrolling in courses at CSULB and were offered an Amazon gift card as incentive. Students were emailed a link to a Qualtrics survey where the data was collected. The full survey contained 96 items.

This study focuses on 46 items that measured the following seven constructs: Student Agency, Academic Stress, Help Seeking, Self-Efficacy, Math Anxiety, Science Identity, and Math Motivation. These items all had Likert Scale responses where higher values indicated a student exhibited the underlying construct the items attempted to measure. Items and codebook can be found in Appendix A.

Analysis

Descriptive Statistics

Tables in Appendix B record the endorsement percentages per response category. Please note that values left blank denote a question that only had four responses. Additional tables provide the item-total score correlations for each construct measured in the survey. The correlation between an individual's response and their item-totals provides information how well the item measures the underlying construct. Items that have a low correlation with the item-total

are often a point of concern when selecting items for a test and might be discarded (Howerd & Forehand, 1962). Most items in this survey have reasonably high correlations with only 3 items having an item-total correlation less than the suggested 0.30 cutoff (Cristobal & Flavian, 2007).

Chronbach's Alpha was calculated and reported an alpha of 0.824 using 46 items and a sample size of 320. Chronbach's Alpha is a measure of internal consistency and can be used to determine if a survey measures a single underlying construct. With an alpha of 0.824 there is an error variance of 0.176 which is very low. (Tavakol & Dennick, 2011)

Model Selection

Previous research suggests that for higher education survey data using a rating scale response a Graded Response Model (GRM) would be the preferred polytomous IRT model (Sharkness & DeAngelo, 2010). A potential second model we could fit to the data would be the Generalized Partial Credit Model (GPCM). Both the GRM and the GPCM can be used with rating scale responses; however, current research suggests that it is not recommended to compare GRM and GPCM based on relative fit indices (AIC, BIC) when the sample size is less than 300 and the length is less than 5 (Dai et al., 2021). Based on this recommendation the following BIC comparisons should be used with caution.

Table 1 below contains the fit indices for both the GRM and the GPCM models. The Delta column records the difference in BIC values for the GRM and GPCM models. If the GPCM model had a higher BIC, indicating not as good model fit, the Delta column would contain negative number. (Kass & Raftery, 1995) Based on the BIC differences, there is evidence favoring the Graded Response Model over a Generalized Partial Credit Model.

Table 1

BIC Comparison for 2020 Survey Constructs

Construct Measured	Delta 2020	Delta 2021
Student Agency	-0.49	-0.49
Academic Stress	-7.68	-7.68
Help Seeking	-5.87	-5.87
Self-Efficacy	-1	-1
Math Anxiety	-2.62	-2.62
Science Identity	-2.73	-2.73
Math Motivation	-7.56	-7.56

Item Fit Statistics

After fitting the Graded Response Model to the data, item fit statistics were calculated using the Orlando and Thissen (2000) and Kang and Chen (2007) Generalized $S - \chi^2$ for dichotomous and polytomous IRT models using R 4.1.1 (2021) and the MIRT package (Chalmers, 2012). The tables with fit indices can be found in Appendix C. Six items were significant at $\alpha = 0.05$ which indicates a potential item level model miss-fit for these items where the expected item performance is significantly different than the observed performance. Of these six items, only two (Q124, Q43) have an RMSEA larger than the suggested cutoff of 0.08. (Van de Schoot et al., 2012)

Item Characteristics

The Item Characteristic Curves, and Item Information Curves were plotted for each construct and can be found in Appendix D. Multiple items showed low levels of information across all theta levels along with Category Response Curves that do not show clear separation between responses across theta levels.

Test Characteristics

Expected score curves for each construct measured in 2020 and 2021 can be found in Appendix D. The expected score curves for each year appear similar with approximately equal expected scores at $\theta = 0$ (the estimated average latent trait value).

Latent Trait Estimates for 2020 and 2021 Responses

Latent trait estimates for each construct measured were calculated using the *Expected A Posteriori* (EAP) method. In the MIRT package, the prior distribution for EAP estimation is set to be a multivariate normal distribution using equally spaced quadrature (Chalmers, 2012). Please see Appendix D for the full tables of latent trait estimates by year and gender. Pearson's correlation-coefficient between latent traits was also calculated using the EAP estimates and recorded in Appendix D.

Significant Differences Between Groups

Item responses and their corresponding latent trait estimates were separated into 2020 estimates and 2021 estimates. Data for both years were inspected for Normality and a 2-Sample t-test with unequal variances was performed to test the hypothesis that the average latent trait estimate for each construct was equal for both years.

Item responses and their corresponding latent trait estimates were also separated into Male and Female subjects and data were visually inspected for Normality. A 2-Sample t-test with unequal variances was performed to test the hypothesis that the average latent trait estimate for each construct was equal for between Male and Female responses in 2020 and 2021.

Since each latent trait estimates for a construct is treated as separate dataset there is no need to control for multiple comparisons and their impact on Type I Errors.

Results

The most significant correlations for 2020 respondents were between Math Anxiety and Academic Stress, Math Motivation and Help Seeking, Science Identity and Self-Efficacy, and Math Motivation and Math Anxiety. In 2021 the most significant correlations were between Help Seeking and Academic Stress, Student Agency and Science Identity, Student Agency and Math Motivation, Math Motivation and Self-Efficacy, and Math Motivation and Science Identity. Tables 2 and 3 below contain the Pearson Correlations between latent trait estimates for each construct measured separated by year.

Table 2

Correlations for Latent Trait Estimates 2020

Measure	Student Agency	Academic Stress	Help Seeking	Self-Efficacy	Math Anxiety	Science Identity	Math Motivation
Student Agency	1						
Academic Stress	-0.14	1					
Help Seeking	0.61	0	1				
Self-Efficacy	-0.61	-0.02*	0.42	1			
Math Anxiety	-0.03	0.28**	0.07	-0.13	1		
Science Identity	0.22*	-0.19*	0.18*	0.27**	0.1	1	
Math Motivation	0.21*	0	0.24**	0.11	-0.25**	0.18*	1

Note. $N = 138$. Pearson's r reported.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 3

Correlations for Latent Trait Estimates 2021

Measure	Student Agency	Academic Stress	Help Seeking	Self-Efficacy	Math Anxiety	Science Identity	Math Motivation
Student Agency	1						
Academic Stress	-0.05	1					
Help Seeking	0.29	0.2**	1				
Self-Efficacy	0.52	-0.06	0.17*	1			
Math Anxiety	-0.1	0.41	0.15*	-0.16*	1		
Science Identity	0.27**	0.05	0.14	0.28	0.02	1	
Math Motivation	0.22**	0.02	0.14*	0.22**	-0.18*	0.23**	1

Note. $N = 188$. Pearson's r reported.
* $p < .05$, ** $p < .01$, *** $p < .001$.

There was not enough evidence to conclude that there was significant difference in the average latent traits for each construct the survey measured between 2020 and 2021. Additionally, there was n was not enough evidence to conclude that there was significant difference in the average latent estimates for each construct between male and female respondents in 2020. However, in 2021, there was a significant difference in the average male and female latent trait estimate for the Math Anxiety construct. The results of the two-sample t-tests were recorded in Tables 4 through 6 below.

Table 4

2-Sample t-test for Equal Means Between Years

	Means			
	2020	2021	t-test	95% CI
Student Agency	0	0	1	(-0.22, 0.22)
Academic Stress	0	0	1	(-0.22, 0.22)
Help Seeking	0	0	1	(-0.21, 0.21)
Self-Efficacy	0	0	1	(-0.22, 0.22)
Math Anxiety	0	0	1	(-0.21, 0.21)
Science Identity	0	0	1	(-0.22, 0.22)
Math Motivation	0	0	1	(-0.22, 0.22)

Note. Welch Two Sample t-test performed
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 5

2-Sample t-test for Equal Means Between Gender in 2020

	Means			
	Male	Female	t-test	95% CI
Student Agency	-0.02	0.06	-0.44	(-0.45, 0.29)
Academic Stress	-0.15	0.04	-0.97	(-0.57, 0.20)
Help Seeking	-0.18	0.09	-1.63	(-0.61, 0.06)
Self-Efficacy	-0.06	0.04	-0.49	(-0.47, 0.29)
Math Anxiety	0.07	-0.04	0.65	(-0.22, 0.44)
Science Identity	0	0	0.28	(-0.37, 0.50)
Math Motivation	-0.03	0.04	-0.40	(-0.44, 0.30)

Note. Welch Two Sample t-test performed
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 6

2-Sample t-test for Equal Means Between Gender in 2021

	Means			
	Male	Female	t-test	95% CI
Student Agency	0.08	-0.39	0.85	(-0.16, 0.40)
Academic Stress	-0.12	0.06	-1.3	(-0.44, 0.09)
Help Seeking	-0.04	0.02	-0.4	(-0.33, 0.22)
Self-Efficacy	-0.06	0.04	-0.49	(-0.47, 0.29)
Math Anxiety	-0.21	0.12	-2.40*	(-0.61, -0.06)
Science Identity	0.01	0.01	0.01	(-0.29, 0.29)
Math Motivation	-0.04	0.03	-0.48	(-0.36, 0.22)

Note. Welch Two Sample t-test performed
* $p < .05$, ** $p < .01$, *** $p < .001$.

Discussion

Research Questions

Research Question 1 was to determine if there was any significant difference between the latent trait estimates of students who were admitted as Biological Sciences Majors to California State University, Long Beach in 2020 as compared to students admitted in 2021. Based on the results of the two-sample t-test with unequal variances there was not sufficient evidence to conclude that there was a significant difference in average latent trait estimates for each construct measured between 2020 and 2021.

Research Question 2 asked if there is a significant difference in latent trait estimates between male and female students. A two-sample t-test was performed with unequal variances to compare the average male and female latent trait estimates for each construct measured. From the test results there was not sufficient evidence to conclude that there was a significant difference in the latent trait estimates between male and female students in 2020. However, in 2021 the average latent trait estimates for the construct Math Anxiety for male respondents ($\bar{\theta}_{Male} = -0.21$) was found to be significantly different then for female respondents ($\bar{\theta}_{Female} = 0.12$).

Research Question 3 compared the correlations between constructs measured. Students who have a higher latent trait estimates for Science Identity are associated with lower levels of Academic Stress, and higher levels of Student Agency, Help Seeking behavior, and Self-Efficiency. Students with higher latent trait estimates for Math Motivation are associated with lower levels of Math Anxiety, and higher levels of Student Agency, Help Seeking behavior, and report a higher Science Identity. Students with higher latent trait estimates for Math Anxiety are associated with higher levels of Academic Stress and lower Self-Efficacy. Students who are more Self-Efficient are associated with lower level of Academic Stress.

Recommendations for Future Research

Based on the correlations, future research should focus on designing interventions and courses that help students become more efficient at identifying and asking for help and increasing student agency and efficiency. All three of these constructs were significantly correlated with either a student's identity as a scientist and their motivation in mathematics courses. Additionally, a student's identity as a scientist and their motivation in mathematics are significantly positively correlated which indicates that as students become more secure in mathematics their perception of themselves as a scientist increases.

Limitations

Six items (13%) on the survey were flagged as a potential item level model miss-fit. This may affect the latent trait estimates for students. Furthermore, multiple items showed low levels of information across all theta levels along with Category Response Curves that do not show clear separation between responses across theta levels. These items should be examined and potentially re-written to obtain more precise latent trait estimates. With such a low response rate, caution should be exercised when attempting to generalize these results.

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Appendix A

Question Codebook and Response Options

Table A1

Coded Questions and Descriptions

Code	Question Description
Q19_5	I have created a realistic degree plan
Q103	I finish whatever I begin
Q102	Setbacks don't discourage me
Q101	I am diligent
Q104	I am a hard worker
Q22	Competition with my peers
Q23	My teachers being critical of my academic performance
Q24	Teachers having unrealistic expectations of me
Q25	The unrealistic academic expectations of my parents
Q26	I believe that the amount of coursework assigned to me is too much
Q27	I am unable to catch up if I get behind in my work
Q29	seek help from a tutor or the instructor
Q30	seek help from online sources
Q31	seek help from a friend
Q32	set some goals for yourself to deal with the situation
Q33	discuss your concerns with a friend
Q34	turn your full attention to solving the problem
Q35	form a plan of action in your mind
Q36	try to distract yourself from the problem
Q39	In college, I will be able to achieve most of the goals that I have set for myself
Q40	When facing difficult tasks in college, I am certain that I will accomplish them
Q41	In college, I believe I can succeed at most any endeavor to which I set my mind
Q42	I will be able to successfully overcome many challenges in college
Q43	Even when things are tough, I can perform quite well in college
Q118	Having to use the tables in the back of a math book
Q118_1	Thinking about an upcoming math test 1 day before
Q119	Watching a teacher work on algebraic equation on the blackboard
Q120	Taking an examination in a math course
Q121	Being given a homework assignment of many difficult problems that is due the next class meeting
Q122	Listening to another student explain a math formula
Q123	Being given a "pop" quiz in math class

Q124	Starting a new chapter in a math book
Q52	I consider myself a science person
Q53	Being involved in science is a key part of who I am
Q54	It is important to me that professors see me as a science person
Q55	Being good in science is an important part of who I am
Q57	I am really keen to learn a lot of mathematics
Q58	Mathematics is important to me personally
Q59	It is important to me personally to be good at mathematics
Q60	I enjoy puzzling over mathematics problems
Q61	I always look forward to mathematics lessons
Q62	If I can learn something new in mathematics, I am prepared to use my free time to do so
Q63	I will need good mathematics skills for my later life (training, studies, work)
Q64	Good grades in mathematics can be of great value to me later
Q65	I would have to sacrifice a lot of free time to be good at mathematics
Q66	I would have to invest a lot of time to get good grades in mathematics

Appendix B

Descriptive Statistics

Table 1B

Endorsement Percentages Per Response Category

Questions	Percent 1	Percent 2	Percent 3	Percent 4	Percent 5
Q19-5	0.75%	3.01%	7.52%	36.09%	52.63%
Q103	0.76%	10.69%	30.53%	35.11%	22.90%
Q102	7.63%	29.01%	33.59%	18.32%	11.45%
Q101	0.00%	6.87%	38.17%	36.64%	18.32%
Q104	0.00%	3.82%	22.90%	37.40%	35.88%
Q22	17.42%	30.30%	28.79%	18.94%	4.55%
Q23	7.58%	21.97%	36.36%	21.21%	12.88%
Q24	23.48%	20.45%	24.24%	17.42%	14.39%
Q25	34.09%	19.70%	15.91%	16.67%	13.64%
Q26	8.33%	23.48%	37.88%	20.45%	9.85%
Q27	25.00%	32.58%	20.45%	11.36%	10.61%
Q29	13.64%	55.30%	16.67%	9.09%	5.30%
Q30	1.52%	18.94%	27.27%	34.09%	18.18%
Q31	9.02%	29.32%	25.56%	22.56%	13.53%
Q32	6.06%	26.52%	26.52%	30.30%	10.61%
Q33	9.02%	21.05%	12.03%	34.59%	23.31%
Q34	0.00%	15.15%	25.00%	43.18%	16.67%
Q35	1.50%	15.79%	24.06%	37.59%	21.05%
Q36	9.02%	45.86%	21.05%	13.53%	10.53%
Q39	1.50%	5.26%	54.14%	39.10%	0.00%
Q40	0.75%	5.26%	52.63%	41.35%	0.00%
Q41	0.75%	3.01%	47.37%	48.87%	0.00%
Q42	0.76%	3.79%	48.48%	46.97%	0.00%
Q43	1.50%	11.28%	57.14%	30.08%	0.00%
Q118	45.86%	23.31%	18.05%	6.02%	6.77%
Q118_1	7.52%	12.78%	14.29%	30.83%	34.59%
Q119	43.61%	24.81%	17.29%	6.02%	8.27%
Q120	6.77%	11.28%	21.05%	21.80%	39.10%
Q121	2.26%	8.27%	26.32%	20.30%	42.86%
Q122	38.35%	24.81%	25.56%	4.51%	6.77%
Q123	3.01%	7.52%	20.30%	17.29%	51.88%
Q124	33.83%	21.05%	28.57%	9.02%	7.52%
Q52	0.75%	7.52%	46.62%	45.11%	0.00%
Q53	3.76%	14.29%	45.11%	36.84%	0.00%
Q54	9.02%	34.59%	36.09%	20.30%	0.00%
Q55	6.77%	19.55%	44.36%	29.32%	0.00%
Q57	27.07%	26.32%	27.07%	12.78%	6.77%

Q58	33.08%	29.32%	18.05%	14.29%	5.26%
Q59	18.80%	20.30%	29.32%	21.05%	10.53%
Q60	39.10%	18.80%	25.56%	9.77%	6.77%
Q61	42.86%	26.32%	17.29%	8.27%	5.26%
Q62	49.62%	21.80%	16.54%	7.52%	4.51%
Q63	9.02%	30.83%	23.31%	24.06%	12.78%
Q64	7.52%	18.05%	27.82%	27.82%	18.80%
Q65	18.05%	29.32%	20.30%	18.80%	13.53%
Q66	8.27%	25.56%	21.05%	26.32%	18.80%

Table 2B

Item-Total Score Correlation for Student Agency

Question	Correlation with Total Score 2020	Correlation with Total Score 2021
Q19-5	0.53	0.58
Q103	0.75	0.67
Q102	0.68	0.72
Q101	0.82	0.72
Q104	0.80	0.76

Table 3B

Item-Total Score Correlation for Academic Stress

Question	Correlation with Total Score 2020	Correlation with Total Score 2021
Q22	0.58	0.53
Q23	0.69	0.64
Q24	0.77	0.73
Q25	0.64	0.62
Q26	0.59	0.64
Q27	0.54	0.62

Table 4B

Item-Total Score Correlation for Help Seeking

Question	Correlation with Total Score 2020	Correlation with Total Score 2021
Q29	0.53	0.50
Q30	0.64	0.62
Q31	0.63	0.67
Q32	0.67	0.62
Q33	0.59	0.69
Q34	0.68	0.42
Q35	0.71	0.48
Q36	0.14	0.25

Table 5B

Item-Total Score Correlation for Self-Efficacy

Question	Correlation with Total Score 2020	Correlation with Total Score 2021
Q39	0.72	0.72
Q40	0.80	0.82
Q41	0.74	0.82
Q42	0.83	0.82
Q43	0.70	0.74

Table 6B

Item-Total Score Correlation for Math Anxiety

Question	Correlation with Total Score 2020	Correlation with Total Score 2021
Q118	0.61	0.72
Q118_1	0.73	0.80
Q119	0.74	0.79
Q120	0.72	0.77
Q121	0.66	0.74
Q122	0.64	0.79
Q123	0.67	0.69
Q124	0.67	0.73

Table 7B

Item-Total Score Correlation for Science Identity

Question	Correlation with Total Score 2020	Correlation with Total Score 2021
Q52	0.80	0.73
Q53	0.87	0.83
Q54	0.73	0.84
Q55	0.90	0.87

Table 8B

Item-Total Score Correlation for Math Motivation

Question	Correlation with Total Score 2020	Correlation with Total Score 2021
Q57	0.74	0.80
Q58	0.79	0.81
Q59	0.77	0.75
Q60	0.67	0.69
Q61	0.77	0.76
Q62	0.75	0.73
Q63	0.59	0.70
Q64	0.66	0.70
Q65	0.34	0.30
Q66	0.46	0.23

Appendix C

Item Fit Statistics

Table 1C

Item Fit Statistics – Student Agency

Item	$S-\chi^2$ 2020	RMSEA 2020	$S-\chi^2$ 2021	RMSEA 2021
Q19_5	18.48	0.06	15.48	0.04
Q103	16.53	0.08	12.44	0.00
Q102	14.30	0.00	11.99	0.00
Q101	3.71	0.00	9.34	0.00
Q104	4.58	0.00	5.74	0.00

*p < .05

Table 2C

Item Fit Statistics – Academic Stress

Item	$S-\chi^2$ 2020	RMSEA 2020	$S-\chi^2$ 2021	RMSEA 2021
Q22	40.85*	0.07	42.12	0.04
Q23	25.85	0.02	28.75	0.01
Q24	14.81	0.00	28.90	0.00
Q25	37.76	0.04	40.25	0.02
Q26	27.93	0.03	26.04	0.00

*p < .05

Table 3C

Item Fit Statistics – Help Seeking

Item	$S-\chi^2$ 2020	RMSEA 2020	$S-\chi^2$ 2021	RMSEA 2021
Q29	20.34	0.00	31.50	0.02
Q30	31.85	0.02	15.94	0.00
Q31	30.13	0.00	37.45	0.04
Q32	23.37	0.00	24.40	0.00
Q33	33.38	0.01	28.64	0.00
Q34	24.04	0.03	43.16	0.04
Q35	30.29*	0.07	37.48	0.02
Q36	40.30	0.03	45.14	0.04

*p < .05

Table 4C

Item Fit Statistics – Self Efficacy

Item	$S-\chi^2$ 2020	RMSEA 2020	$S-\chi^2$ 2021	RMSEA 2021
Q39	2.11	0.02	3.11	0.06
Q40	5.04	0.11	0.69	0.00
Q41	1.94	0.08	1.17	0.03
Q42	1.53	0.06	2.91	0.05
Q43	7.75*	0.15	4.18	0.08

*p < .05

Table 5C

Item Fit Statistics – Math Anxiety

Item	$S-\chi^2$ 2020	RMSEA 2020	$S-\chi^2$ 2021	RMSEA 2021
Q118	32.84*	0.07	40.86	0.04
Q118_1	32.34	0.05	25.23	0.00
Q119	20.82	0.03	36.99*	0.06
Q120	26.41	0.03	33.20	0.04
Q121	22.71	0.00	31.39	0.04
Q122	22.81	0.02	29.27	0.03
Q123	26.64	0.05	28.07	0.03
Q124	49.73*	0.10	23.33	0.00

*p < .05

Table 6C

Item Fit Statistics – Science Identity

Item	$S-\chi^2$ 2020	RMSEA 2020	$S-\chi^2$ 2021	RMSEA 2021
Q52	1.36	0.05	9.62	0.07
Q53	6.18	0.01	4.22	0.05
Q54	13.81	0.08	9.08	0.05
Q55	1.21	0.00	9.61	0.05

*p < .05

Table 7C

Item Fit Statistics – Math Motivation

Item	$S-\chi^2$ 2020	RMSEA 2020	$S-\chi^2$ 2021	RMSEA 2021
Q57	24.78	0.03	30.80	0.05
Q58	25.64	0.06	30.19	0.03
Q59	26.57	0.00	25.69	0.00
Q60	22.96	0.00	38.09	0.04
Q61	29.39*	0.07	32.93	0.04
Q62	21.05	0.02	20.62	0.00
Q63	39.12	0.04	31.31	0.00
Q64	32.11	0.02	46.84	0.03
Q65	37.18	0.00	68.11	0.02
Q66	47.11	0.03	52.37	0.00
Q57	24.78	0.03	30.80	0.05

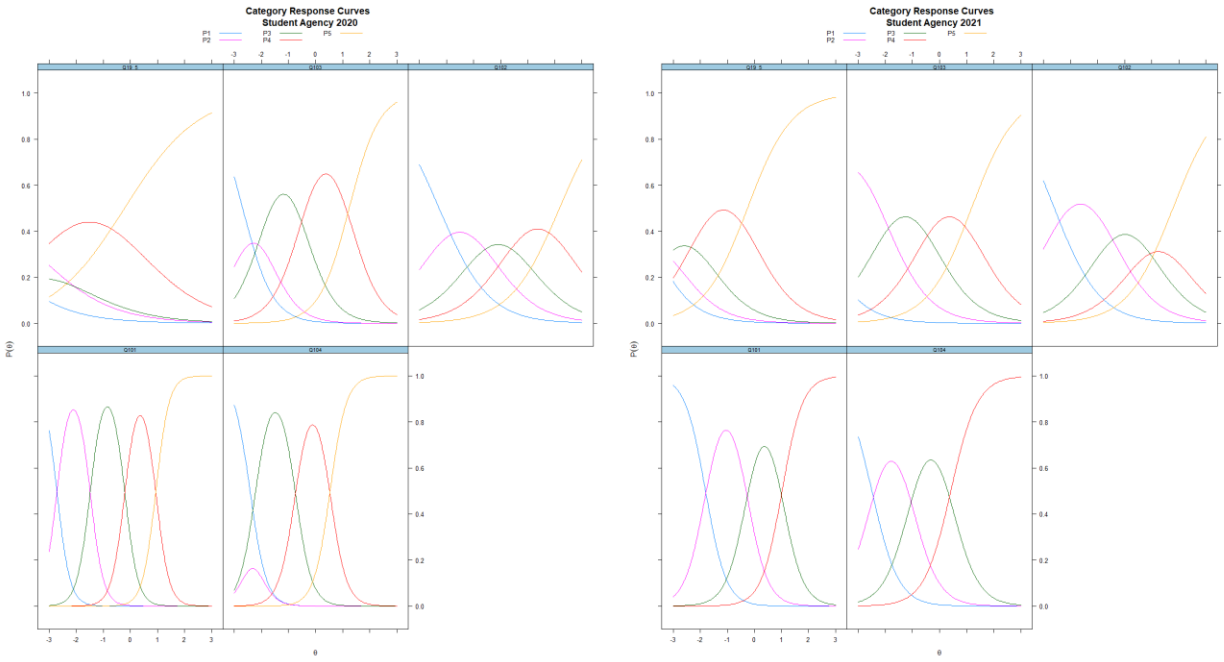
*p < .05

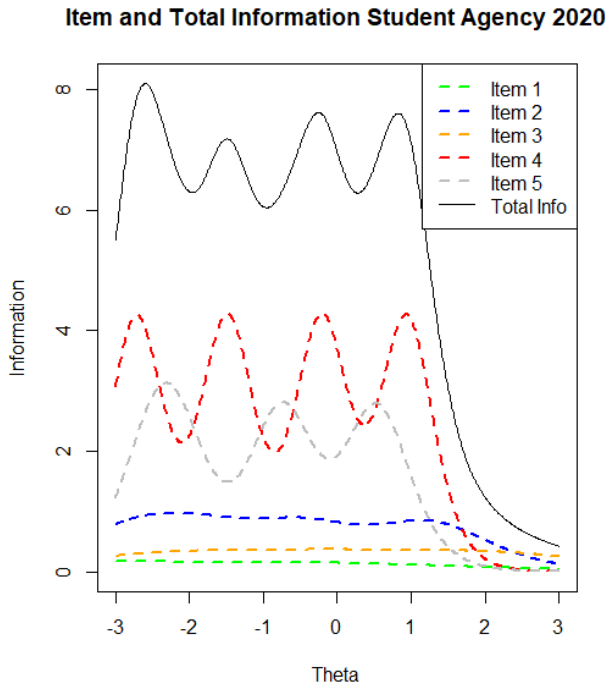
Appendix D

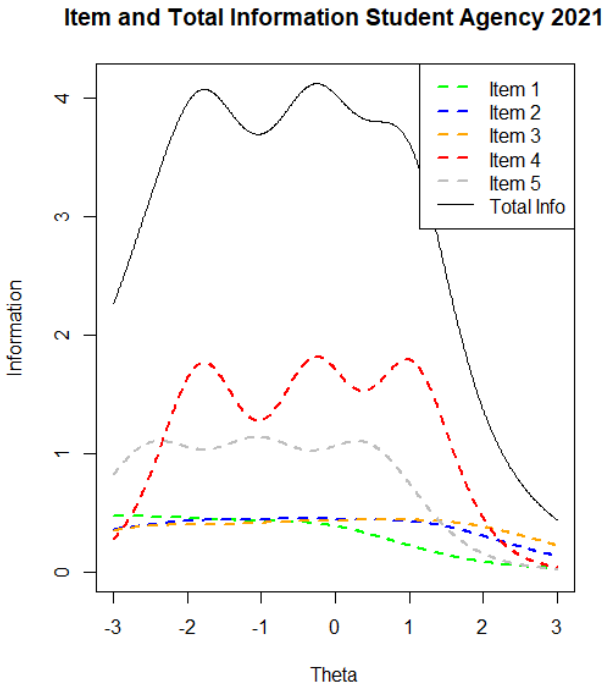
Graphs of Characteristics, Information, and Expected Score

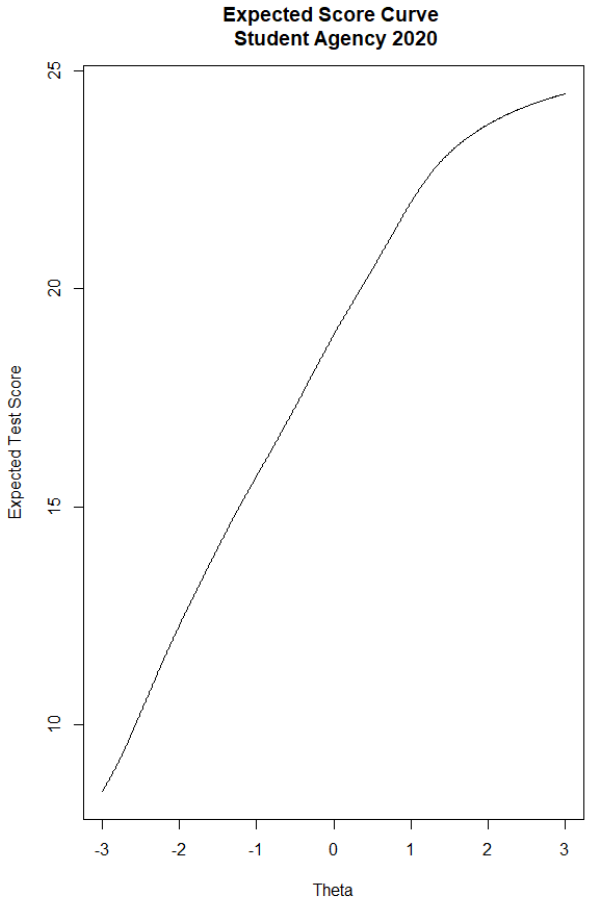
Graphs 1D

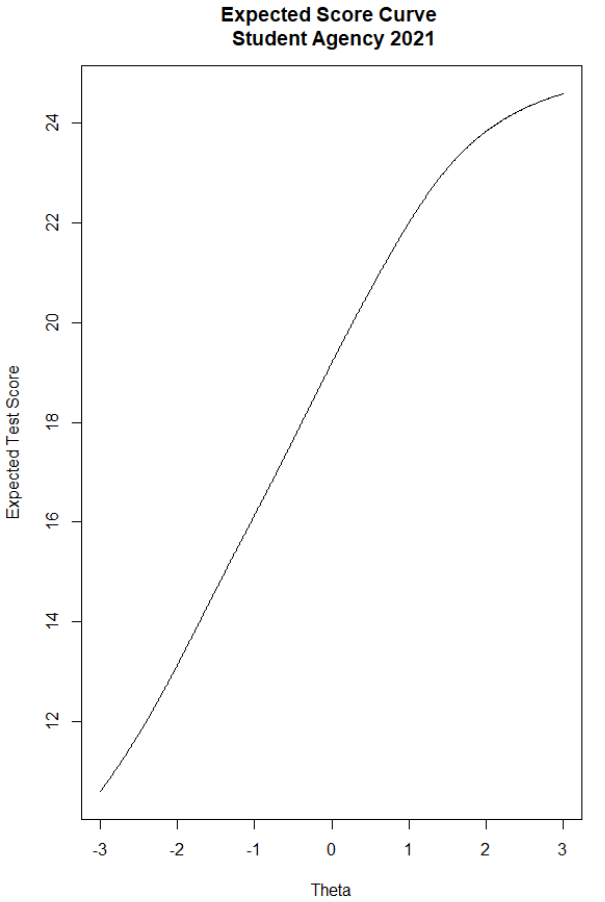
Student Agency




Item and Total Information Student Agency 2020
Item 1
Item 2
Item 3
Item 4
Item 5
Total Info
Information
Theta

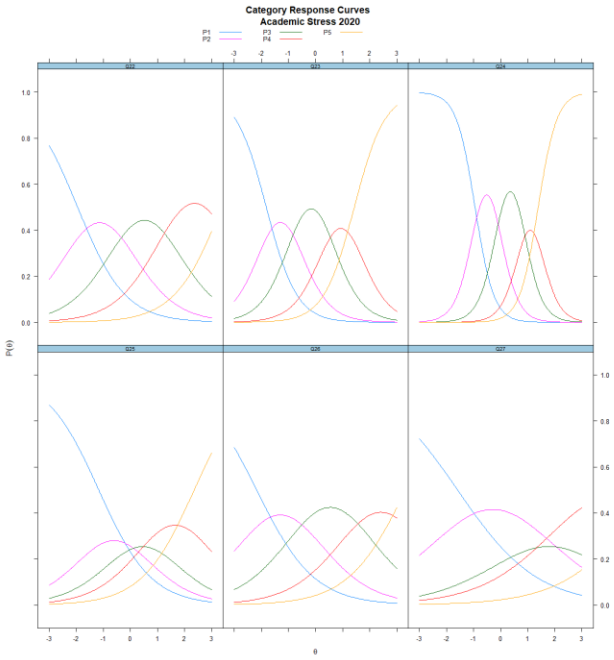

Item and Total Information Student Agency 2021
Item 1
Item 2
Item 3
Item 4
Item 5
Total Info
Information
Theta

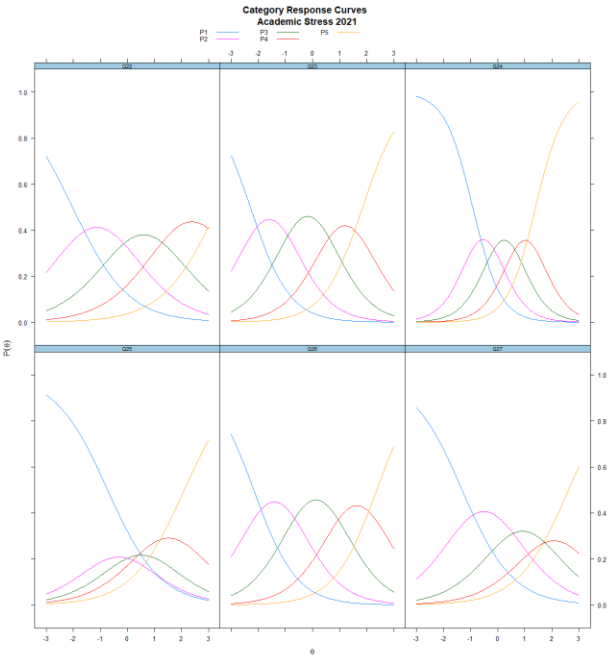

Expected Score Curve
Student Agency 2020
Expected Test Score
Theta

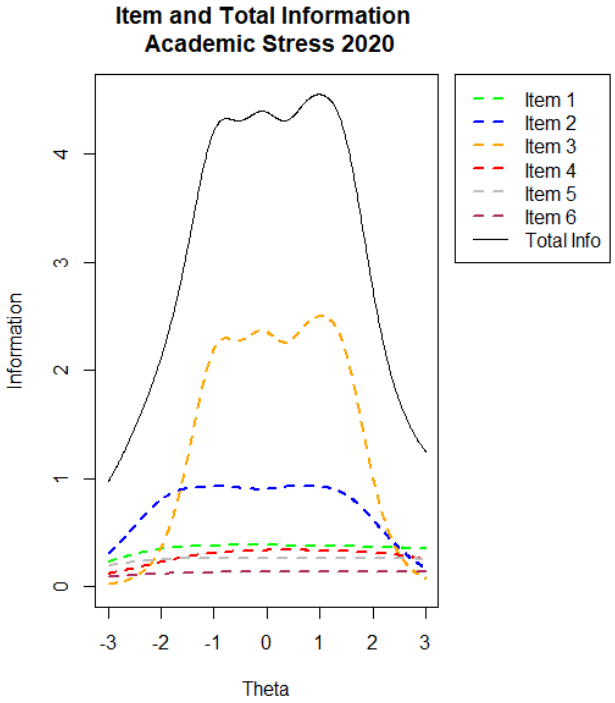

Expected Score Curve
Student Agency 2021
Expected Test Score
Theta

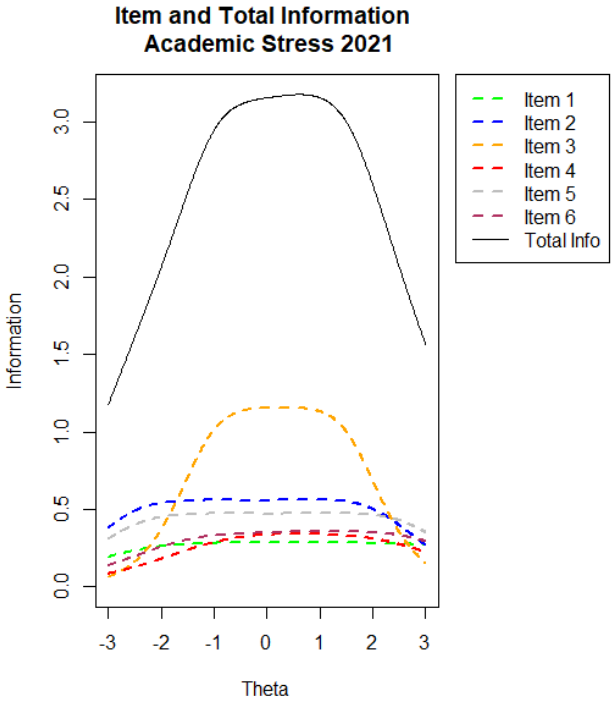
Graphs 2D

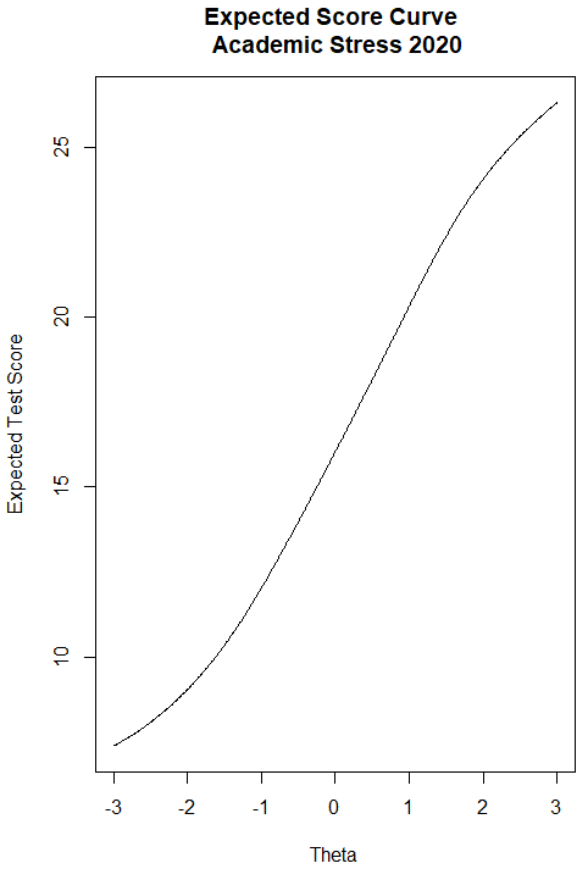
Academic Stress

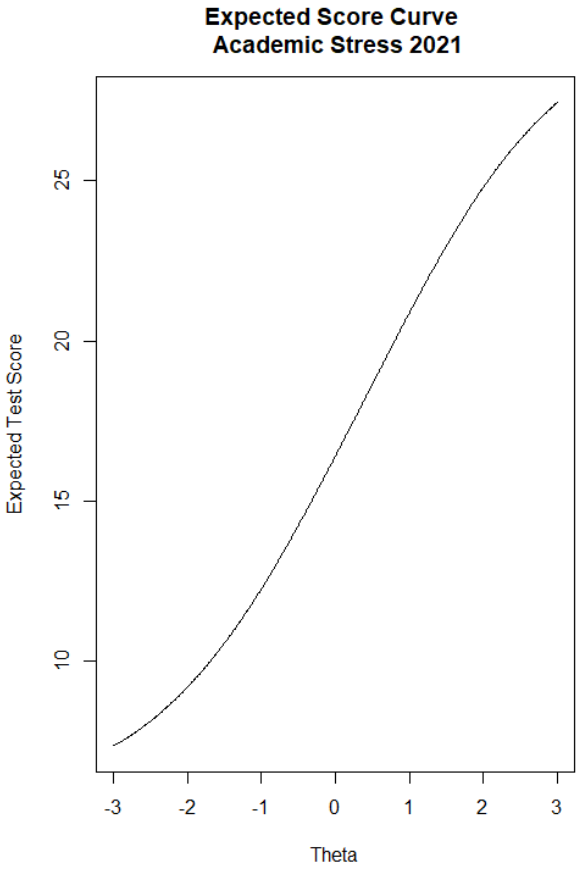






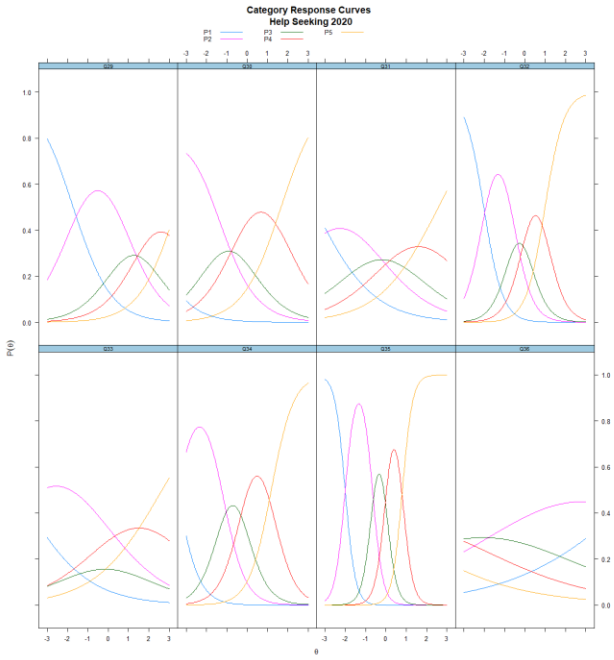


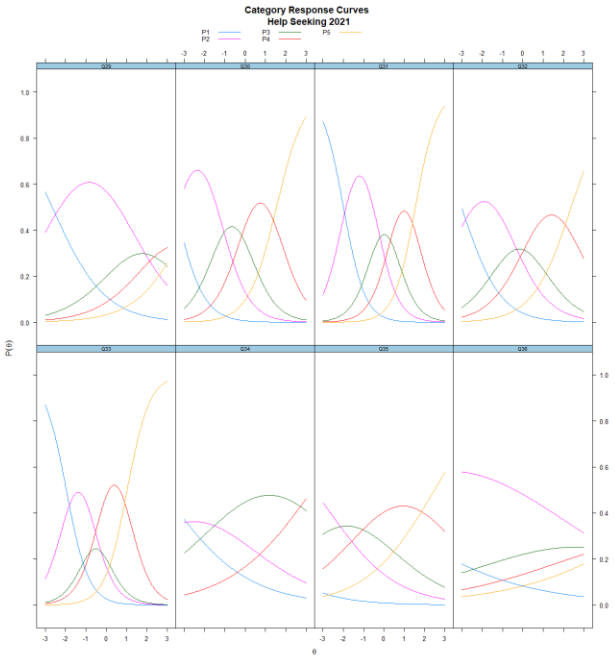

Expected Score Curve
Academic Stress 2020
Expected Test Score
10
15
20
25
-3
-2
-1
0
1
2
3
Theta

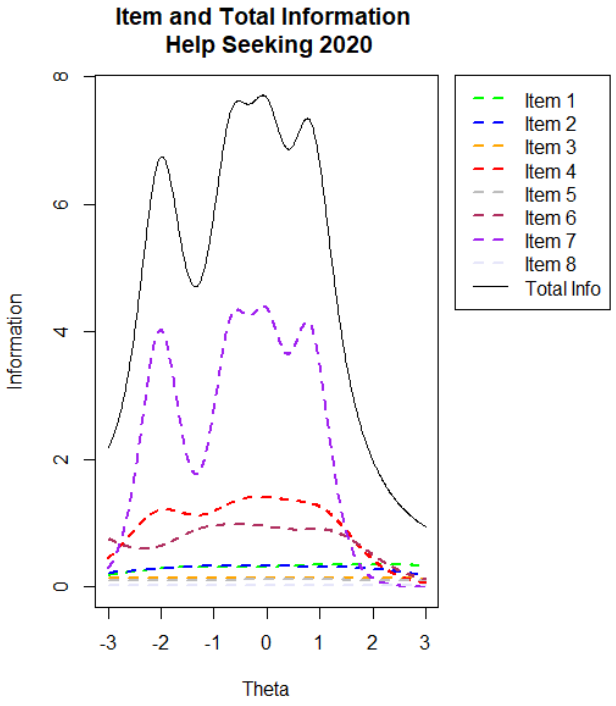

Expected Score Curve
Academic Stress 2021
Expected Test Score
10
15
20
25
-3
-2
-1
0
1
2
3
Theta

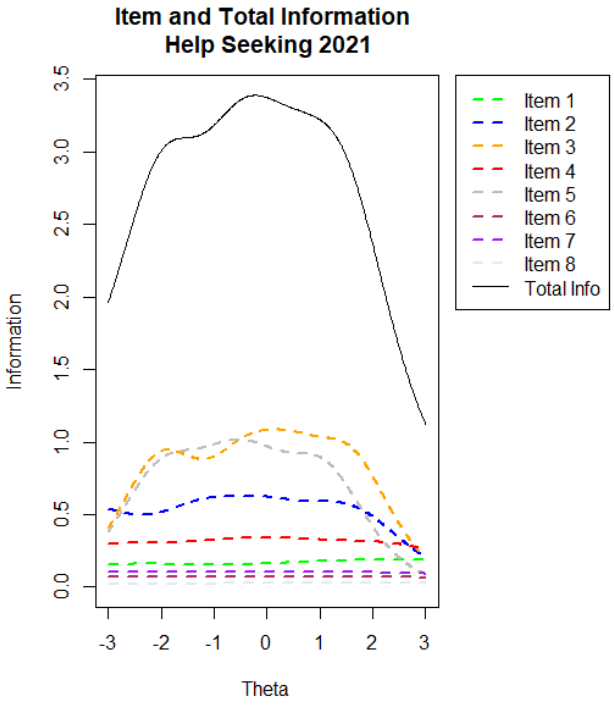
Graph 3D

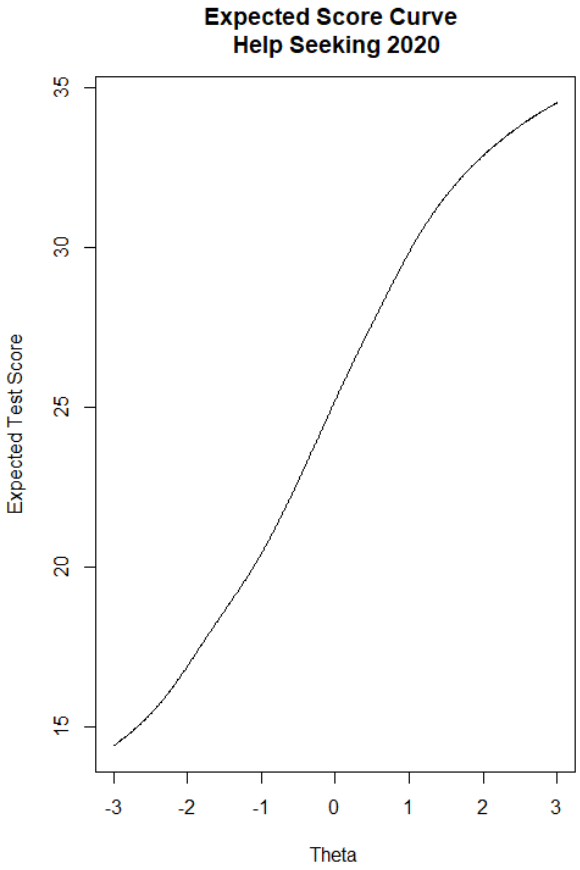
Help Seeking

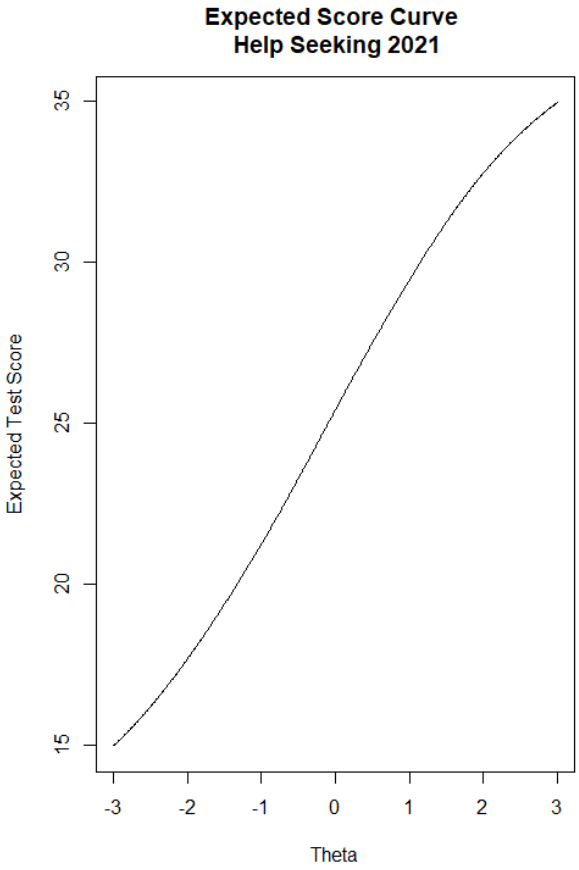






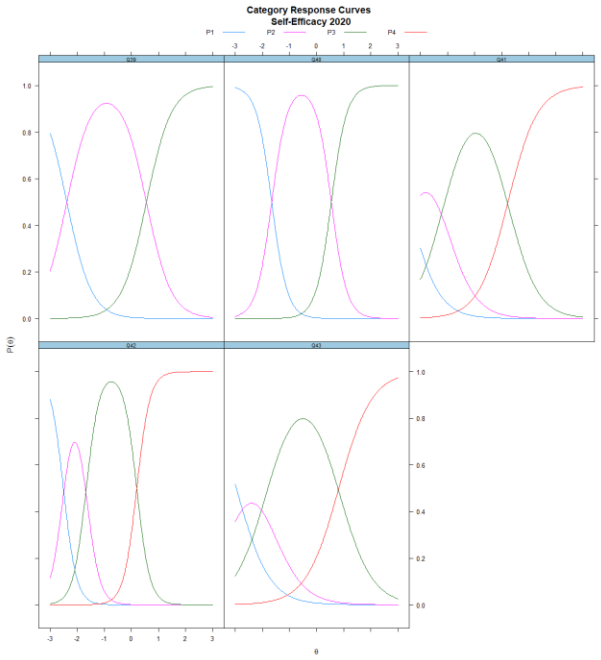


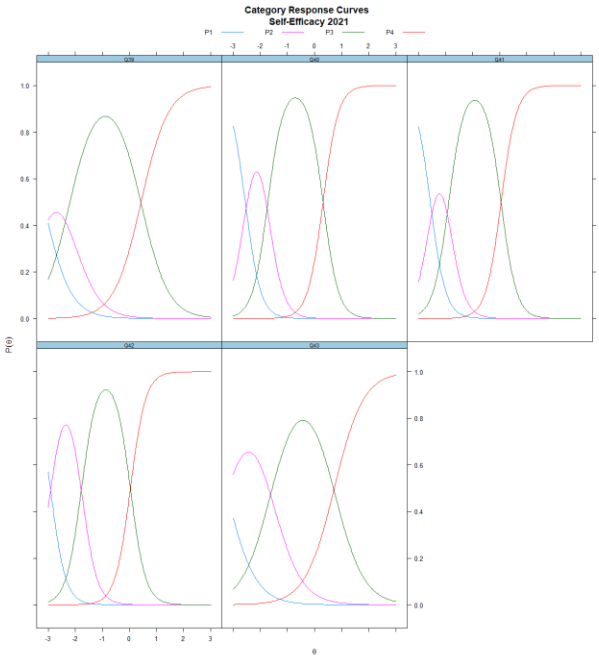

Expected Score Curve
Help Seeking 2020
Expected Test Score
15
20
25
30
35
-3
-2
-1
0
1
2
3
Theta

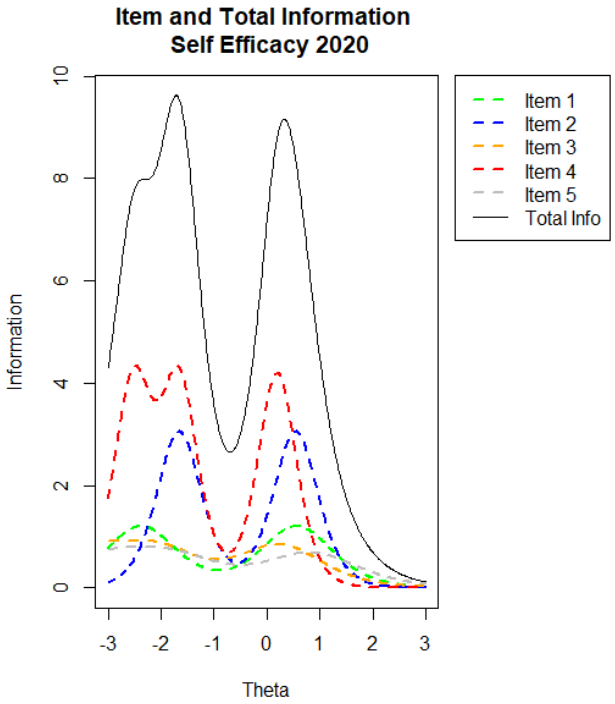

Expected Score Curve
Help Seeking 2021
Expected Test Score
15
20
25
30
35
-3
-2
-1
0
1
2
3
Theta

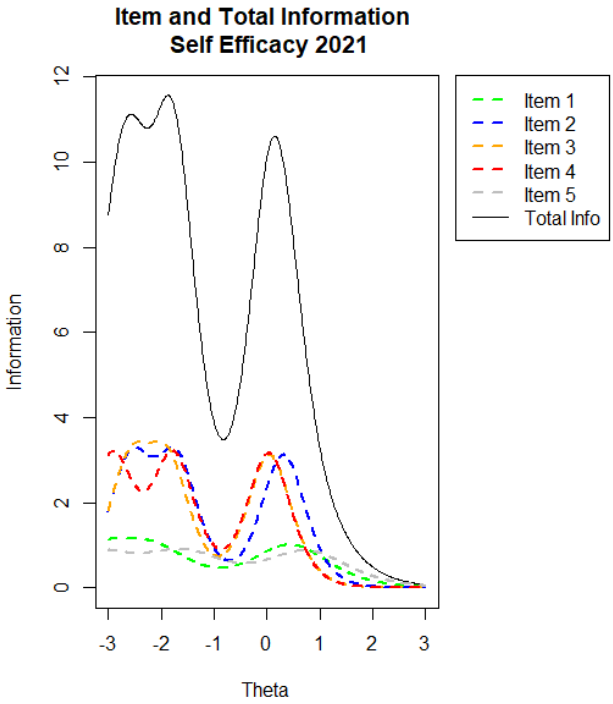
Graph 4D

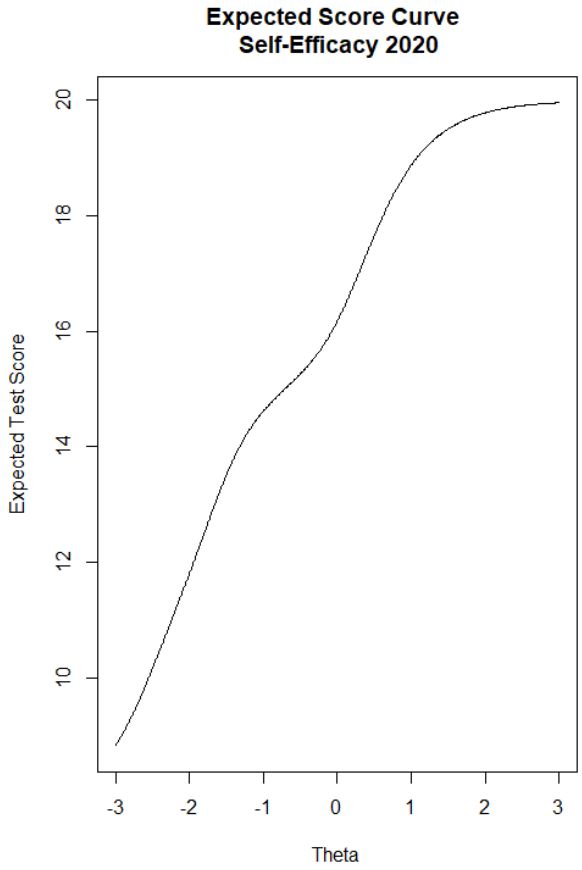
Self-Efficacy

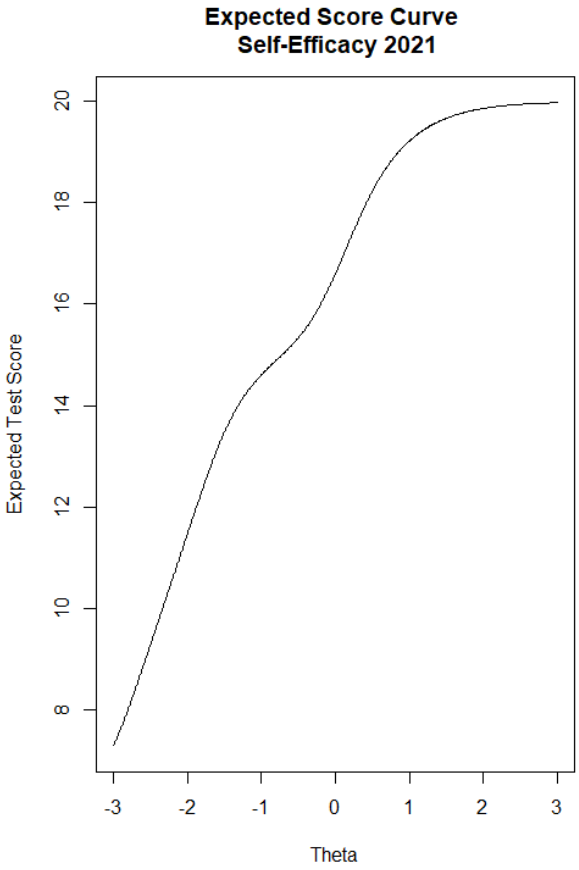






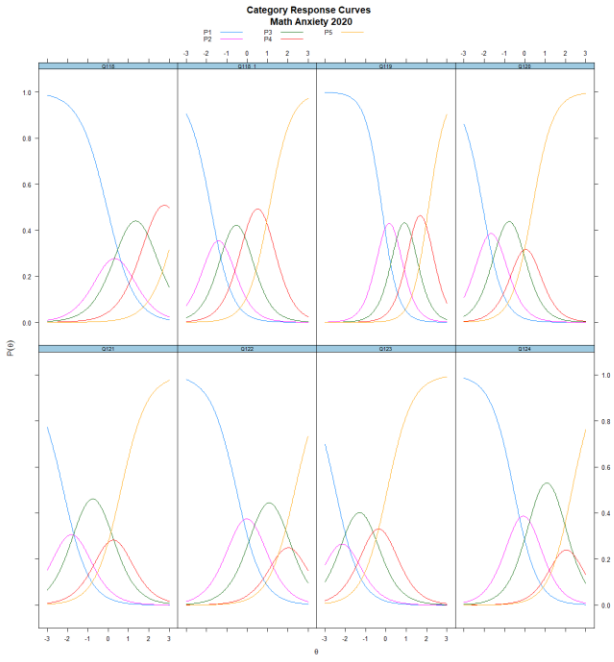


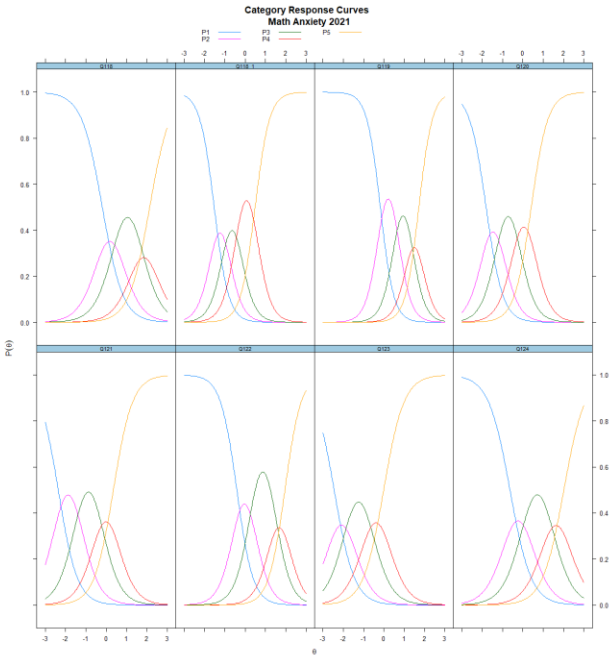

Expected Score Curve
Self-Efficacy 2020
Expected Test Score
10
12
14
16
18
20
-3
-2
-1
0
1
2
3
Theta

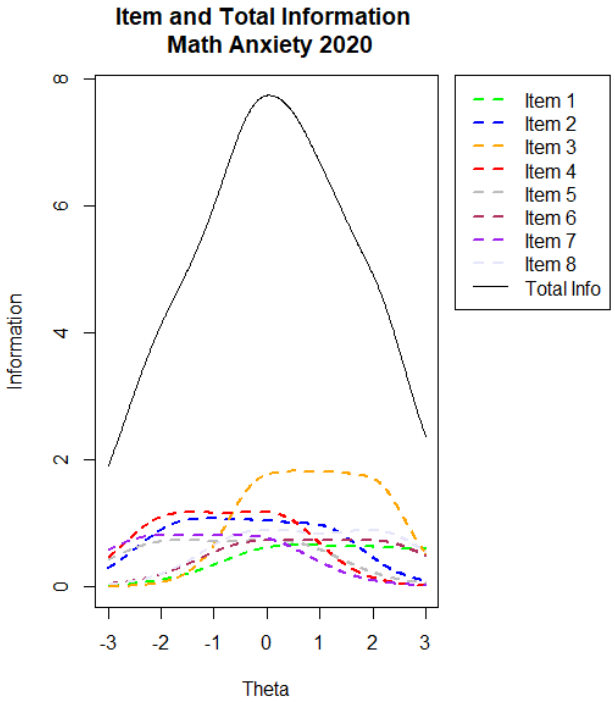

Expected Score Curve
Self-Efficacy 2021
Expected Test Score
8
10
12
14
16
18
20
-3
-2
-1
0
1
2
3
Theta

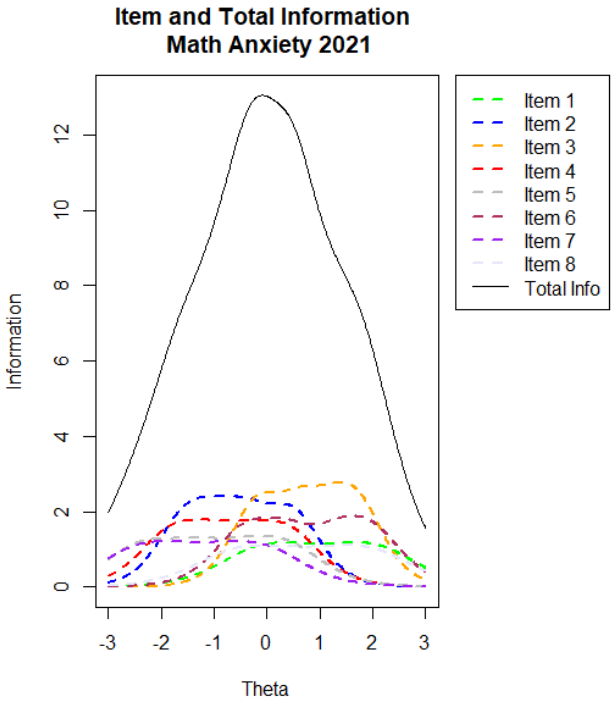
Graph 5D

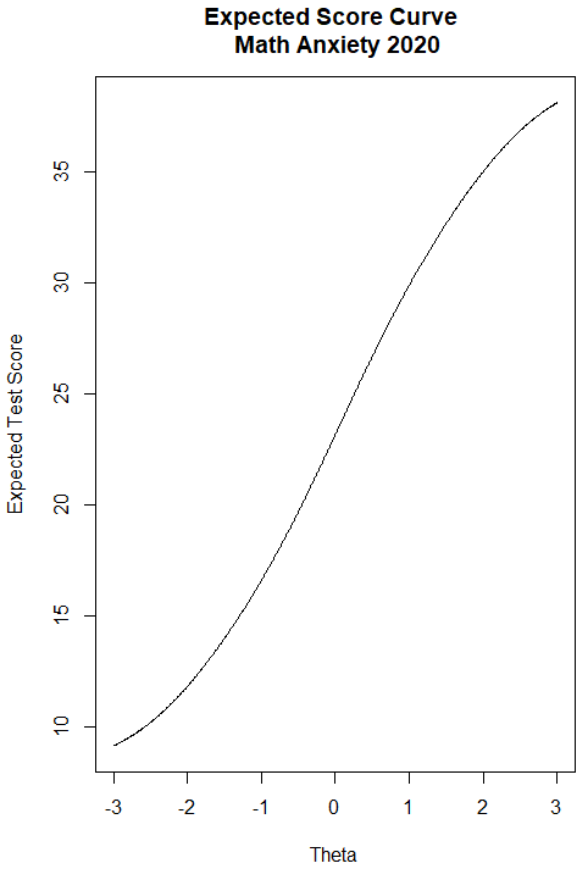
Math Anxiety

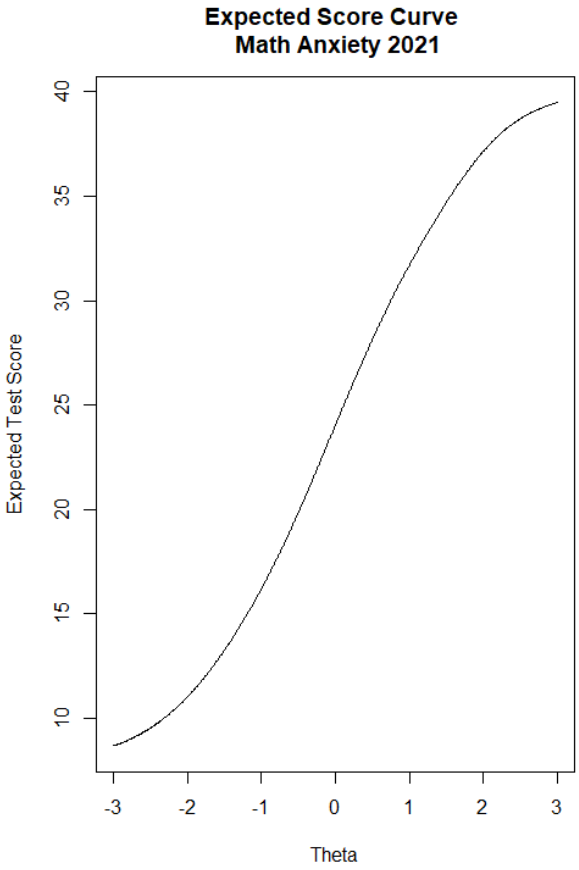






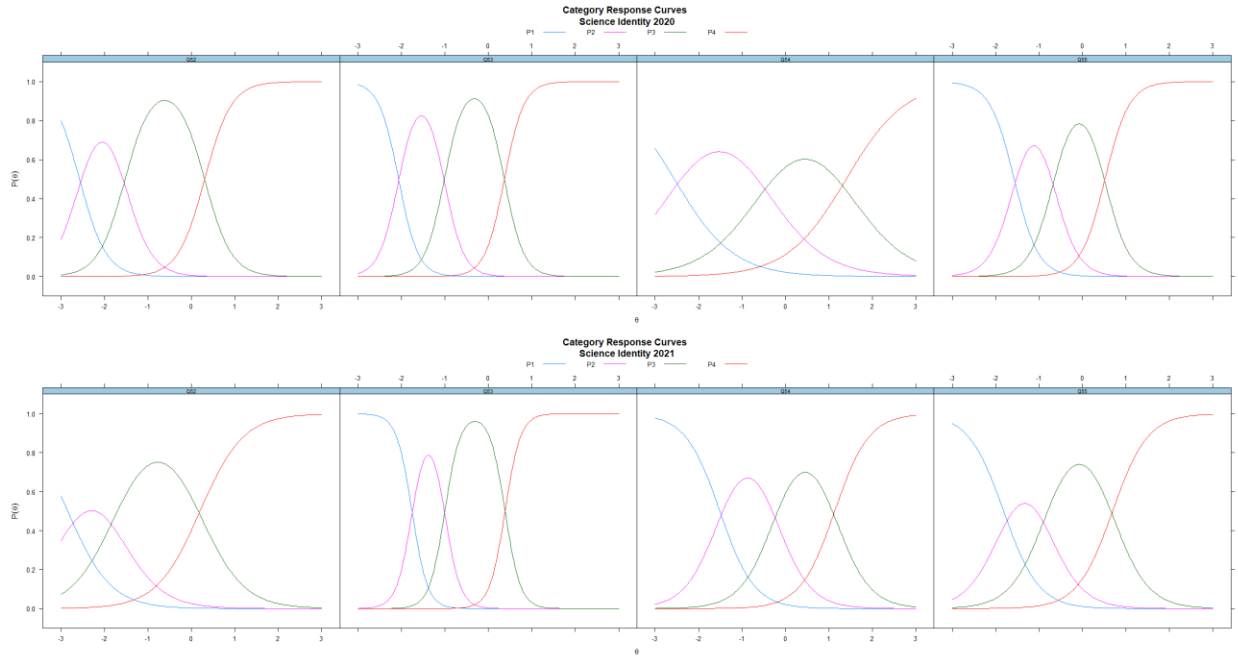


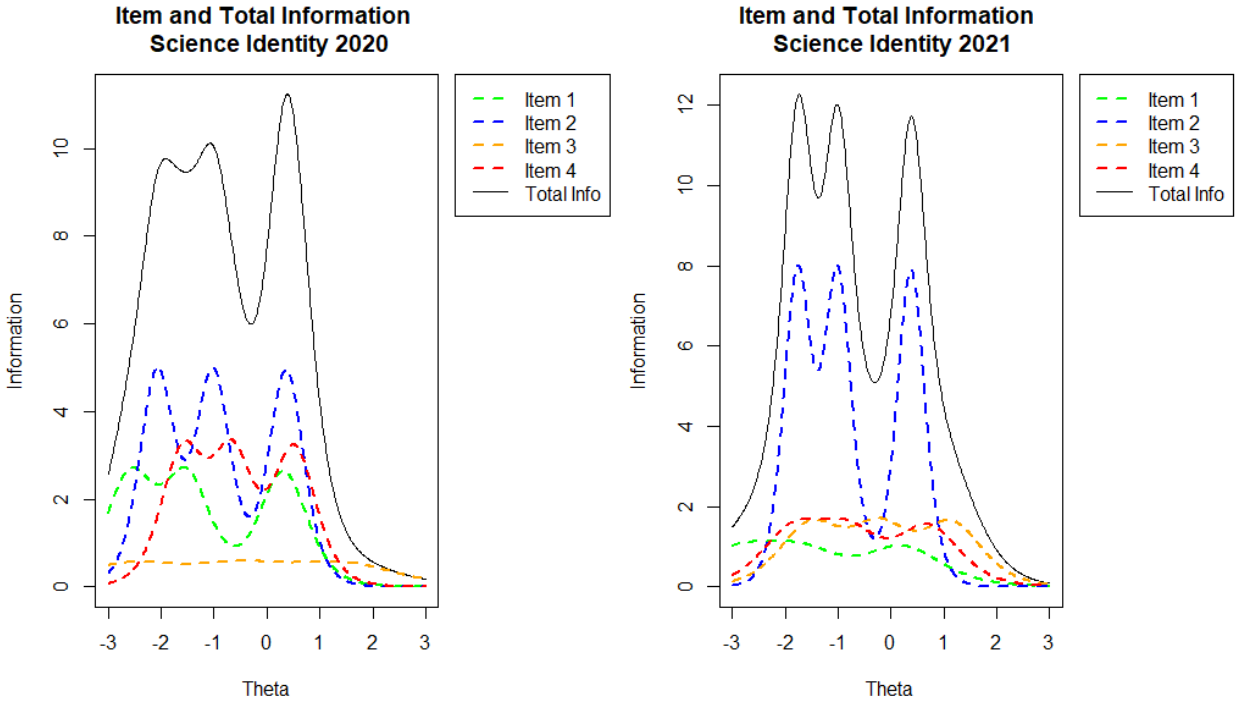

Expected Score Curve
Math Anxiety 2020
Expected Test Score
10
15
20
25
30
35
-3
-2
-1
0
1
2
3
Theta

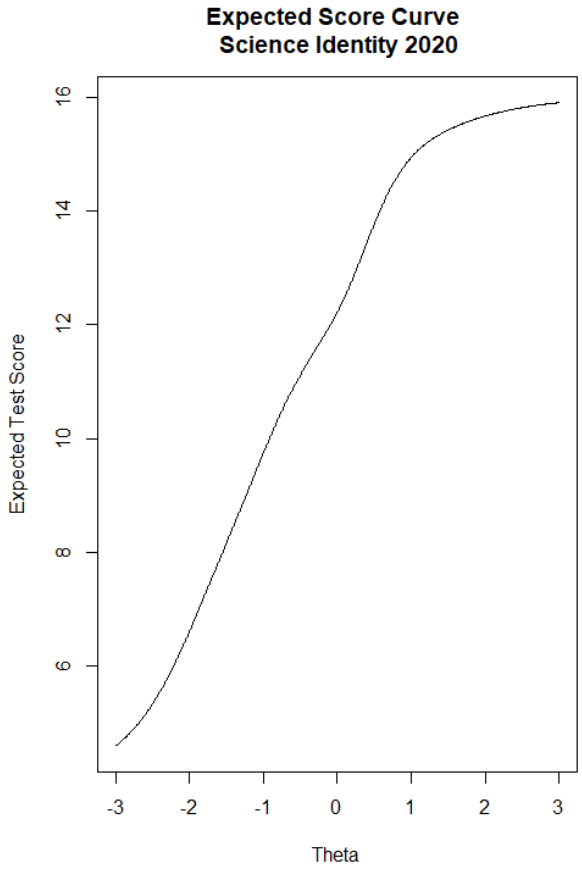

Expected Score Curve
Math Anxiety 2021
Expected Test Score
10
15
20
25
30
35
40
-3
-2
-1
0
1
2
3
Theta

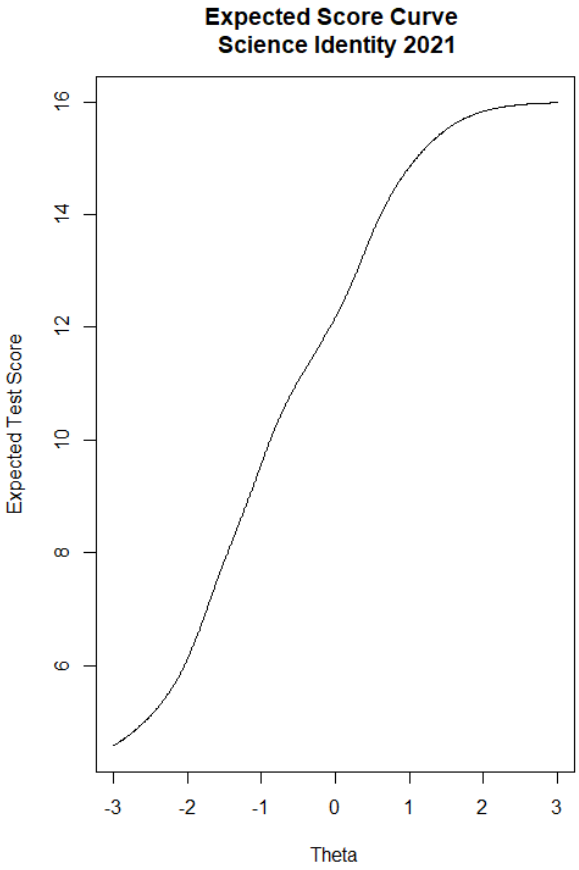
Graph 6D

Science Identity



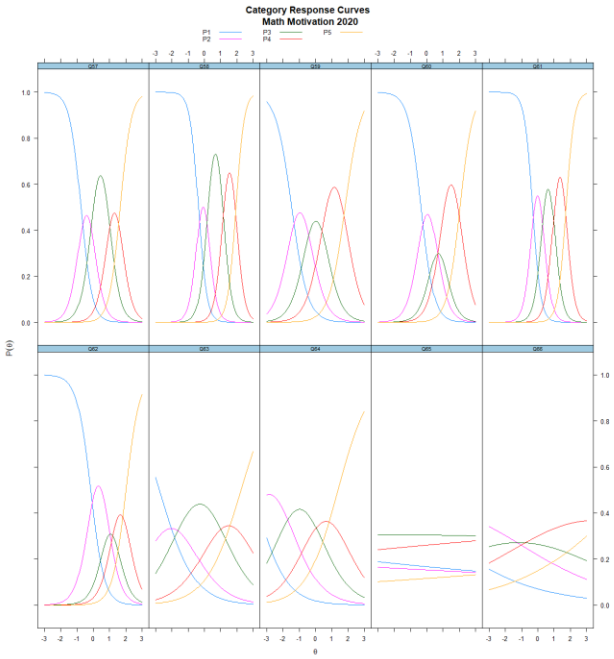


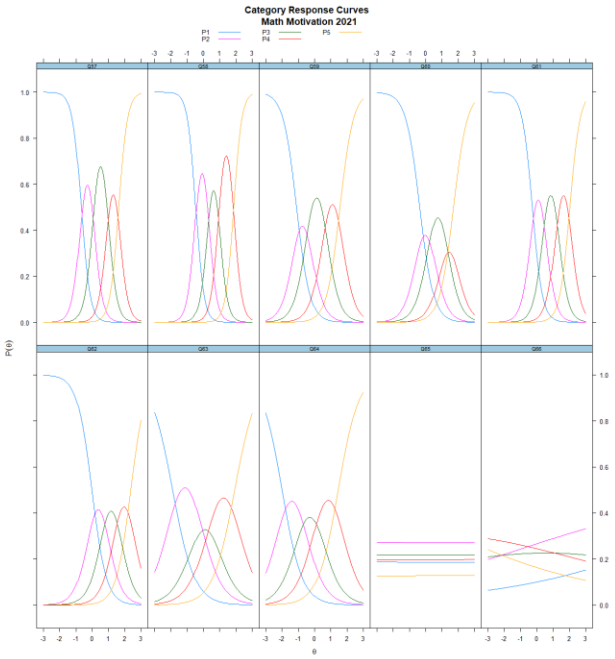

Expected Score Curve
Science Identity 2020
Expected Test Score
6
8
10
12
14
16
-3
-2
-1
0
1
2
3
Theta

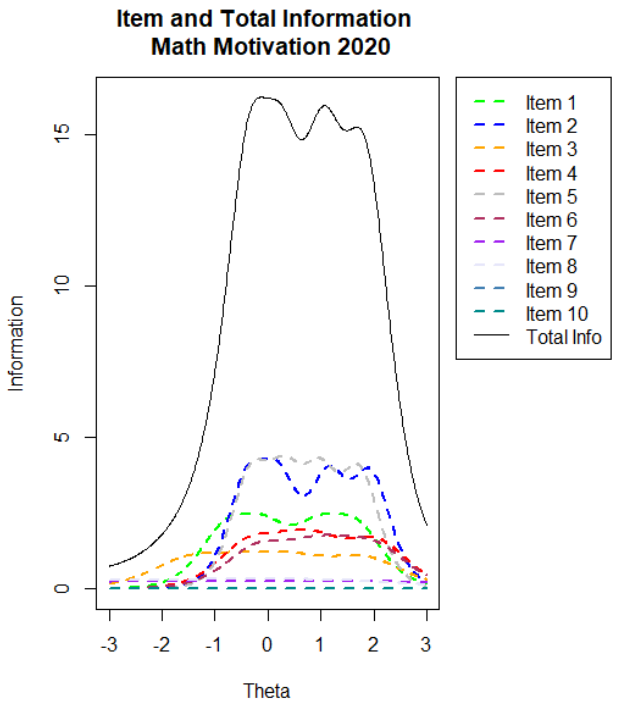

Expected Score Curve
Science Identity 2021
Expected Test Score
6
8
10
12
14
16
-3
-2
-1
0
1
2
3
Theta

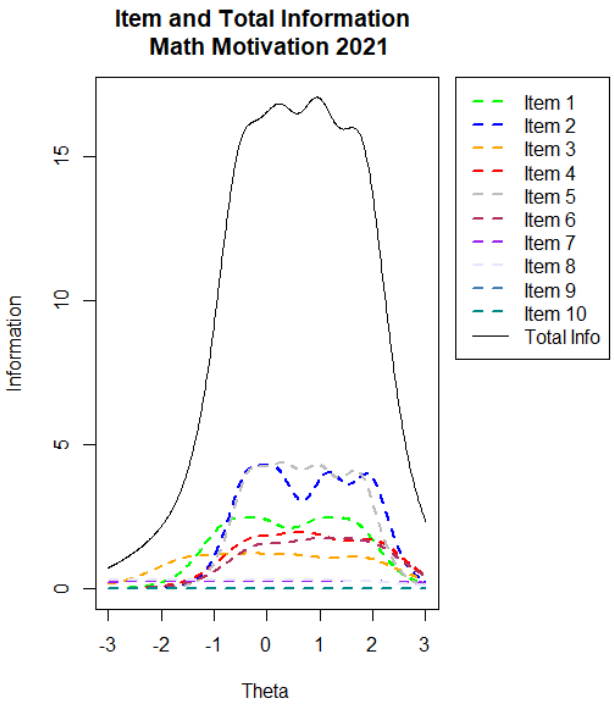
Graph 7D

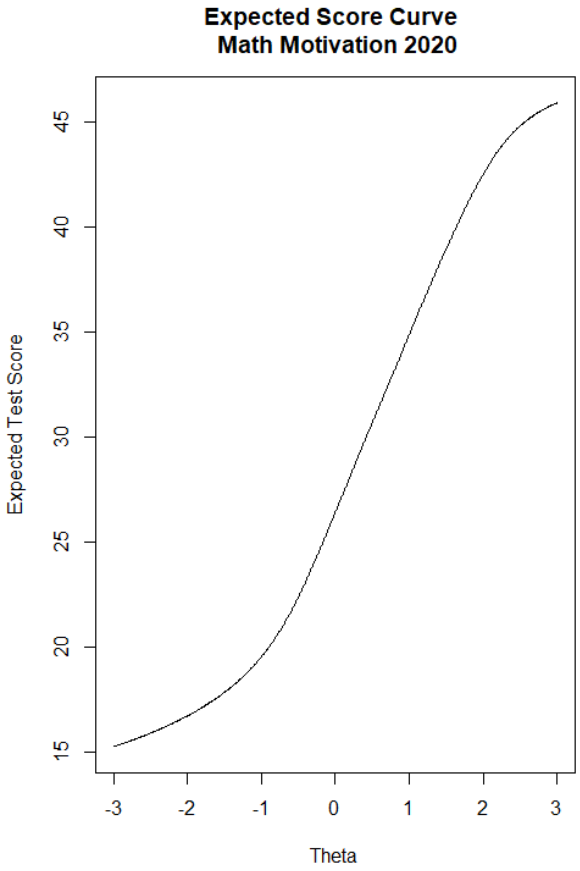
Math Motivation

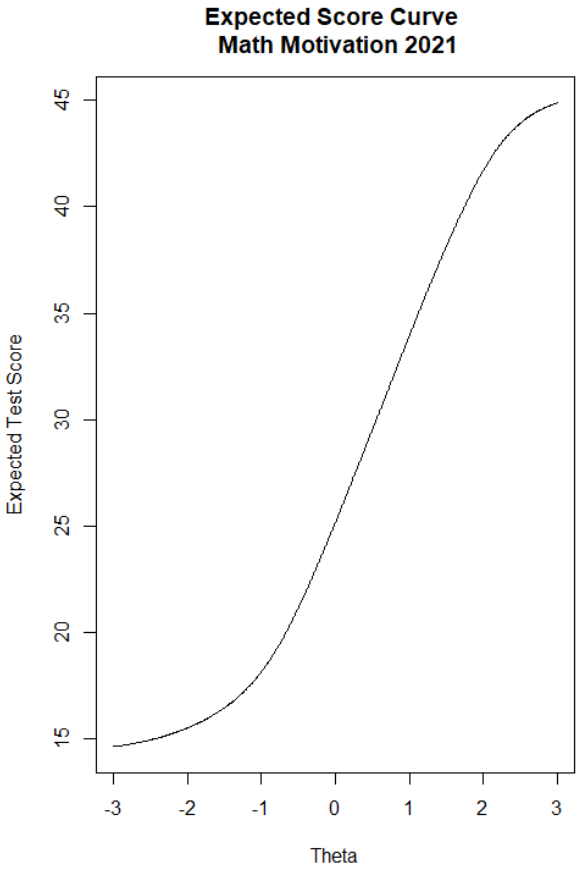









Expected Score Curve
Math Motivation 2020
Expected Test Score
15
20
25
30
35
40
45
-3
-2
-1
0
1
2
3
Theta


Expected Score Curve
Math Motivation 2021
Expected Test Score
15
20
25
30
35
40
45
-3
-2
-1
0
1
2
3
Theta

Appendix E

R-Code for Analysis

```
# Load Libraries and Read Data ----

library(data.table)
library(tibble)
library(tidyr)
library(ggplot2)
library(ltm)
library(dplyr)
library(reshape2)
library(mirt)
library(psych)
library(lmtest)
library(gridExtra)

BioData = read.csv("Project_Data.csv", header = TRUE)

# Data Cleaning ----

## Correct Data Types and Names ----

BioData$Year = as.factor(BioData$Year)
BioData$Q75 = as.factor(BioData$Q75)

names(BioData)[names(BioData) == "Q75"] <- "Gender"

variables = as.data.frame(colnames(BioData))

# Chronbach Alpha Full Data
```

```
alpha_dataset = BioData %>%
  select(-c(1:3))

cronbach.alpha(drop_na(alpha_dataset))


## Create Construct datasets and total score column----

Student_Agency_2020 = BioData %>%
  filter(Year == 2020) %>%
  select(Identifier, Year, Gender, Q19_5, Q103, Q102, Q101, Q104) %>%
  mutate(Total_Score = select(., Q19_5:Q104) %>% rowSums(na.rm = TRUE))



Student_Agency_2021 = BioData %>%
  filter(Year == 2021) %>%
  select(Identifier, Year, Gender, Q19_5, Q103, Q102, Q101, Q104) %>%
  mutate(Total_Score = select(., Q19_5:Q104) %>% rowSums(na.rm = TRUE))

Academic_Stress_2020 = BioData %>%
  filter(Year == 2020) %>%
  select(Identifier, Year, Gender, Q22,Q23,Q24,Q25,Q26,Q27 )%>%
  mutate(Total_Score = select(., Q22:Q27) %>% rowSums(na.rm = TRUE))

Academic_Stress_2021 = BioData %>%
  filter(Year == 2021) %>%
  select(Identifier, Year, Gender, Q22,Q23,Q24,Q25,Q26,Q27) %>%
  mutate(Total_Score = select(., Q22:Q27) %>% rowSums(na.rm = TRUE))

Help_Seeking_2020 = BioData %>%
  filter(Year == 2020) %>%
  select(Identifier, Year, Gender, Q29,Q30,Q31,Q32,   Q33, Q34, Q35, Q36) %>%
```

```
  mutate(Total_Score = select(., Q29:Q36) %>% rowSums(na.rm = TRUE))


Help_Seeking_2021 = BioData %>%
  filter(Year == 2021) %>%
  select(Identifier, Year, Gender, Q29,Q30,Q31,Q32,   Q33,  Q34,  Q35, Q36)
%>%
  mutate(Total_Score = select(., Q29:Q36) %>% rowSums(na.rm = TRUE))


Self_Efficacy_2020 = BioData %>%
  filter(Year == 2020) %>%
  select(Identifier, Year, Gender, Q39,Q40,Q41,Q42,Q43) %>%
  mutate(Total_Score = select(., Q39:Q43) %>% rowSums(na.rm = TRUE))


Self_Efficacy_2021 = BioData %>%
  filter(Year == 2021) %>%
  select(Identifier, Year, Gender, Q39,Q40,Q41,Q42,Q43) %>%
  mutate(Total_Score = select(., Q39:Q43) %>% rowSums(na.rm = TRUE))


Math_Anxiety_2020= BioData %>%
  filter(Year == 2020) %>%
  select(Identifier, Year, Gender, Q118,Q118_1,Q119,Q120,Q121,Q122,Q123,Q124)
%>%
  mutate(Total_Score = select(., Q118:Q124) %>% rowSums(na.rm = TRUE))


Math_Anxiety_2021= BioData %>%
  filter(Year == 2021) %>%
  select(Identifier, Year, Gender, Q118,Q118_1,Q119,Q120,Q121,Q122,Q123,Q124)
%>%
  mutate(Total_Score = select(., Q118:Q124) %>% rowSums(na.rm = TRUE))


Science_Identity_2020 = BioData %>%
  filter(Year == 2020) %>%
  select(Identifier, Year, Gender, Q52,Q53,Q54,Q55) %>%
  mutate(Total_Score = select(., Q52:Q55) %>% rowSums(na.rm = TRUE))
```

```
Science_Identity_2021 = BioData %>%
  filter(Year == 2021) %>%
  select(Identifier, Year, Gender, Q52,Q53,Q54,Q55) %>%
  mutate(Total_Score = select(., Q52:Q55) %>% rowSums(na.rm = TRUE))


Math_Motivation_2020 = BioData %>%
  filter(Year == 2020) %>%
  select(Identifier, Year, Gender, Q57,Q58,Q59,Q60,Q61,Q62,Q63,Q64,Q65,Q66)
%>%
  mutate(Total_Score = select(., Q57:Q66) %>% rowSums(na.rm = TRUE))


Math_Motivation_2021 = BioData %>%
  filter(Year == 2021) %>%
  select(Identifier, Year, Gender, Q57,Q58,Q59,Q60,Q61,Q62,Q63,Q64,Q65,Q66)
%>%
  mutate(Total_Score = select(., Q57:Q66) %>% rowSums(na.rm = TRUE))



# Descriptives of responses ----


Bio_total = BioData %>%
  mutate(Total_Score = select(., Q19_5:Q66) %>% rowSums(na.rm = TRUE))


cor_BioData <- Bio_total %>%
  select(., Q19_5:Total_Score) %>%
  as.matrix %>%
  cor(use="complete.obs") %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)


## Item-Total Score Correlations ----


cor_Student_Agency_2020 <- Student_Agency_2020 %>%
```

```
  select(., Q19_5:Total_Score) %>%
  as.matrix %>%
  cor %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

cor_Student_Agency_2021 <- Student_Agency_2021 %>%
  select(., Q19_5:Total_Score) %>%
  as.matrix %>%
  cor(use="complete.obs") %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

cor_Academic_Stress_2020 <- Academic_Stress_2020 %>%
  select(., Q22:Total_Score) %>%
  as.matrix %>%
  cor(use="complete.obs") %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

cor_Academic_Stress_2021 <- Academic_Stress_2021 %>%
  select(., Q22:Total_Score) %>%
  as.matrix %>%
  cor(use="complete.obs") %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

cor_Help_Seeking_2020 <- Help_Seeking_2020 %>%
  select(., Q29:Total_Score) %>%
```

```
  as.matrix %>%
  cor(use="complete.obs") %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

cor_Help_Seeking_2021 <- Help_Seeking_2021 %>%
  select(., Q29:Total_Score) %>%
  as.matrix %>%
  cor(use="complete.obs") %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

cor_Self_Efficacy_2020 <- Self_Efficacy_2020 %>%
  select(., Q39:Total_Score) %>%
  as.matrix %>%
  cor(use="complete.obs") %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

cor_Self_Efficacy_2021 <- Self_Efficacy_2021 %>%
  select(., Q39:Total_Score) %>%
  as.matrix %>%
  cor(use="complete.obs") %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

cor_Math_Anxiety_2020 <- Math_Anxiety_2020 %>%
  select(., Q118:Total_Score) %>%
  as.matrix %>%
```

```
  cor(use="complete.obs") %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

cor_Math_Anxiety_2021 <- Math_Anxiety_2021 %>%
  select(., Q118:Total_Score) %>%
  as.matrix %>%
  cor(use="complete.obs") %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

cor_Science_Identity_2020 <- Science_Identity_2020 %>%
  select(., Q52:Total_Score) %>%
  as.matrix %>%
  cor(use="complete.obs") %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

cor_Science_Identity_2021 <- Science_Identity_2021 %>%
  select(., Q52:Total_Score) %>%
  as.matrix %>%
  cor(use="complete.obs") %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

cor_Math_Motivation_2020 <- Math_Motivation_2020 %>%
  select(., Q57:Total_Score) %>%
  as.matrix %>%
  cor(use="complete.obs") %>%
```

```
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

cor_Math_Motivation_2021 <- Math_Motivation_2021 %>%
  select(., Q57:Total_Score) %>%
  as.matrix %>%
  cor(use="complete.obs") %>%
  as.data.frame %>%
  rownames_to_column(var = 'var1') %>%
  gather(var2, value, -var1)

# Model Fit ----

## 2020 Models ----

### Student_Agency ----

M0_Student_Agency_2020 = BioData %>%
  filter(Year == 2020) %>%
  select(Q19_5, Q103, Q102, Q101, Q104)

GRM_SA_2020 <- mirt(data  = M0_Student_Agency_2020,
            model = 1, #unidimentional Factor
            itemtype="graded",
            SE=TRUE)

extract.mirt(GRM_SA_2020, 'BIC')

GPCM_SA_2020 <- mirt(data  = M0_Student_Agency_2020,
             model = 1,
             itemtype="gpcm",
             SE=TRUE)
```

```
extract.mirt(GPCM_SA_2020, 'BIC')

### Academic Stress ----

M0_Academic_Stress_2020 = BioData %>%
  filter(Year == 2020) %>%
  select(Q22,Q23,Q24,Q25,Q26,Q27 )

GRM_AS_2020 <- mirt(data  = M0_Academic_Stress_2020,
                    model = 1, #unidimentional Factor
                    itemtype="graded",
                    SE=TRUE)

extract.mirt(GRM_AS_2020, 'BIC')

GPCM_AS_2020 <- mirt(data  = M0_Academic_Stress_2020,
                     model = 1,
                     itemtype="gpcm",
                     SE=TRUE)

extract.mirt(GPCM_AS_2020, 'BIC')

### Help Seeking ----

M0_Help_Seeking_2020 = BioData %>%
  filter(Year == 2020) %>%
  select(Q29,Q30,Q31,Q32,     Q33, Q34, Q35, Q36)

GRM_HS_2020 <- mirt(data  = M0_Help_Seeking_2020,
                    model = 1, #unidimentional Factor
                    itemtype="graded",
                    SE=TRUE)
```

```
extract.mirt(GRM_HS_2020, 'BIC')

GPCM_HS_2020 <- mirt(data  = M0_Help_Seeking_2020,
                     model = 1,
                     itemtype="gpcm",
                     SE=TRUE)

extract.mirt(GPCM_HS_2020, 'BIC')

### Self-Efficacy ----

M0_Self_Efficacy_2020 = BioData %>%
  filter(Year == 2020) %>%
  select(Q39,Q40,Q41,Q42,Q43)

GRM_SE_2020 <- mirt(data  = M0_Self_Efficacy_2020,
                    model = 1, #unidimentional Factor
                    itemtype="graded",
                    SE=TRUE)

extract.mirt(GRM_SE_2020, 'BIC')

GPCM_SE_2020 <- mirt(data  = M0_Self_Efficacy_2020,
                     model = 1,
                     itemtype="gpcm",
                     SE=TRUE)

extract.mirt(GPCM_SE_2020, 'BIC')

### Math Anxiety ----

M0_Math_Anxiety_2020= BioData %>%
```

```
  filter(Year == 2020) %>%
  select(Q118,Q118_1,Q119,Q120,Q121,Q122,Q123,Q124)

GRM_MA_2020 <- mirt(data  = M0_Math_Anxiety_2020,
                    model = 1, #unidimentional Factor
                    itemtype="graded",
                    SE=TRUE)

extract.mirt(GRM_MA_2020, 'BIC')

GPCM_MA_2020 <- mirt(data  = M0_Math_Anxiety_2020,
                     model = 1,
                     itemtype="gpcm",
                     SE=TRUE)

extract.mirt(GPCM_MA_2020, 'BIC')

### Science Identity ----

M0_Science_Identity_2020 = BioData %>%
  filter(Year == 2020) %>%
  select(Q52,Q53,Q54,Q55)

GRM_SI_2020 <- mirt(data  = M0_Science_Identity_2020,
                    model = 1, #unidimentional Factor
                    itemtype="graded",
                    SE=TRUE)

extract.mirt(GRM_SI_2020, 'BIC')

GPCM_SI_2020 <- mirt(data  = M0_Science_Identity_2020,
                     model = 1,
                     itemtype="gpcm",
```

```
                      SE=TRUE)

extract.mirt(GPCM_SI_2020, 'BIC')

### Math Motivation ----

M0_Math_Motivation_2020 = BioData %>%
  filter(Year == 2020) %>%
  select(Q57,Q58,Q59,Q60,Q61,Q62,Q63,Q64,Q65,Q66)

GRM_MM_2020 <- mirt(data  = M0_Math_Motivation_2020,
                    model = 1, #unidimentional Factor
                    itemtype="graded",
                    SE=TRUE)

extract.mirt(GRM_MM_2020, 'BIC')

GPCM_MM_2020 <- mirt(data  = M0_Math_Motivation_2020,
                     model = 1,
                     itemtype="gpcm",
                     SE=TRUE)

extract.mirt(GPCM_MM_2020, 'BIC')

## 2021 Models ----

### Student_Agency ----

M0_Student_Agency_2021 = BioData %>%
  filter(Year == 2021) %>%
  select(Q19_5, Q103, Q102, Q101, Q104)

GRM_SA_2021 <- mirt(data  = M0_Student_Agency_2021,
```

```
                    model = 1, #unidimentional Factor
                    itemtype="graded",
                    SE=TRUE)

extract.mirt(GRM_SA_2021, 'BIC')

GPCM_SA_2021 <- mirt(data  = M0_Student_Agency_2021,
                     model = 1,
                     itemtype="gpcm",
                     SE=TRUE)

extract.mirt(GPCM_SA_2021, 'BIC')

### Academic Stress ----

M0_Academic_Stress_2021 = BioData %>%
  filter(Year == 2021) %>%
  select(Q22,Q23,Q24,Q25,Q26,Q27 )

GRM_AS_2021 <- mirt(data  = M0_Academic_Stress_2021,
                    model = 1, #unidimentional Factor
                    itemtype="graded",
                    SE=TRUE)

extract.mirt(GRM_AS_2021, 'BIC')

GPCM_AS_2021 <- mirt(data  = M0_Academic_Stress_2021,
                     model = 1,
                     itemtype="gpcm",
                     SE=TRUE)

extract.mirt(GPCM_AS_2021, 'BIC')
```

```
### Help Seeking ----

M0_Help_Seeking_2021 = BioData %>%
  filter(Year == 2021) %>%
  select(Q29,Q30,Q31,Q32,     Q33, Q34, Q35, Q36)

GRM_HS_2021 <- mirt(data  = M0_Help_Seeking_2021,
                    model = 1, #unidimentional Factor
                    itemtype="graded",
                    SE=TRUE)

extract.mirt(GRM_HS_2021, 'BIC')

GPCM_HS_2021 <- mirt(data  = M0_Help_Seeking_2021,
                     model = 1,
                     itemtype="gpcm",
                     SE=TRUE)

extract.mirt(GPCM_HS_2021, 'BIC')

### Self-Efficacy ----

M0_Self_Efficacy_2021 = BioData %>%
  filter(Year == 2021) %>%
  select(Q39,Q40,Q41,Q42,Q43)

GRM_SE_2021 <- mirt(data  = M0_Self_Efficacy_2021,
                    model = 1, #unidimentional Factor
                    itemtype="graded",
                    SE=TRUE)

extract.mirt(GRM_SE_2021, 'BIC')
```

```
GPCM_SE_2021 <- mirt(data  = M0_Self_Efficacy_2021,
                     model = 1,
                     itemtype="gpcm",
                     SE=TRUE)

extract.mirt(GPCM_SE_2021, 'BIC')

### Math Anxiety ----

M0_Math_Anxiety_2021= BioData %>%
  filter(Year == 2021) %>%
  select(Q118,Q118_1,Q119,Q120,Q121,Q122,Q123,Q124)

GRM_MA_2021 <- mirt(data  = M0_Math_Anxiety_2021,
                    model = 1, #unidimentional Factor
                    itemtype="graded",
                    SE=TRUE)

extract.mirt(GRM_MA_2021, 'BIC')

GPCM_MA_2021 <- mirt(data  = M0_Math_Anxiety_2021,
                     model = 1,
                     itemtype="gpcm",
                     SE=TRUE)

extract.mirt(GPCM_MA_2021, 'BIC')

### Science Identity ----

M0_Science_Identity_2021 = BioData %>%
  filter(Year == 2021) %>%
  select(Q52,Q53,Q54,Q55)
```

```
GRM_SI_2021 <- mirt(data  = M0_Science_Identity_2021,
                    model = 1, #unidimentional Factor
                    itemtype="graded",
                    SE=TRUE)

extract.mirt(GRM_SI_2021, 'BIC')

GPCM_SI_2021 <- mirt(data  = M0_Science_Identity_2021,
                     model = 1,
                     itemtype="gpcm",
                     SE=TRUE)

extract.mirt(GPCM_SI_2021, 'BIC')

### Math Motivation ----

M0_Math_Motivation_2021 = BioData %>%
  filter(Year == 2021) %>%
  select(Q57,Q58,Q59,Q60,Q61,Q62,Q63,Q64,Q65,Q66)

GRM_MM_2021 <- mirt(data  = M0_Math_Motivation_2021,
                    model = 1, #unidimentional Factor
                    itemtype="graded",
                    SE=TRUE)

extract.mirt(GRM_MM_2021, 'BIC')

GPCM_MM_2021 <- mirt(data  = M0_Math_Motivation_2021,
                     model = 1,
                     itemtype="gpcm",
                     SE=TRUE)

extract.mirt(GPCM_MM_2021, 'BIC')
```

```
# Item Fit 2020 S-X^2----

itemfit(GRM_SA_2020, 'S_X2' ,na.rm=TRUE)
itemfit(GRM_AS_2020 , 'S_X2',na.rm=TRUE)
itemfit(GRM_HS_2020 , 'S_X2',na.rm=TRUE)
itemfit(GRM_SE_2020 , 'S_X2',na.rm=TRUE)
itemfit(GRM_MA_2020 , 'S_X2',na.rm=TRUE)
itemfit(GRM_SI_2020 , 'S_X2',na.rm=TRUE)
itemfit(GRM_MM_2020 , 'S_X2',na.rm=TRUE)

# Item Fit 2021 S-X^2 ----

itemfit(GRM_SA_2021, 'S_X2' ,na.rm=TRUE)
itemfit(GRM_AS_2021 , 'S_X2',na.rm=TRUE)
itemfit(GRM_HS_2021 , 'S_X2',na.rm=TRUE)
itemfit(GRM_SE_2021 , 'S_X2',na.rm=TRUE)
itemfit(GRM_MA_2021 , 'S_X2',na.rm=TRUE)
itemfit(GRM_SI_2021 , 'S_X2',na.rm=TRUE)
itemfit(GRM_MM_2021 , 'S_X2',na.rm=TRUE)

# Category Response Curves ----

library(gridExtra)

# Student Agency
plot_1 = plot(GRM_SA_2020, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Student Agency 2020")
plot_2 = plot(GRM_SA_2021, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
```

```
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Student Agency 2021")

grid.arrange(plot_1, plot_2, ncol = 2)

# Academic Stress
plot_1 = plot(GRM_AS_2020, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Academic Stress 2020")

plot_2 = plot(GRM_AS_2021, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Academic Stress 2021")

grid.arrange(plot_1, plot_2, ncol = 2)

# Help Seeking
plot_1 = plot(GRM_HS_2020, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Help Seeking 2020")

plot_2 = plot(GRM_HS_2021, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Help Seeking 2021")
```

```
grid.arrange(plot_1, plot_2, ncol = 2)

# Self Efficacy

plot_1 = plot(GRM_SE_2020, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Self-Efficacy 2020")

plot_2 = plot(GRM_SE_2021, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Self-Efficacy 2021")

grid.arrange(plot_1, plot_2, ncol = 2)

# Math Anxiety

plot_1 = plot(GRM_MA_2020, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Math Anxiety 2020")

plot_2 = plot(GRM_MA_2021, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Math Anxiety 2021")
```

```
grid.arrange(plot_1, plot_2, ncol = 2)

# Science Identity
plot_1 = plot(GRM_SI_2020, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Science Identity 2020")

plot_2 = plot(GRM_SI_2021, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Science Identity 2021")

grid.arrange(plot_1, plot_2, ncol = 1)



# Math Motivation
plot_1 = plot(GRM_MM_2020, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Math Motivation 2020")

plot_2 = plot(GRM_MM_2021, type='trace', facet_items=T,
     as.table = TRUE, auto.key=list(points=F, lines=T, columns=4,
                                    space = 'top', cex = .8),
     theta_lim = c(-3, 3),
     main = "Category Response Curves \n Math Motivation 2021")

grid.arrange(plot_1, plot_2, ncol = 2)
```

```
# Expected test score ----
Theta = seq(-3,3,.01)

exp.score_GRM_SA_2020 <- expected.test(GRM_SA_2020,as.matrix(Theta))

exp.score_GRM_SA_2021 <- expected.test(GRM_SA_2021,as.matrix(Theta))


par(mfrow = c(1,2))
plot(Theta,exp.score_GRM_SA_2020,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Student Agency 2020")
plot(Theta,exp.score_GRM_SA_2021,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Student Agency 2021")

##

exp.score_GRM_AS_2020 <- expected.test(GRM_AS_2020,as.matrix(Theta))

exp.score_GRM_AS_2021 <- expected.test(GRM_AS_2021,as.matrix(Theta))


par(mfrow = c(1,2))
plot(Theta,exp.score_GRM_AS_2020,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Academic Stress 2020")
plot(Theta,exp.score_GRM_AS_2021,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Academic Stress 2021")
##

exp.score_GRM_HS_2020 <- expected.test(GRM_HS_2020,as.matrix(Theta))

exp.score_GRM_HS_2021 <- expected.test(GRM_HS_2021,as.matrix(Theta))
```

```
par(mfrow = c(1,2))
plot(Theta,exp.score_GRM_HS_2020,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Help Seeking 2020")
plot(Theta,exp.score_GRM_HS_2021,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Help Seeking 2021")
##

exp.score_GRM_SE_2020 <- expected.test(GRM_SE_2020,as.matrix(Theta))

exp.score_GRM_SE_2021 <- expected.test(GRM_SE_2021,as.matrix(Theta))


par(mfrow = c(1,2))
plot(Theta,exp.score_GRM_SE_2020,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Self-Efficacy 2020")
plot(Theta,exp.score_GRM_SE_2021,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Self-Efficacy 2021")
##

exp.score_GRM_MA_2020 <- expected.test(GRM_MA_2020,as.matrix(Theta))

exp.score_GRM_MA_2021 <- expected.test(GRM_MA_2021,as.matrix(Theta))


par(mfrow = c(1,2))
plot(Theta,exp.score_GRM_MA_2020,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Math Anxiety 2020")
plot(Theta,exp.score_GRM_MA_2021,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Math Anxiety 2021")
##
```

```
exp.score_GRM_SI_2020 <- expected.test(GRM_SI_2020,as.matrix(Theta))

exp.score_GRM_SI_2021 <- expected.test(GRM_SI_2021,as.matrix(Theta))


par(mfrow = c(1,2))
plot(Theta,exp.score_GRM_SI_2020,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Science Identity 2020")
plot(Theta,exp.score_GRM_SI_2021,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Science Identity 2021")
##

exp.score_GRM_MM_2020 <- expected.test(GRM_MM_2020,as.matrix(Theta))

exp.score_GRM_MM_2021 <- expected.test(GRM_MM_2021,as.matrix(Theta))


par(mfrow = c(1,2))
plot(Theta,exp.score_GRM_MM_2020,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Math Motivation 2020")
plot(Theta,exp.score_GRM_MM_2021,type="l",ylab="Expected Test Score",
     main = "Expected Score Curve \n Math Motivation 2021")

#Item Info and Total Info ----

# Student Agency

par(mfrow=c(1,2))

Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_SA_2020,Theta=Theta),type="l",
     ylab="Information",ylim=c(0,max(testinfo(GRM_SA_2020,Theta=Theta))))
```

```
extr.1 <- extract.item(GRM_SA_2020,1)
extr.2 <- extract.item(GRM_SA_2020,2)
extr.3 <- extract.item(GRM_SA_2020,3)
extr.4 <- extract.item(GRM_SA_2020,4)
extr.5 <- extract.item(GRM_SA_2020,5)

points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
       type="l",lty=2,col="green",lwd=2)

points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)

points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)

points(Theta,iteminfo(extr.5,Theta,total.info=TRUE),
       type="l",lty=2,col="gray",lwd=2)


legend("topright",c("Item 1","Item 2","Item 3","Item 4","Item 5", "Total
Info"),
       lty=c(2,2,2,2,2,1),
       col=c("green","blue","orange","red","gray", "black"),
       lwd=c(2,2,2,2,2,1))

title(main = "Item and Total Information Student Agency 2020")

Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_SA_2021,Theta=Theta),type="l",
     ylab="Information",ylim=c(0,max(testinfo(GRM_SA_2021,Theta=Theta))))
```

```
extr.1 <- extract.item(GRM_SA_2021,1)
extr.2 <- extract.item(GRM_SA_2021,2)
extr.3 <- extract.item(GRM_SA_2021,3)
extr.4 <- extract.item(GRM_SA_2021,4)
extr.5 <- extract.item(GRM_SA_2021,5)

points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
       type="l",lty=2,col="green",lwd=2)

points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)

points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)

points(Theta,iteminfo(extr.5,Theta,total.info=TRUE),
       type="l",lty=2,col="gray",lwd=2)



legend("topright",c("Item 1","Item 2","Item 3","Item 4","Item 5", "Total
Info"),
       lty=c(2,2,2,2,2,1),
       col=c("green","blue","orange","red","gray", "black"),
       lwd=c(2,2,2,2,2,1))

title(main = "Item and Total Information Student Agency 2021")

# Academic Stress

par(mar = c(5, 4, 4, 8),
    xpd = TRUE
```

```
    )

Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_AS_2020,Theta=Theta),type="l",
     ylab="Information",ylim=c(0,max(testinfo(GRM_AS_2020,Theta=Theta))))

extr.1 <- extract.item(GRM_AS_2020,1)
extr.2 <- extract.item(GRM_AS_2020,2)
extr.3 <- extract.item(GRM_AS_2020,3)
extr.4 <- extract.item(GRM_AS_2020,4)
extr.5 <- extract.item(GRM_AS_2020,5)
extr.6 <- extract.item(GRM_AS_2020,6)

points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
       type="l",lty=2,col="green",lwd=2)

points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)

points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)

points(Theta,iteminfo(extr.5,Theta,total.info=TRUE),
       type="l",lty=2,col="gray",lwd=2)

points(Theta,iteminfo(extr.6,Theta,total.info=TRUE),
       type="l",lty=2,col="maroon",lwd=2)

legend("topright",
       inset = c(- 0.5, 0),
```

```
       c("Item 1","Item 2","Item 3","Item 4","Item 5", "Item 6", "Total
Info"),
       lty=c(2,2,2,2,2,2,1),
       col=c("green","blue","orange","red","gray", "maroon", "black"),
       lwd=c(2,2,2,2,2,2,1))

title(main = "Item and Total Information \n Academic Stress 2020")

Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_AS_2021,Theta=Theta),type="l",
     ylab="Information",ylim=c(0,max(testinfo(GRM_AS_2021,Theta=Theta))))

extr.1 <- extract.item(GRM_AS_2021,1)
extr.2 <- extract.item(GRM_AS_2021,2)
extr.3 <- extract.item(GRM_AS_2021,3)
extr.4 <- extract.item(GRM_AS_2021,4)
extr.5 <- extract.item(GRM_AS_2021,5)
extr.6 <- extract.item(GRM_AS_2021,6)

points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
       type="l",lty=2,col="green",lwd=2)

points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)

points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)

points(Theta,iteminfo(extr.5,Theta,total.info=TRUE),
       type="l",lty=2,col="gray",lwd=2)
```

```
points(Theta,iteminfo(extr.6,Theta,total.info=TRUE),
       type="l",lty=2,col="maroon",lwd=2)


legend("topright",
       inset = c(- 0.5, 0),
       c("Item 1","Item 2","Item 3","Item 4","Item 5", "Item 6", "Total
Info"),
       lty=c(2,2,2,2,2,2,1),
       col=c("green","blue","orange","red","gray", "maroon", "black"),
       lwd=c(2,2,2,2,2,2,1))


title(main = "Item and Total Information \n Academic Stress 2021")


## Help Seeking


par(mar = c(5, 4, 4, 8),
    xpd = TRUE
)


Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_HS_2020,Theta=Theta),type="l",
     ylab="Information",ylim=c(0,max(testinfo(GRM_HS_2020,Theta=Theta))))


extr.1 <- extract.item(GRM_HS_2020,1)
extr.2 <- extract.item(GRM_HS_2020,2)
extr.3 <- extract.item(GRM_HS_2020,3)
extr.4 <- extract.item(GRM_HS_2020,4)
extr.5 <- extract.item(GRM_HS_2020,5)
extr.6 <- extract.item(GRM_HS_2020,6)
extr.7 <- extract.item(GRM_HS_2020,7)
extr.8 <- extract.item(GRM_HS_2020,8)


points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
       type="l",lty=2,col="green",lwd=2)
```

```
points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)

points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)

points(Theta,iteminfo(extr.5,Theta,total.info=TRUE),
       type="l",lty=2,col="gray",lwd=2)

points(Theta,iteminfo(extr.6,Theta,total.info=TRUE),
       type="l",lty=2,col="maroon",lwd=2)

points(Theta,iteminfo(extr.7,Theta,total.info=TRUE),
       type="l",lty=2,col="purple",lwd=2)

points(Theta,iteminfo(extr.8,Theta,total.info=TRUE),
       type="l",lty=2,col="lavender",lwd=2)

legend("topright",
       inset = c(- 0.5, 0),
       c("Item 1","Item 2","Item 3","Item 4","Item 5", "Item 6",
         "Item 7", "Item 8", "Total Info"),
       lty=c(2,2,2,2,2,2,2,2,1),
       col=c("green","blue","orange","red","gray", "maroon",
             "purple", "lavender", "black"),
       lwd=c(2,2,2,2,2,2,2,2,1))

title(main = "Item and Total Information \n Help Seeking 2020")
```

```
Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_HS_2021,Theta=Theta),type="l",
     ylab="Information",ylim=c(0,max(testinfo(GRM_HS_2021,Theta=Theta))))

extr.1 <- extract.item(GRM_HS_2021,1)
extr.2 <- extract.item(GRM_HS_2021,2)
extr.3 <- extract.item(GRM_HS_2021,3)
extr.4 <- extract.item(GRM_HS_2021,4)
extr.5 <- extract.item(GRM_HS_2021,5)
extr.6 <- extract.item(GRM_HS_2021,6)
extr.7 <- extract.item(GRM_HS_2021,7)
extr.8 <- extract.item(GRM_HS_2021,8)

points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
       type="l",lty=2,col="green",lwd=2)

points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)

points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)

points(Theta,iteminfo(extr.5,Theta,total.info=TRUE),
       type="l",lty=2,col="gray",lwd=2)

points(Theta,iteminfo(extr.6,Theta,total.info=TRUE),
       type="l",lty=2,col="maroon",lwd=2)

points(Theta,iteminfo(extr.7,Theta,total.info=TRUE),
       type="l",lty=2,col="purple",lwd=2)
```

```
points(Theta,iteminfo(extr.8,Theta,total.info=TRUE),
       type="l",lty=2,col="lavender",lwd=2)

legend("topright",
       inset = c(- 0.5, 0),
       c("Item 1","Item 2","Item 3","Item 4","Item 5", "Item 6",
         "Item 7", "Item 8", "Total Info"),
       lty=c(2,2,2,2,2,2,2,2,1),
       col=c("green","blue","orange","red","gray", "maroon",
             "purple", "lavender", "black"),
       lwd=c(2,2,2,2,2,2,2,2,1))

title(main = "Item and Total Information \n Help Seeking 2021")

## Self Efficacy

par(mar = c(5, 4, 4, 8),
    xpd = TRUE
)

Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_SE_2020,Theta=Theta),type="l",
     ylab="Information",ylim=c(0,max(testinfo(GRM_SE_2020,Theta=Theta))))

extr.1 <- extract.item(GRM_SE_2020,1)
extr.2 <- extract.item(GRM_SE_2020,2)
extr.3 <- extract.item(GRM_SE_2020,3)
extr.4 <- extract.item(GRM_SE_2020,4)
extr.5 <- extract.item(GRM_SE_2020,5)


points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
```

```
       type="l",lty=2,col="green",lwd=2)

points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)

points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)

points(Theta,iteminfo(extr.5,Theta,total.info=TRUE),
       type="l",lty=2,col="gray",lwd=2)

legend("topright",
       inset = c(- 0.5, 0),
       c("Item 1","Item 2","Item 3","Item 4","Item 5", "Total Info"),
       lty=c(2,2,2,2,2,1),
       col=c("green","blue","orange","red","gray","black"),
       lwd=c(2,2,2,2,2,1))

title(main = "Item and Total Information \n Self Efficacy 2020")

Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_SE_2021,Theta=Theta),type="l",
     ylab="Information",ylim=c(0,max(testinfo(GRM_SE_2021,Theta=Theta))))

extr.1 <- extract.item(GRM_SE_2021,1)
extr.2 <- extract.item(GRM_SE_2021,2)
extr.3 <- extract.item(GRM_SE_2021,3)
extr.4 <- extract.item(GRM_SE_2021,4)
extr.5 <- extract.item(GRM_SE_2021,5)
```

```
points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
       type="l",lty=2,col="green",lwd=2)

points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)

points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)

points(Theta,iteminfo(extr.5,Theta,total.info=TRUE),
       type="l",lty=2,col="gray",lwd=2)

legend("topright",
       inset = c(- 0.5, 0),
       c("Item 1","Item 2","Item 3","Item 4","Item 5", "Total Info"),
       lty=c(2,2,2,2,2,1),
       col=c("green","blue","orange","red","gray","black"),
       lwd=c(2,2,2,2,2,1))

title(main = "Item and Total Information \n Self Efficacy 2021")

## Math Anxiety

par(mar = c(5, 4, 4, 8),
    xpd = TRUE
)

Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_MA_2020,Theta=Theta),type="l",
     ylab="Information",ylim=c(0,max(testinfo(GRM_MA_2020,Theta=Theta))))
```

```
extr.1 <- extract.item(GRM_MA_2020,1)
extr.2 <- extract.item(GRM_MA_2020,2)
extr.3 <- extract.item(GRM_MA_2020,3)
extr.4 <- extract.item(GRM_MA_2020,4)
extr.5 <- extract.item(GRM_MA_2020,5)
extr.6 <- extract.item(GRM_MA_2020,6)
extr.7 <- extract.item(GRM_MA_2020,7)
extr.8 <- extract.item(GRM_MA_2020,8)

points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
       type="l",lty=2,col="green",lwd=2)

points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)

points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)

points(Theta,iteminfo(extr.5,Theta,total.info=TRUE),
       type="l",lty=2,col="gray",lwd=2)

points(Theta,iteminfo(extr.6,Theta,total.info=TRUE),
       type="l",lty=2,col="maroon",lwd=2)

points(Theta,iteminfo(extr.7,Theta,total.info=TRUE),
       type="l",lty=2,col="purple",lwd=2)

points(Theta,iteminfo(extr.8,Theta,total.info=TRUE),
       type="l",lty=2,col="lavender",lwd=2)
```

```
legend("topright",
       inset = c(- 0.5, 0),
       c("Item 1","Item 2","Item 3","Item 4","Item 5", "Item 6",
         "Item 7", "Item 8", "Total Info"),
       lty=c(2,2,2,2,2,2,2,2,1),
       col=c("green","blue","orange","red","gray", "maroon",
             "purple", "lavender", "black"),
       lwd=c(2,2,2,2,2,2,2,2,1))

title(main = "Item and Total Information \n Math Anxiety 2020")

Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_MA_2021,Theta=Theta),type="l",
     ylab="Information",ylim=c(0,max(testinfo(GRM_MA_2021,Theta=Theta))))

extr.1 <- extract.item(GRM_MA_2021,1)
extr.2 <- extract.item(GRM_MA_2021,2)
extr.3 <- extract.item(GRM_MA_2021,3)
extr.4 <- extract.item(GRM_MA_2021,4)
extr.5 <- extract.item(GRM_MA_2021,5)
extr.6 <- extract.item(GRM_MA_2021,6)
extr.7 <- extract.item(GRM_MA_2021,7)
extr.8 <- extract.item(GRM_MA_2021,8)

points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
       type="l",lty=2,col="green",lwd=2)

points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)
```

```
points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)

points(Theta,iteminfo(extr.5,Theta,total.info=TRUE),
       type="l",lty=2,col="gray",lwd=2)

points(Theta,iteminfo(extr.6,Theta,total.info=TRUE),
       type="l",lty=2,col="maroon",lwd=2)

points(Theta,iteminfo(extr.7,Theta,total.info=TRUE),
       type="l",lty=2,col="purple",lwd=2)

points(Theta,iteminfo(extr.8,Theta,total.info=TRUE),
       type="l",lty=2,col="lavender",lwd=2)

legend("topright",
       inset = c(- 0.5, 0),
       c("Item 1","Item 2","Item 3","Item 4","Item 5", "Item 6",
         "Item 7", "Item 8", "Total Info"),
       lty=c(2,2,2,2,2,2,2,2,1),
       col=c("green","blue","orange","red","gray", "maroon",
             "purple", "lavender", "black"),
       lwd=c(2,2,2,2,2,2,2,2,1))

title(main = "Item and Total Information \n Math Anxiety 2021")

## Science Identity

par(mar = c(5, 4, 4, 8),
    xpd = TRUE
)
```

```
Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_SI_2020,Theta=Theta),type="l",
     ylab="Information",ylim=c(0,max(testinfo(GRM_SI_2020,Theta=Theta))))

extr.1 <- extract.item(GRM_SI_2020,1)
extr.2 <- extract.item(GRM_SI_2020,2)
extr.3 <- extract.item(GRM_SI_2020,3)
extr.4 <- extract.item(GRM_SI_2020,4)


points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
       type="l",lty=2,col="green",lwd=2)

points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)

points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)

legend("topright",
       inset = c(- 0.5, 0),
       c("Item 1","Item 2","Item 3","Item 4","Total Info"),
       lty=c(2,2,2,2,1),
       col=c("green","blue","orange","red","black"),
       lwd=c(2,2,2,2,1))

title(main = "Item and Total Information \n Science Identity 2020")

Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_SI_2021,Theta=Theta),type="l",
```

```
     ylab="Information",ylim=c(0,max(testinfo(GRM_SI_2021,Theta=Theta))))

extr.1 <- extract.item(GRM_SI_2021,1)
extr.2 <- extract.item(GRM_SI_2021,2)
extr.3 <- extract.item(GRM_SI_2021,3)
extr.4 <- extract.item(GRM_SI_2021,4)

points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
       type="l",lty=2,col="green",lwd=2)

points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)

points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)



legend("topright",
       inset = c(- 0.5, 0),
       c("Item 1","Item 2","Item 3","Item 4", "Total Info"),
       lty=c(2,2,2,2,1),
       col=c("green","blue","orange","red", "black"),
       lwd=c(2,2,2,2,1))

title(main = "Item and Total Information \n Science Identity 2021")

## Math Motivation

par(mar = c(5, 4, 4, 8),
    xpd = TRUE
```

```
)

Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_MM_2020,Theta=Theta),type="l",
     ylab="Information",ylim=c(0,max(testinfo(GRM_MM_2020,Theta=Theta))))

extr.1 <- extract.item(GRM_MM_2020,1)
extr.2 <- extract.item(GRM_MM_2020,2)
extr.3 <- extract.item(GRM_MM_2020,3)
extr.4 <- extract.item(GRM_MM_2020,4)
extr.5 <- extract.item(GRM_MM_2020,5)
extr.6 <- extract.item(GRM_MM_2020,6)
extr.7 <- extract.item(GRM_MM_2020,7)
extr.8 <- extract.item(GRM_MM_2020,8)
extr.9 <- extract.item(GRM_MM_2020,9)
extr.10 <- extract.item(GRM_MM_2020,10)

points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
       type="l",lty=2,col="green",lwd=2)

points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)

points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)

points(Theta,iteminfo(extr.5,Theta,total.info=TRUE),
       type="l",lty=2,col="gray",lwd=2)

points(Theta,iteminfo(extr.6,Theta,total.info=TRUE),
```

```
       type="l",lty=2,col="maroon",lwd=2)

points(Theta,iteminfo(extr.7,Theta,total.info=TRUE),
       type="l",lty=2,col="purple",lwd=2)

points(Theta,iteminfo(extr.8,Theta,total.info=TRUE),
       type="l",lty=2,col="lavender",lwd=2)

points(Theta,iteminfo(extr.9,Theta,total.info=TRUE),
       type="l",lty=2,col="steelblue",lwd=2)

points(Theta,iteminfo(extr.10,Theta,total.info=TRUE),
       type="l",lty=2,col="darkcyan",lwd=2)

legend("topright",
       inset = c(- 0.5, 0),
       c("Item 1","Item 2","Item 3","Item 4","Item 5", "Item 6",
         "Item 7", "Item 8", "Item 9", "Item 10", "Total Info"),
       lty=c(2,2,2,2,2,2,2,2,2,2,1),
       col=c("green","blue","orange","red","gray", "maroon",
             "purple", "lavender", "steelblue", "darkcyan", "black"),
       lwd=c(2,2,2,2,2,2,2,2,2,2,1))

title(main = "Item and Total Information \n Math Motivation 2020")

Theta = seq(-3,3,.01)
plot(Theta,testinfo(GRM_MM_2021,Theta=Theta),type="l",
     ylab="Information",ylim=c(0,max(testinfo(GRM_MM_2021,Theta=Theta))))

extr.1 <- extract.item(GRM_MM_2020,1)
extr.2 <- extract.item(GRM_MM_2020,2)
extr.3 <- extract.item(GRM_MM_2020,3)
extr.4 <- extract.item(GRM_MM_2020,4)
```

```
extr.5 <- extract.item(GRM_MM_2020,5)
extr.6 <- extract.item(GRM_MM_2020,6)
extr.7 <- extract.item(GRM_MM_2020,7)
extr.8 <- extract.item(GRM_MM_2020,8)
extr.9 <- extract.item(GRM_MM_2020,9)
extr.10 <- extract.item(GRM_MM_2020,10)

points(Theta,iteminfo(extr.1,Theta,total.info=TRUE),
       type="l",lty=2,col="green",lwd=2)

points(Theta,iteminfo(extr.2,Theta,total.info=TRUE),
       type="l",lty=2,col="blue",lwd=2)

points(Theta,iteminfo(extr.3,Theta,total.info=TRUE),
       type="l",lty=2,col="orange",lwd=2)

points(Theta,iteminfo(extr.4,Theta,total.info=TRUE),
       type="l",lty=2,col="red",lwd=2)

points(Theta,iteminfo(extr.5,Theta,total.info=TRUE),
       type="l",lty=2,col="gray",lwd=2)

points(Theta,iteminfo(extr.6,Theta,total.info=TRUE),
       type="l",lty=2,col="maroon",lwd=2)

points(Theta,iteminfo(extr.7,Theta,total.info=TRUE),
       type="l",lty=2,col="purple",lwd=2)

points(Theta,iteminfo(extr.8,Theta,total.info=TRUE),
       type="l",lty=2,col="lavender",lwd=2)

points(Theta,iteminfo(extr.9,Theta,total.info=TRUE),
       type="l",lty=2,col="steelblue",lwd=2)
```

```
points(Theta,iteminfo(extr.10,Theta,total.info=TRUE),
       type="l",lty=2,col="darkcyan",lwd=2)

legend("topright",
       inset = c(- 0.5, 0),
       c("Item 1","Item 2","Item 3","Item 4","Item 5", "Item 6",
         "Item 7", "Item 8", "Item 9", "Item 10", "Total Info"),
       lty=c(2,2,2,2,2,2,2,2,2,2,1),
       col=c("green","blue","orange","red","gray", "maroon",
             "purple", "lavender", "steelblue", "darkcyan", "black"),
       lwd=c(2,2,2,2,2,2,2,2,2,2,1))

title(main = "Item and Total Information \n Math Motivation 2021")




# EAP Parameter Estimation ----

theta_2020 <- as.data.frame(Student_Agency_2020[,c(1)])
names(theta_2020)[names(theta_2020) ==
                    "Student_Agency_2020[, c(1)]"] <- "Identifier"

theta_2020$SA_hat <- round(fscores(GRM_SA_2020,method="EAP"),2)
theta_2020$AS_hat <- round(fscores(GRM_AS_2020,method="EAP"),2)
theta_2020$HS_hat <- round(fscores(GRM_HS_2020,method="EAP"),2)
theta_2020$SE_hat <- round(fscores(GRM_SE_2020,method="EAP"),2)
theta_2020$MA_hat <- round(fscores(GRM_MA_2020,method="EAP"),2)
theta_2020$SI_hat <- round(fscores(GRM_SI_2020,method="EAP"),2)
theta_2020$MM_hat <- round(fscores(GRM_MM_2020,method="EAP"),2)
```

```
colMeans(theta_2020)
apply(theta_2020, 2, sd)

theta_2021 <- as.data.frame(Student_Agency_2021[,c(1)])
names(theta_2021)[names(theta_2021) ==
                    "Student_Agency_2021[, c(1)]"] <- "Identifier"

theta_2021$SA_hat <- round(fscores(GRM_SA_2021,method="EAP"),2)
theta_2021$AS_hat <- round(fscores(GRM_AS_2021,method="EAP"),2)
theta_2021$HS_hat <- round(fscores(GRM_HS_2021,method="EAP"),2)
theta_2021$SE_hat <- round(fscores(GRM_SE_2021,method="EAP"),2)
theta_2021$MA_hat <- round(fscores(GRM_MA_2021,method="EAP"),2)
theta_2021$SI_hat <- round(fscores(GRM_SI_2021,method="EAP"),2)
theta_2021$MM_hat <- round(fscores(GRM_MM_2021,method="EAP"),2)

colMeans(theta_2021, na.rm = TRUE)
apply(theta_2021, 2, sd, na.rm = TRUE)

# Merge latent trait estimates back into dataframes

BioData_2020 = BioData %>%
  filter(Year == 2020)

BioData_2021 = BioData %>%
  filter(Year == 2021)

BioData_2020_Estimate <- merge(BioData_2020, theta_2020, by = "Identifier")
BioData_2021_Estimate <- merge(BioData_2021, theta_2021, by = "Identifier")

# Filter by Gender and get Means 2020
M_2020 = BioData_2020_Estimate %>%
  filter(Gender == "Male") %>%
  select(SA_hat, AS_hat, HS_hat, SE_hat, MA_hat, SI_hat, MM_hat)
```

```
F_2020 = BioData_2020_Estimate %>%
  filter(Gender == "Female") %>%
  select(SA_hat, AS_hat, HS_hat, SE_hat, MA_hat, SI_hat, MM_hat)

colMeans(M_2020, na.rm = TRUE)
colMeans(F_2020, na.rm = TRUE)

# Filter by Gender and get Means 2021
M_2021 = BioData_2021_Estimate %>%
  filter(Gender == "Male") %>%
  select(SA_hat, AS_hat, HS_hat, SE_hat, MA_hat, SI_hat, MM_hat)

F_2021 = BioData_2021_Estimate %>%
  filter(Gender == "Female") %>%
  select(SA_hat, AS_hat, HS_hat, SE_hat, MA_hat, SI_hat, MM_hat)

colMeans(M_2021, na.rm = TRUE)
colMeans(F_2021, na.rm = TRUE)

# Correlations ----

library(Hmisc)
rcorr(as.matrix(theta_2020))

rcorr(as.matrix(theta_2021))

# T-tests

#Between Years
t.test(theta_2020$SA_hat, theta_2020$SA_hat)
t.test(theta_2020$AS_hat, theta_2020$AS_hat)
t.test(theta_2020$HS_hat, theta_2020$HS_hat)
```

```
t.test(theta_2020$SE_hat, theta_2020$SE_hat)
t.test(theta_2020$MA_hat, theta_2020$MA_hat)
t.test(theta_2020$SI_hat, theta_2020$SI_hat)
t.test(theta_2020$MM_hat, theta_2020$MM_hat)


# Gender 2021
t.test(M_2021$SA_hat, F_2021$SA_hat)
t.test(M_2021$AS_hat, F_2021$AS_hat)
t.test(M_2021$HS_hat, F_2021$HS_hat)
t.test(M_2021$SE_hat, F_2021$SE_hat)
t.test(M_2021$MA_hat, F_2021$MA_hat)
t.test(M_2021$SI_hat, F_2021$SI_hat)
t.test(M_2021$MM_hat, F_2021$MM_hat)

# Gender 2020
t.test(M_2020$SA_hat, F_2020$SA_hat)
t.test(M_2020$AS_hat, F_2020$AS_hat)
t.test(M_2020$HS_hat, F_2020$HS_hat)
t.test(M_2020$SE_hat, F_2020$SE_hat)
t.test(M_2020$MA_hat, F_2020$MA_hat)
t.test(M_2020$SI_hat, F_2020$SI_hat)
t.test(M_2020$MM_hat, F_2020$MM_hat)
```