

**ANALYSIS AND ADAPTATION OF QUESTIONNAIRES
BASED ON ITEM RESPONSE THEORY**

Experiments & Statistical Analysis

2019

1.EXPERIMENTS

To validate the proposed methodology, two experiments were performed; The first one considers a course on “Data Classification and Searching”, offered at the Institute of Informatics at UFRGS, considering the periods 2016-I, 2016-II, and 2017-II. From this course were obtained the answers of 2 questionnaires: Algorithms Complexity and Hashing (showed in Figure 7 and Figure 8), which were applied during the course in a different order. The second experiment was performed for the course of Electrical Engineering, also at UFRGS, during the periods 2016-II, 2017-I, 2017-II, and 2018-I, the answers of 12 questionnaires were obtained.

1.1 Experiment 1: “Data Classification and Searching” course

This experiment considered a dataset collected from a course named “Data Classification and Searching” at UFRGS. Such course applied many questionnaires using Moodle, but two of them were used in this experiment; they were related to (a) “Hashing” and (b) “Algorithms Complexity” subjects. The questionnaires were answered by students over the periods of 2016-I, 2016-II, and 2017-II. The “Hashing” questionnaire is composed of 11 questions, while the “Algorithms Complexity” is composed of 6 questions (Figure 7).

Figure 7: Questions of the Algorithms Complexity Questionnaire

1	☰⚙️ Análise de complexidade 1 Analise o seguinte algoritmo escrito em uma linguagem ...	1,0
2	☰⚙️ Análise de complexidade 2 Analise o seguinte algoritmo escrito em uma linguagem ...	1,0
3	☰⚙️ Categorias de complexidade 1 Analise a seguinte frase: _Um algoritmo de complexi...	1,0
4	☰⚙️ n dobra e o tempo de execução também dobra Qual das opções preenche correta...	1,0
5	☰⚙️ Tempo Complexidade A complexidade do método de ordenação M é O (n2) e foi pos...	1,0
6	••⚙️ Assintotica Para análise de complexidade de algoritmos, interessa verificar o compor...	1,0

Source: the author.

Figure 8: Questions of the Hashing Questionnaire

i	Questão 1: Cálculo de endereços (modificada) Questão 1: Calcule os endereços (...)	
1	Questão 2: Indique alternativa correta Questão 2 De acordo com os valores de end...	1,00
2	Questão 4: Questão 4: Usando os mesmos valores de chaves e a função do exercíci...	1,00
i	Questão 3: Encadeamento aberto linear Questão 3: A tabela abaixo organizada por...	
3	Questão 5: Questão 5: Observando-se a tabela 2 e utilizando-se dos valores encontr...	1,00
4	Questão 6: Questão 6: A entrada 1 já esteve ocupada anteriormente.	1,00
5	Questão 7: Questão 7: A entrada 5 não esteve ocupada anteriormente.	1,00
6	Questão 8: Questão 8: Se a entrada 2 for ocupada, apenas o campo "Ocupado" pass...	1,00
7	Colisões As colisões, no método hashing, podem ser tratadas por listas encadeadas ...	1,00
8	Desempenho Quanto ao método de pesquisa hashing podemos dizer que o fator de ...	1,00
9	Colisões I O tratamento de colisões é necessário para o bom funcionamento do méto...	1,00
10	Desempenho I No método hashing a ordenação das chaves a serem inseridas melho...	1,00
11	Função Hashing ideal A função de _hashing_ ideal é aquela que nunca gera valores...	1,00

Source: the author.

Each questionnaire was extracted from Moodle in a CSV file. The “Algorithms Complexity”, for instance, presented six questions in a score scale varying from 0.0 to 1.7. While the “Hashing” questionnaire presented 11 questions varying from 0.0 to 0.91. In Table 1, it is shown a sample of the data collected from Moodle during the 2017-II period, and it was composed of the following items:

1. **ID:** Auto Numerical value assigned for the student.
2. **Status:** Information value for questions completed answered.
3. **Date:** Date value when the student responds to the questionnaire.
4. **Used Time:** Time elapsed during the questionnaire.
5. **Grade:** Total score for the questionnaire.
6. **Q1 ... Q6:** *score* individual for each question (*score* = Number of questions/10).

Table 1. A sample of “Algorithms Complexity” CSV file for the 2017-II period

ID	Status	Date	Used Time	Grade	Q1	Q2	Q3	Q4	Q5	Q6
1	Finished	28-3	9m 15s	10.0	1.7	1.7	1.7	1.7	1.7	1.7
3	Finished	4-4	56s	10.0	1.7	1.7	1.7	1.7	1.7	1.7
5	Finished	9-3	57s	10.0	1.7	1.7	1.7	1.7	1.7	1.7
8	Finished	12-4	4m 47s	8.3	1.7	1.7	1.7	1.7	1.7	0
12	Finished	6-4	1m 17s	10.0	1.7	1.7	1.7	1.7	1.7	1.7
14	Finished	11-4	1m 16s	8.3	1.7	1.7	1.7	1.7	1.7	0

Source: the author.

It can be seen that no information concerning the students involved in the process was used (i.e., they cannot be identified). Finally, each period has generated two CSV files, one for each questionnaire, totaling six files were used with the methodology proposed.

1.1.1 Methodology Application

In this section, we explain the steps applied, i.e., data cleaning and preprocessing, application of IRT, and the selection and ranking of questions.

1.1.1.2 Methodology (Step 1): Data Cleaning and Preprocessing

The questionnaires were cleaned to eliminate attempts that were not finalized and multiple attempts. The performed changes are:

Questionnaire 1: Hashing

- (a) From 46 records originally presented in the 2016-1 period, 15 records were excluded.
- (b) From 40 records originally presented in 2016-II period, 14 records were excluded.

Questionnaire 2: Algorithms Complexity There were no changes.

During cleaning, only 72% of the 111 records collected from Moodle were kept, which represents 81 attempts. Once cleaned, it is necessary to binarize CSV files, considering the following criteria: if the student has reached at least 70% of the grade of a question, the grade is then replaced by 1, otherwise by 0.

1.1.1.3 Methodology (Step 2): Application of Item Response Theory

From the graphic analysis of the calculated logistic models described in Figure 9 and Figure 10, were identified the questions with the highest index of discrimination in questionnaires Hashing and Complexity respectively; According to Pasquali et al. (2003) “ [...] if an item presents a perfect discrimination, then the angle of incidence of the curve would be 90 degrees, that is, a perpendicular. In this case, the item is able to discriminate infinitesimally minimal differences in the levels of theta [...]” in addition was used the value of the discrimination coefficient for each logistic model (2PL - 3PL) and its angle of incidence, were made the selections of questions in each period analyzed. Then, were searched matches between the most repeated questions, with the aforementioned characteristics. a criterion of descending importance is established from higher to lower among the indices of discrimination.

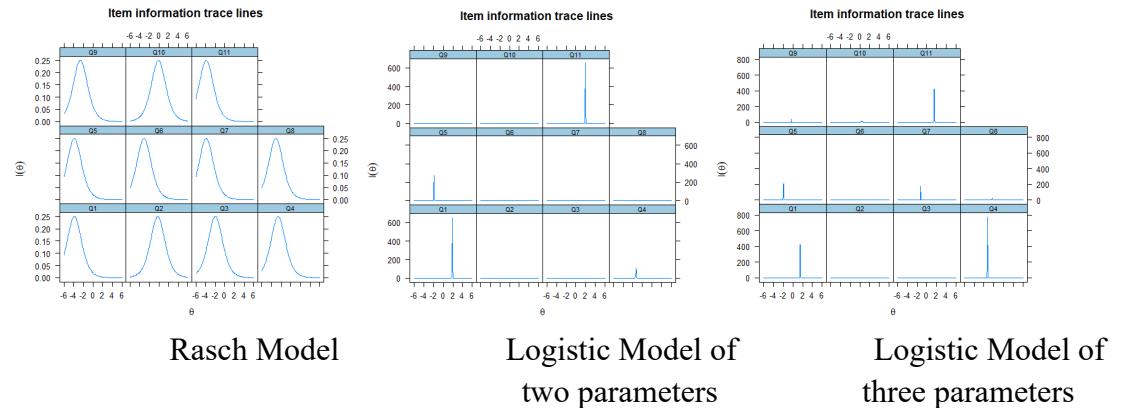
The graphics of the rasch model were not used because the discrimination index is constant by definition ($a = 1$).

Table 2 presents the coefficients between periods 2016-I,2016-II and 2017-II, the highlighted values represent the highest value for each logistic model. The most difficult questions were: Q3 with a difficulty level (b) = -1.944, the question Q2 (b) = -0.49 and the question Q2(b)=-1.91 for Rasch model; the questions Q9 (b) = 10.041, Q9(b) = 1.433 and the question Q6 = -1.008 for the two parameter model (2PL); Finally the questions Q10 (b)= 327, Q9 (b)= 322 and Q7=0.19 for the three parameter (3PL) model; similarly the Questions more discriminative were Q5 with a parameter (a) = 33.224, Q6 (a) = 39.36, Q3,Q5 (a) = 58.262 for the two parameter model (2PL); the questions Q4 (a) = 57.209, Q10 (a) = 896, Q2 (a) = 754 for the three parameter (3PL) model; the period with more variability in the success of hit was 2016-II with values in the “ c ” parameter, only the question Q6 was excluded.

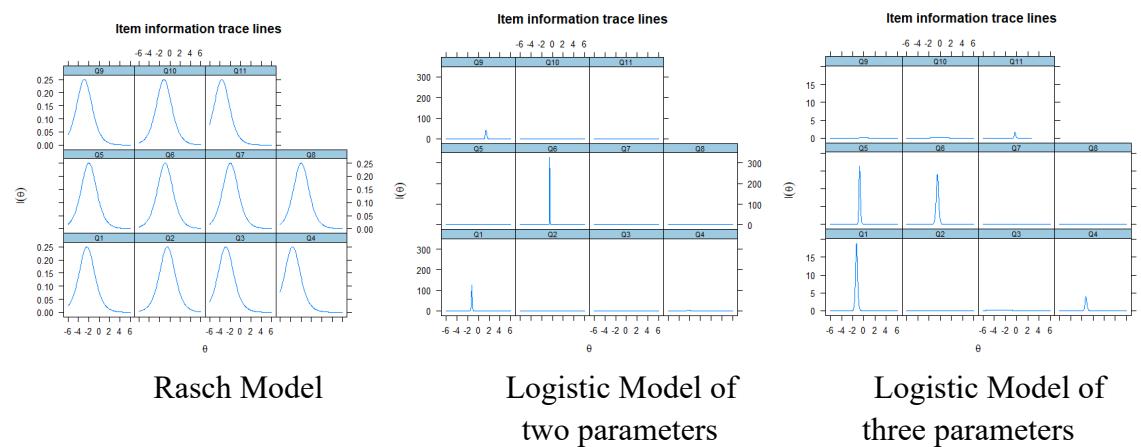
Questionnaire 1: Hashing

Figure 9: IRT Analysis for Hashing Questionnaire

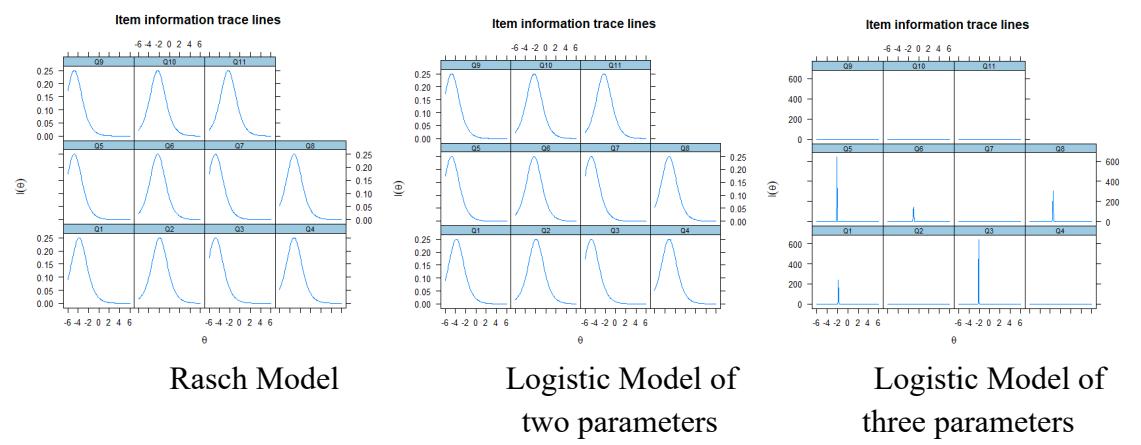
Period:2016-I



Period:2016-II



Period:2017-II



Source: the author.

Table 2: Coefficients of Logistic Models - Hashing - Questionnaire

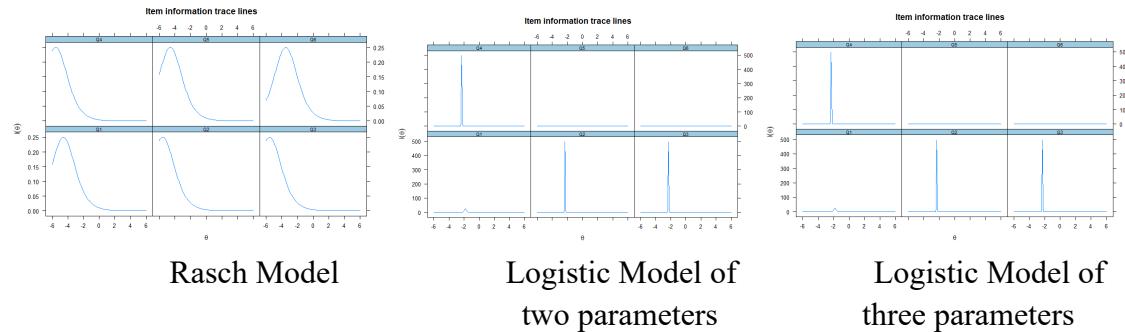
QUESTION	PERIOD	Rasch (b)	2PL (a)	2PL (b)	3PL (a)	3PL (b)	3PL (c)
Q1	2016-1	-3.848	-51.168	1.901	-57.414	1.507	0
Q2	2016-1	-232	305	-0.64	548	-452	0
Q3	2016-1	-1.944	2.01	-1.303	2.082	-1.326	0
Q4	2016-1	-2.599	21.238	-1.3	57.209	-1.304	0
Q5	2016-1	-3.848	33.224	-1.905	32.145	-1.926	0
Q6	2016-1	-3.078	1.563	-2.305	1.014	-3.11	0
Q7	2016-1	-3.848	1.8	-2.648	56.543	-1.302	667
Q8	2016-1	-3.078	-523	5.358	-54.91	-293	892
Q9	2016-1	-2.599	-225	10.041	-53.438	-288	838
Q10	2016-1	-76	722	-86	8.833	327	256
Q11	2016-1	-3.848	-51.168	1.901	-57.414	1.507	0
Q1	2016-2	-2.352	22.708	-1.221	8.785	-1.314	6
Q2	2016-2	-0.49	607	-731	493	-862	14
Q3	2016-2	-2.85	951	-2.941	873	-3.207	16
Q4	2016-2	-3.64	2.443	-2.15	8.487	-1.32	666
Q5	2016-2	-1.973	3.046	-1.18	11.089	-803	325
Q6	2016-2	-911	39.36	-491	7.518	-522	0
Q7	2016-2	-1.973	129	-12.876	492	-3.498	31
Q8	2016-2	-1.973	34	-48.958	443	-2.934	302
Q9	2016-2	-2.85	-13.138	1.433	-2.401	322	829
Q10	2016-2	-1.139	829	-1.31	896	-634	318
Q11	2016-2	-3.64	988	-3.644	11.444	-311	918
Q1	2017-2	-3.822	31.204	-1.786	18.827	-1.696	0
Q2	2017-2	-1.91	729	-1.871	754	-1.799	0
Q3	2017-2	-4.754	58.262	-2.099	17.366	-2.162	0
Q4	2017-2	-3.196	1.879	-1.801	1.844	-1.774	0
Q5	2017-2	-4.754	58.262	-2.099	17.366	-2.162	0
Q6	2017-2	-2.281	24.423	-1.008	12.336	-921	0
Q7	2017-2	-4.754	94	-34.122	5.945	0.19	0.93
Q8	2017-2	-3.196	35.35	-1.471	19.733	-1.357	0
Q9	2017-2	-4.754	2.605	-2.376	19.587	-1.648	528
Q10	2017-2	-2.281	1.803	-1.319	8.734	-701	229
Q11	2017-2	-2.281	673	-2.367	7.066	0	607

Source: the author.

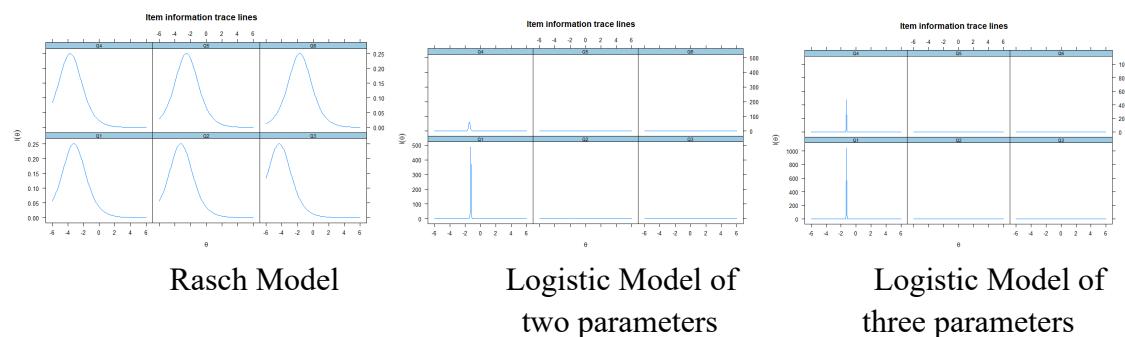
Questionnaire 2: Algorithms Complexity

Figure 10: IRT Analysis for Algorithms Complexity Questionnaire

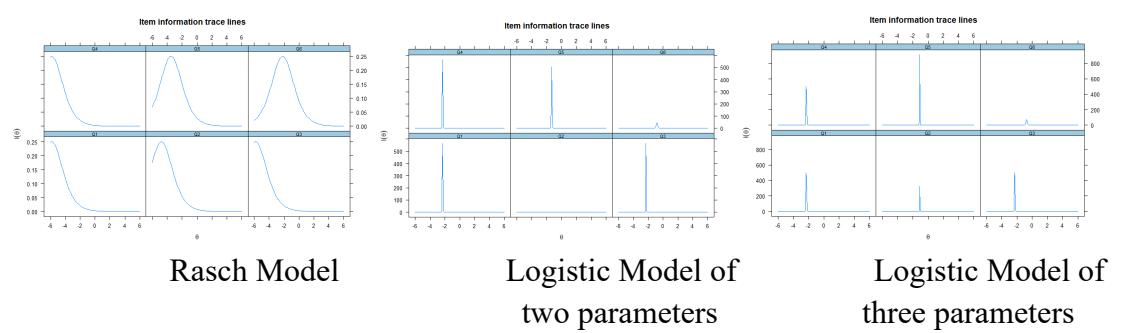
Period:2016-I



Period:2016-II



Period:2017-II



Source: the author.

Table 3 presents the coefficients between periods 2016-I, 2016-II and 2017-II, the highlighted values represent the highest value for each logistic model. The most difficult questions was: Q6 with a difficulty level (b) = -3.5, Q6 (b) = -1.705 and Q6 (b) = -2.186 for Rasch model; the questions Q1 (b) = 1.82, Q6 = -1006 and Q5 = -1.309 for the two parameter model (2PL); Finally the questions Q1 (b) = -1.84, Q6 = -1.005 and Q6 = -0.74 for the three parameter model; similarly the questions more discriminative were Q2, Q3 and Q4 with a parameter (a) = 58.481, Q1 (a) = 49.502 and Q1, Q2 and Q4 (a) = 64.045 for the three parameter model (3PL); The random success of hit was founded in the questions Q6 with a parameter (c) = 685, Q4 (c) = 249 and Q2 (c) = 0.5.

Table 3: Coefficients of Logistic Models - Algorithm Complexity - Questionnaire

QUESTION	PERIOD	Rasch (b)	2PL (a)	2PL (b)	3PL (a)	3PL (b)	3PL (c)
Q1	2016-1	-4.585	10.029	-1.82	6.204	-1.84	0
Q2	2016-1	-5.555	58.481	-2.295	82.177	-2.296	0
Q3	2016-1	-5.555	58.481	-2.295	82.177	-2.296	0
Q4	2016-1	-5.555	58.481	-2.295	82.177	-2.296	0
Q5	2016-1	-4.585	2.529	-2.162	2.52	-2.154	0
Q6	2016-1	-3.5	812	-3.113	4.304	-772	605
Q1	2016-2	-3.241	49.502	-1.277	64.91	-1.294	0
Q2	2016-2	-3.241	3.294	-1.43	3.717	-1.419	0
Q3	2016-2	-4.331	1.96	-2.206	1.815	-2.307	0
Q4	2016-2	-3.712	15.87	-1.449	58.92	-1.313	249
Q5	2016-2	-2.52	991	-1.927	884	-2.109	0
Q6	2016-2	-1.705	1.576	-1.006	1.623	-1.005	0
Q1	2017-2	-5.82	64.045	-2.296	68.089	-2.293	0
Q2	2017-2	-4.776	2.037	-2.233	83.533	-1.105	0.5
Q3	2017-2	-5.82	64.045	-2.296	68.089	-2.293	0
Q4	2017-2	-5.82	64.045	-2.296	68.089	-2.293	0
Q5	2017-2	-3.47	46.941	-1.309	63.428	-1.106	0
Q6	2017-2	-2.186	13.26	-837	17.372	-0.74	0

Source: the author.

1.1.1.4 Methodology (Step 3): Selection and Ranking

Finally, criteria 1 and 2 previously described in section 4.3 were applied to Tables 4 and 5, and the discrimination index for each question are analyzed, as described in the following paragraphs.

Hashing Questionnaire:

By criterium 1: Good information, good discrimination and a reasonable chance of success
Questions selected: Q3, Q4

By criterium 2: Lots of information, high discrimination and low probability of success
Questions selected: Q3, Q5, Q6

Final selection (criteria 1 and 2): **Q3, Q4, Q5, Q6**

Algorithm Complexity Questionnaire:

By criterium 1: Good information, good discrimination and a reasonable chance of success
Questions selected: Q1, Q3, Q4

By criterium 2: Lots of information, high discrimination and low probability of success
Questions selected: Q1, Q2, Q3, Q4

Final selection (criteria 1 and 2): **Q1, Q3**

In this case, questions Q2 and Q4 were discarded by a high probability for random success.

Table 4: Question ranked by the amount of information - Hashing Questionnaire

Questionnaire	Hashing		
Period	Rasch	2PL	3PL
16-1	Q1 Q3 Q4 Q5 Q7 Q8 Q9 Q11	Q11 Q1 Q5 Q4	Q4 Q11 Q1 Q5 Q7 Q9 Q10
16-2	Q1 Q3 Q4 Q7 Q9 Q11	Q6 Q1 Q9	Q1 Q5 Q6 Q4 Q11 Q10 Q9
17-2	Q1 Q3 Q4 Q5 Q7 Q8 Q9 Q11	Q5 Q3 Q8 Q1 Q6	Q1 Q3 Q5 Q6 Q8

Q: Low amount of info | **Q**: big amount of info | Q: Good amount of information

Source: the author.

Table 5: Question ranked by the amount of information - Algorithm Complexity Questionnaire

Questionnaire	Complexity		
Period	Rasch	2PL	3PL
16-1	Q1 Q2 Q3 Q4 Q5	Q4 Q3 Q2 Q1	Q4 Q3 Q2 Q1
16-2	Q2 Q3 Q4	Q1 Q4 Q2	Q1 Q4
17-2	Q4 Q3 Q1 Q2	Q4 Q3 Q1 Q5 Q6	Q5 Q4 Q3 Q1 Q2 Q6

Q: Low amount of info | **Q**: big amount of info | Q: Good amount of information

Source: the author.

1.2 Experiment 2: “Electrical Engineering” course

The dataset collected from the “Electrical Engineering” course included twelve questionnaires extracted from Moodle. The questionnaires were answered over the periods of 2016-II to 2018-I. Table 6 describes the questionnaires, the periods and the questions used for the analysis.

Table 6: Questionnaires of “Electrical Engineering” course

PERIOD	2016-2	2017-1	2017-2	2018-1	NUMBER OF QUESTIONS
QUESTIONNAIRE					
Kirchoff Laws	X	X	X	X	13
Electrical Installations Concepts		X	X	X	9
Resistive Circuit Resolution	X	X	X	X	14
Sistematic Circuit Resolution		X	X	X	4
Alternating current	X	X	X	X	5
Effective Value	X	X	X	X	6
Phasors	X	X	X	X	5
Transformers	X	X	X	X	4
Multipole Alternator	X	X	X		8
Transformers II	X	X	X	X	7
Three Phase Transformers	X	X	X	X	4
Power Factor	X	X	X	X	4

Source: the author.

After the graphic analysis and creation of the tables according to criteria 1 (food information, good discrimination and a reasonable chance of success), and 2 (lots of

information, high discrimination and low probability of success) (see Appendix), in table 7 are described the questions selected in each questionnaire.

Table 7: Question selected By criteria 1 and 2 for the “Electrical Engineering” course

QUESTIONNAIRE	Questions By criteria 1	Questions By criteria 2	Final Selection
Kirchoff	Q6 Q11	Q12 Q13	Q6 Q11 Q12 Q13
Electrical Installation Concepts	Q5 Q2	Q7 Q8 Q9	Q5 Q7 Q8 Q9 Q2
Resistive circuits	Q3 Q6 Q8 Q11 Q12	Q10	Q3 Q6 Q8 Q11 Q12 Q10
Systemic Circuit	Q1 Q2	Q3 Q4	Q1 Q2 Q3 Q4
Alternating Current	Q3	Q4	Q3 Q4
Effective Value	Q3 Q5	Q2	Q3 Q5 Q2
Phasors	Q1 Q2 Q5	Q4	Q1 Q2 Q5 Q4
Transformers	Q1	Q2 Q4	Q1 Q2 Q4
Multipole Alternator	Q2 Q3	Q5 Q6 Q7 Q8	Q2 Q3 Q5 Q6 Q7 Q8
Transformers II	Q1 Q2	-	Q1 Q2
Three Phase Transformers	-	Q4	Q4
Power Factor	Q1 Q2	Q3	Q3 Q1 Q2

Source: the author.

More Details of the experiment are described in the appendix section.

2. ANALYSIS AND DISCUSSION OF THE RESULTS

The software SPSS for windows (version 21) was used. The results of each questionnaire question were analyzed by means of one-way ANOVA followed by Tukey post hoc test, in order to determine differences between evaluating periods. In addition, differences among evaluating periods and questions were established for the Item Response Theory models. Differences between IRT models considering the parameter of difficulty level were assessed by one-way ANOVA, while differences using discriminatory index were verified by student's t-test. P-values <0.05 were considered significant and data are expressed as mean ± standard error (S.E).

2.1 Experiment 1: Analysis of “Data Classification and Searching” questionnaires

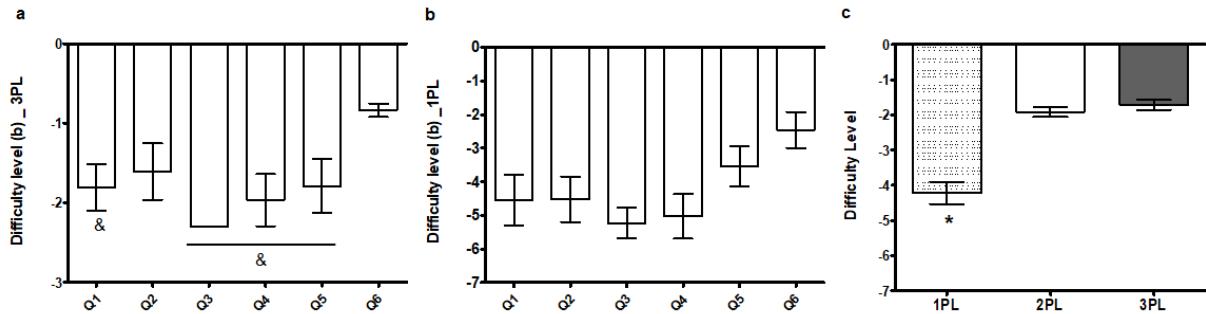
In this section, the analysis of the first experiment concerning the course on “Data Classification and Searching” is described.

2.1.1 Statistical analysis - questionnaire: Algorithms’ complexity

The Analysis of the difficulty level of the “Algorithms’ Complexity” questionnaire considering the logistic model of three parameters (3PL) of IRT showed that question number 6 had a higher difficulty level compared to questions 1, 3, 4 and 5 ($F_{(5,17)} = 3.256$, $p < 0.05$ – Figure 11a). A similar pattern was seen in the logistic model of one parameter (1PL), evidencing once again that the question number 6 was more difficult than the other ones ($F_{(5,17)} = 2.833$, $p = 0.65$, n.s - Figure 11b). In order to analyze the general difficulty levels of the questionnaire, the three IRT logistic models were compared. There was a significant difference between model 1PL as compared to the other models ($F_{(5,17)} = 3.256$, $p < 0.05$ – Figure 11c), suggesting that this model could be more sensible to determine the difficulty level of the questionnaire, which in this case was classified as easy.

Taking each question of this questionnaire into consideration, one way-ANOVA did not show significant differences between them. Moreover, no significant differences ($P > 0.05$) were found between the evaluating periods when the following variables were evaluated: total qualification and time spent in the questionnaire.

Figure 11. Algorithms' Complexity questionnaire



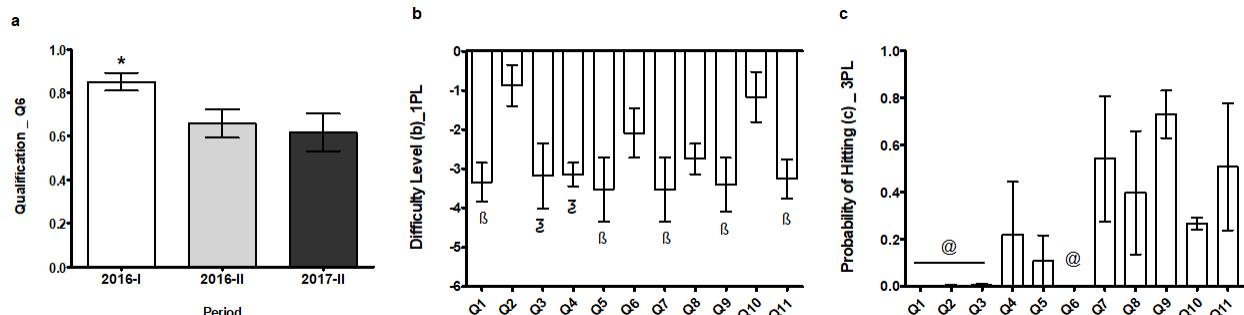
Difficulty levels by each question using the logistic model of one parameter (3PL) (a), and one parameter - 1PL (b). Evaluation of difficulty level by means of IRT models (c). & Significant differences from question 6; *Significant differences from the other evaluating periods. Data analyzed using one-way ANOVA. Significance accepted $p<0.05$. Source: the author.

2.1.2 Statistical analysis - questionnaire: Hashing

As depicted in Figure 12a, there was a significant difference on question 6 of the questionnaire, indicating that it was perceived as more difficult in the period 2016-I when compared to the other periods ($F_{(2,93)}= 3.408$, $p< 0.05$). No additional differences were found, considering the participant's results along the evaluating periods.

One-way ANOVA revealed a significant difference between the questions when the difficulty level of the questionnaire was established by means of the 1PL model ($F_{(10,32)}= 2.311$, $p< 0.05$); pairwise comparison showed that questions 2 and 10 were more difficult than questions 1, 5, 7, 9 and 11. In addition, questions 3 and 4 were easier when compared to question number 2, as shown in Figure 12b. No significant differences were observed between question number 6 and questions 2 and 10. The 3PL model was carried out in order to identify the probability of hitting. There was a significant difference between question 9 when compared to questions number 1, 2, 3, 5 and 6, as shown in Figure 12c.

Figure 12. Hashing Questionnaire



Result of a specific question by each period (a). Difficulty levels by each question using the logistic model of one parameter - 1PL (b). Probability of hitting by each question using the logistic model of three parameter - 3PL (c). *Significant differences from the other evaluating periods. β Significant differences from questions 2 and 10. \ddagger Significant differences from question

2. @Significant differences from question 9. Data analyzed by one-way ANOVA. Significance accepted p<0.05. Source: the author.

2.2 Experiment 2: Analysis of “Electrical Engineering” questionnaires

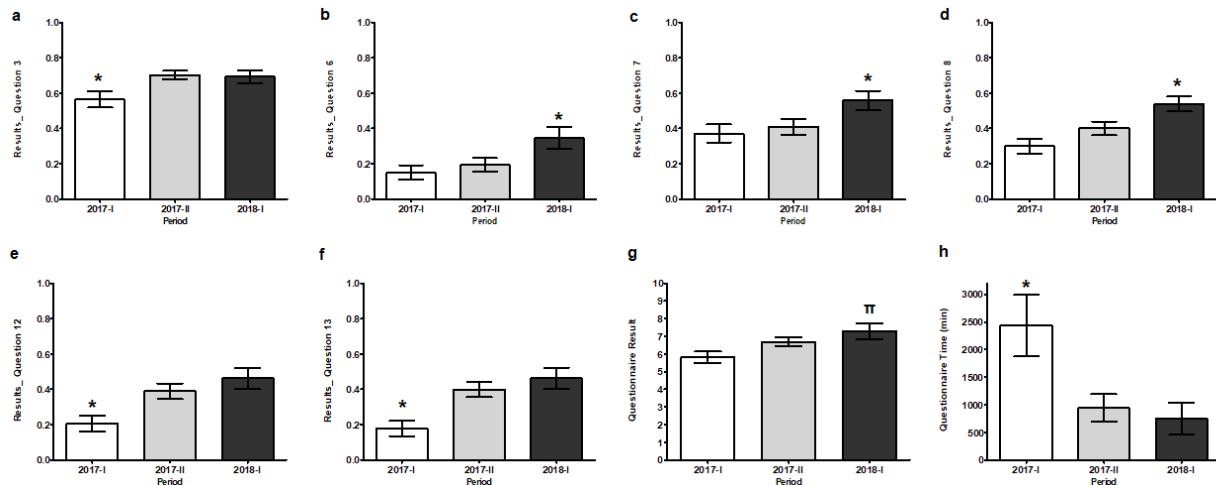
In this section, the analysis of the first experiment concerning the course on “Electrical Engineering” is described.

2.2.1 Statistical analysis - questionnaire 1: Kirchoff Laws

There was a significant effect of the evaluating period when each question was considered, indicating that during the period 2017-I the students had fewer hits for questions 3, 12, and 13 ($F_{(2,174)}= 4.822$; $F_{(2,174)}= 6.415$ and $F_{(2,174)}= 8.601$; $p< 0.05$, respectively - Figure 13a,e-f). Nevertheless, there were more hits for questions 6 to 8 ($F_{(2,174)}= 4.096$; $F_{(2,174)}= 3.082$ and $F_{(2,174)}= 5.597$; $p< 0.05$, respectively) when compared to the other periods (Figure 13b-d).

Participant’s performance was better during the period 2018-I when compared to 2017-I, without significant difference from 2017-II ($F_{(2,174)}= 4.642$, $p<0.05$ - Figure 13g). In addition, the students spent more time completing the Kirchoff Laws questionnaire on the period 2017-I ($F_{(2,174)}= 5.455$, $p<0.05$) as shown in Figure 13h). These data could suggest modifications in teaching strategies of the questionnaire issues throughout the different academic periods.

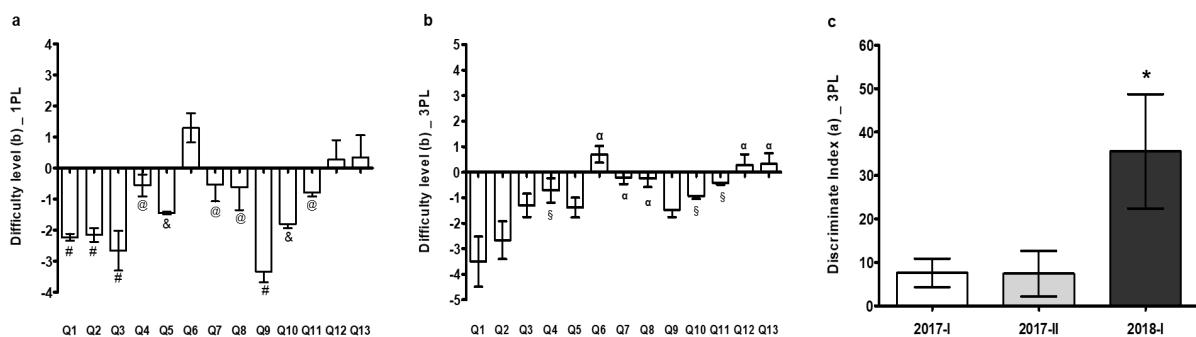
Figure 13. Kirchoff Laws Questionnaire.



Result of a specific question by each period (a-f); general result of the questionnaire (g); Time spent to complete the questionnaire (h). *Significant differences from the other evaluating periods. πSignificant difference from the period 2017-I. Data analyzed by one-way ANOVA. Significance accepted p<0.05. Source: the author.

Using the IRT model in Questionnaire 1, statistical analysis showed significant differences for the logistic models 1PL and 3PL, as observed in figures 14a and 14b ($F_{(12,38)}=8.492$ and $F_{(12,38)}=6.616$; $p<0.05$, respectively). Both models (using the difficulty level parameter - b) showed that questions 6, 12 and 13 were most difficult and questions 1 and 2 the easiest when compared to the other questions. Interestingly, the logistic model 1PL also indicated significant differences on question 9 as compared to questions 4, 7, 8 and 11. Moreover, when the logistic model 3PL was considered, the Kirchoff Laws questionnaire was more discriminative during the period 2018-I as compared to the other two periods ($F_{(2,38)}=3.728$, $p<0.05$ - Figure 14c).

Figure 14. Kirchoff Laws Questionnaire - IRT model

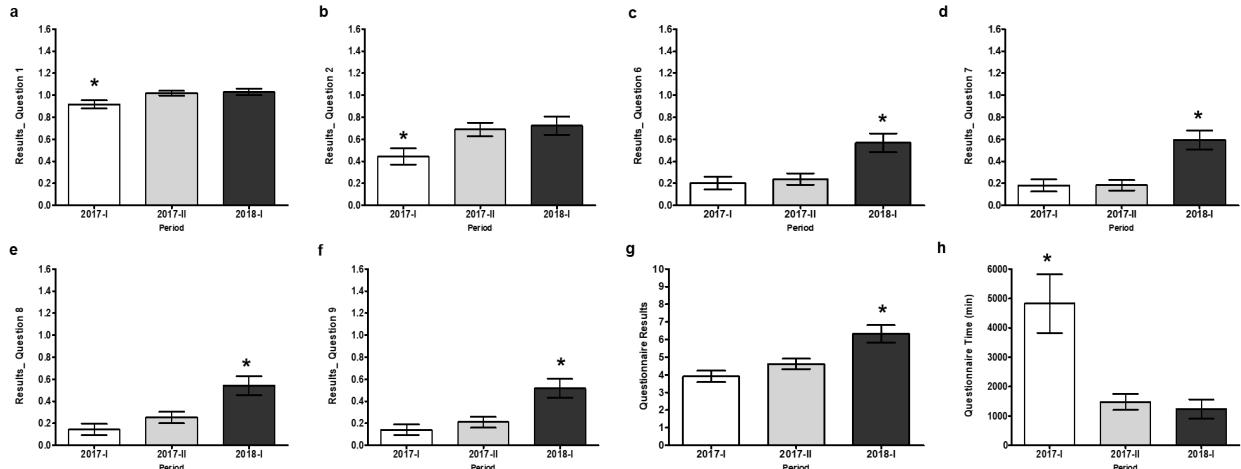


Difficulty levels by each question using the logistic model of one parameter - 1PL (a) and the one of three parameter - 3PL (b). Discrimination index by each period, using 3PL model. #Significant differences from questions 6, 12 and 13; & Significant differences from question 6; @Significant differences from question 9; §significant differences from question 1; ^aSignificant differences from questions 1 and 2. *Significant differences from the other evaluating periods. Data analyzed by one-way ANOVA. Significance accepted $p<0.05$. Source: the author.

2.2.2 Statistical analysis - questionnaire 2: Electrical Installations Concepts

One-way ANOVA revealed significant differences in most of the questions of the questionnaire concerning electrical installations concepts with the exception of questions 3, 4 and 5 ($P>0.05$). As depicted in Figure 15 a-b, questions 1 and 2 had the lowest number of hits during the period 2017-I ($F_{(2,175)}=4.290$ and $F_{(2,175)}=3.970$; $p<0.05$, respectively). In addition, significant differences were observed for questions 6, 7, 8 and 9, which had the highest number of hits by students on the 2018-I period (($F_{(2,175)}=8.383$; $F_{(2,175)}=13.205$; $F_{(2,175)}=9.123$ and $F_{(2,175)}=9.071$; $p<0.01$ - Figure 15 c-f). The best qualification of the questionnaire and the shorter time required to completed it was observed in the period of 2018-I ($F_{(2,175)}=9.656$ and $F_{(2,175)}=9.718$; $p<0.01$ - Figure 15g-h).

Figure 15. Electrical Installations Concepts Questionnaire

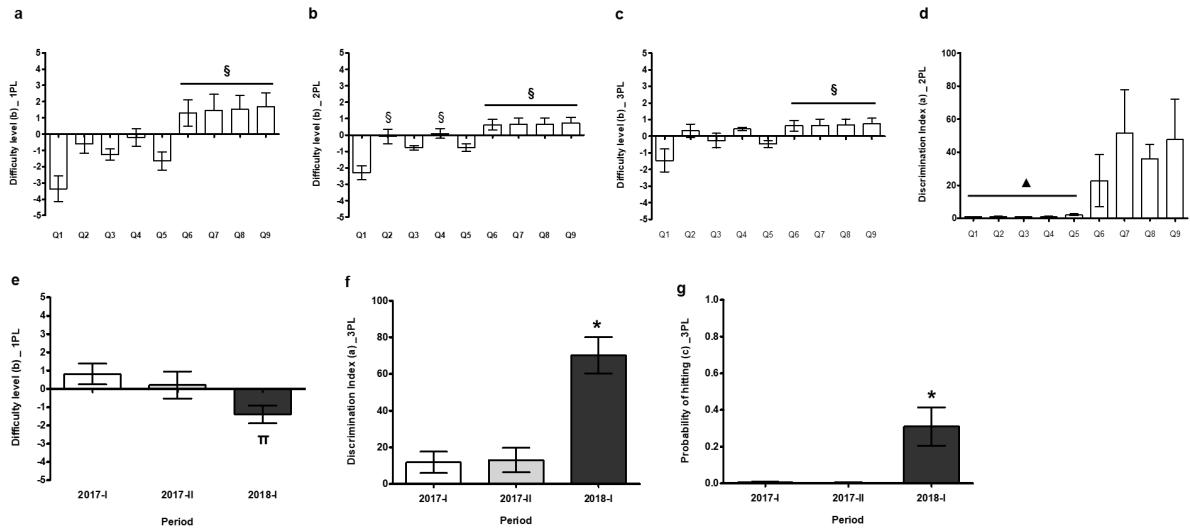


Result of a specific question by each period (a-f); general result of the questionnaire (g); Time spent to complete the questionnaire (h). *Significant differences from the other evaluating periods. Data analyzed by one-way ANOVA. Significance accepted $p<0.05$. Source: the author.

Using IRT analysis, questions 6 to 9 were more difficult than the other ones and this behavior was observed in the three logistic models (1PL, 2PL, and 3PL), confirming the result ($F_{(8,26)}=5.901$; $F_{(8,26)}=9.068$ and $F_{(8,26)}=3.648$; $p< 0.05$), as shown in the Figures 16a-c. The discrimination index of the 2PL model ($F_{(8,26)}= 2.619$, $p< 0.05$) is represented in Figure 16d, indicating that questions 7 and 9 were more discriminative than questions 1 to 5. No significant differences were observed in question 6 and 8.

Analyzing the difficulty level by the 1PL model, evidenced that during the period 2018-I the questionnaire was easier in comparison to the period 2017-I, without significant differences from 2017-II ($F_{(2,26)}=3.559$, $p< 0.05$ - Figure 16e). The discrimination index in the same period was higher ($F_{(2,26)}=19.238$, $p< 0.01$ - Figure 16f) as well as the probability of hitting when compared to the other periods, as shown in Figure 16g ($F_{(2,26)}= 8.559$, $p< 0.05$).

Figure 16. Electrical Installations Concepts Questionnaire - IRT model



Difficulty level by each question using IRT model (a-c). Discrimination index using the logistic model of two parameter – 2PL (d). Evaluation of difficulty level (e), discrimination index (f) and the probability of hitting (g) by each evaluating period. §Significant differences from question 1; ▲Significant differences from questions 7 and 9; *Significant difference from the period 2017-I; *Significant differences from the other evaluating periods. Data analyzed by one-way ANOVA. Significance accepted $p<0.05$. Source: the author.

2.2.3 Statistical analysis - questionnaire 3: Resistive Circuit Resolution

The results of the resistive circuit resolution questionnaire indicated that during the 2017-I period, the students had the worse performance in all questions ($F_{(2,164)}=24.320$, $p< 0.01$) and required also more time to complete it ($F_{(2,164)}=4.233$, $p< 0.05$). In addition, on the 2018-I period, the students showed an increase in the number of hits for questions 8, 9 and 10 when compared to the other periods (Table 8).

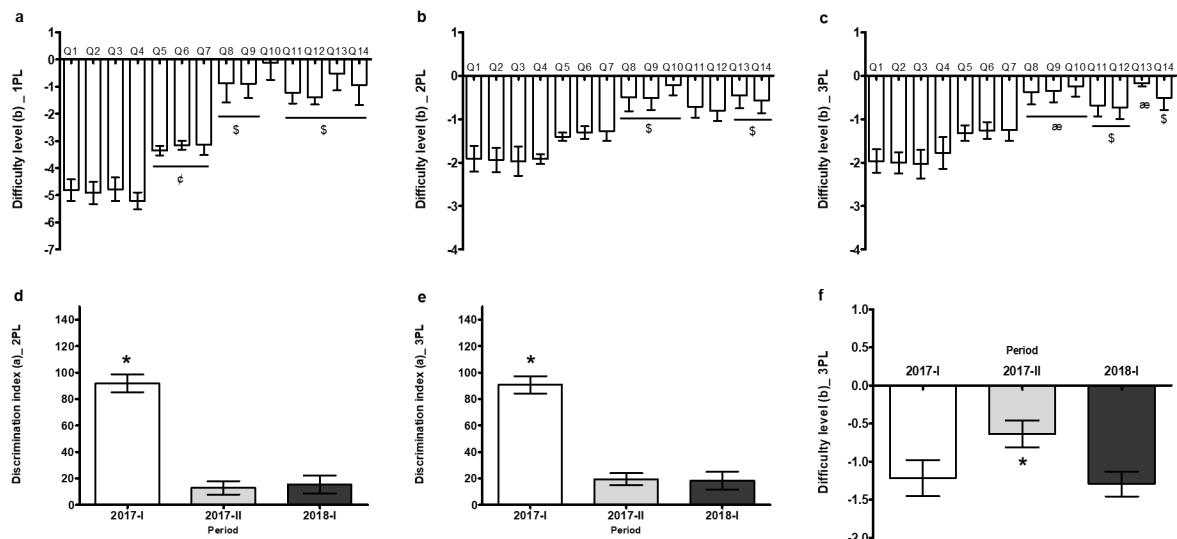
Using the three models of IRT (1PL, 2PL and 3PL - $F_{(13,41)}=15.639$; $F_{(13,41)}=6.467$ and $F_{(13,41)}=7.361$; $p< 0.05$, respectively), it was observed that questions 1 to 4 were the easiest, following by questions 5 to 7 (Figure 17a-c). When models 2PL and 3PL were applied ($F_{(2,41)}=51.420$; $F_{(2,41)}=47.303$; $p< 0.001$) the questionnaire was more discriminative on the 2017-I period in comparison to 2017-II and 2018-I (Figure 17d-e). Finally, in Figure 17f, the 3PL model revealed that the 2017-II period had significant differences from the other ones, being considered with a higher difficulty level ($F_{(2,41)}=3.407$; $p< 0.05$).

Table 8: Description of questionnaire result by each evaluating period

Questionnaire 3	PERIOD		
	2017-I	2017-II	2018-I
Q1	.48*	.65	.65
Q2	.56*	.66	.65
Q3	.52*	.62	.67
Q4	.58	.66	.69 ^{II}
Q5	.37*	.58	.63
Q6	.34*	.57	.61
Q7	.36*	.54	.63
Q8	.19*	.36	.55*
Q9	.19*	.39	.53*
Q10	.04*	.28	.45*
Q11	.18*	.42	.53
Q12	.19*	.45	.53
Q13	.15*	.41	.51
Q14	.14*	.47	.53
Questionnaire Result	4.32*	7.11	8.18
Questionnaire time	1793.02*	869.10	692.50

^{II}Significant difference from the period 2017-I. *Significant differences from the other evaluating periods. Data analyzed by one-way ANOVA. Significance accepted p<0.05.
Source: the author.

Figure 17. Resistive Circuit Resolution Questionnaire – IRT model



Difficulty level by each question using IRT model (a-c). Evaluation of discrimination index using the logistical model of two parameter – 2PL (d) and three parameter -3PL (e) by each evaluating period. Difficulty level by each period according to the logistical model of three parameter-3PL (f). ^{II}Significant differences from the questions 1 to 4. ^æ Significant difference from the questions 10 and 13. ^{*} Significant differences from the other evaluating periods. Data analyzed by one-way ANOVA. Significance accepted p<0.05. Source: the author.

2.2.4 Statistical analysis - questionnaire 4: Systemic Circuit Resolution

The outcomes on 2017-I showed that questions 3-4 had lower hits by the students ($F_{(2,174)}=11.515$; $F_{(2,174)}=10.278$; $p<0.05$, respectively), while on period 2018-I an increase on the number of correct answers for the questions 1 and 2 was observed ($F_{(2,174)}=5.851$; $F_{(2,174)}=3.155$; $p<0.05$). In addition, at 2018-I the time used to complete the questionnaire was lower in comparison to the other evaluating periods. Surprisingly, students spent more time resolving the questionnaire on the 2017-II period ($F_{(2,41)}=3.354$; $p<0.05$ - Table 9).

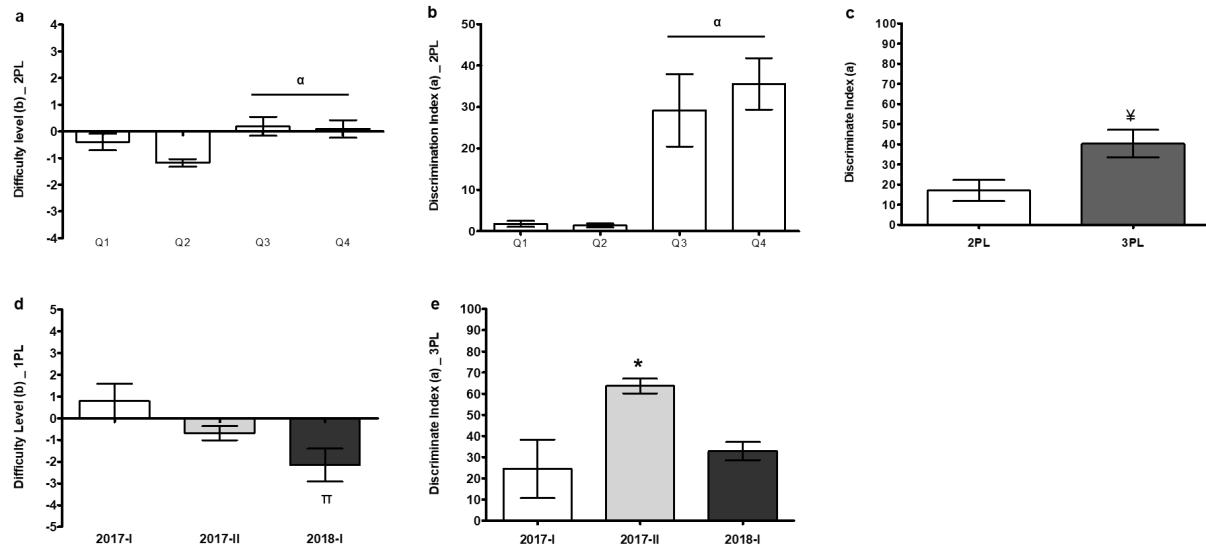
Table 9. Description of questionnaire result by each evaluating period.

Questionnaire 4	PERIOD		
	2017-I	2017-II	2018-I
Q1	Mean 1.20	Mean 1.42	Mean 2.02*
Q2	Mean 1.67	Mean 1.77	Mean 2.20*
Q3	Mean .46*	Mean 1.36	Mean 1.43
Q4	Mean .60*	Mean 1.30	Mean 1.67
Questionnaire Result	Mean 3.94*	Mean 5.85	Mean 7.32*
Questionnaire time	Mean 1155.97	Mean 3256.49	Mean 626.10*

*Significant differences from the other evaluating periods. •Significant difference from the period 2017-II. Data analyzed by one-way ANOVA. Significance accepted $p<0.05$. Source: the author.

Model 2PL evidenced that questions 3 and 4 had higher difficulty level ($F_{(3,11)}=4.452$, $P<0.05$ - Figure 18a) as well as higher discrimination levels ($F_{(3,11)}=11.139$, $P<0.01$ -Figure 18b) when compared to the other two questions. However, when considering the discrimination index using 2PL and 3PL models, the last one was shown to be more discriminating than 2PL ($t_{(22)}=2.729$, $P<0.01$), which could be related to intrinsic characteristics of the 3PL model, due to other variables included (Figure 18c). As observed in previous questionnaires, on the 2018-I period, the systemic circuit resolution questionnaire had also lower difficulty level when compared to 2017-I ($F_{(2,11)}=4.919$, $P<0.05$ - Figure 18d). Finally, 3PL for 2017-II was more discriminative than the other periods analyzed ($F_{(2,11)}=5.785$, $P<0.05$ - Figure 18e).

Figure 18. Systemic Circuit Resolution Questionnaire - IRT model

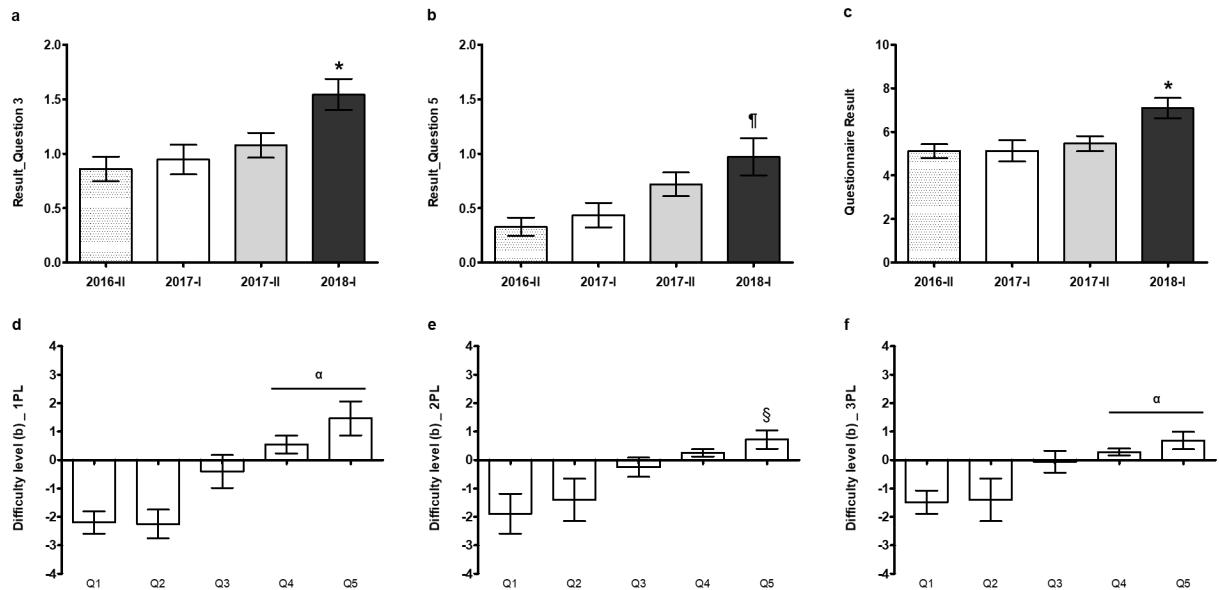


Difficulty level according to the logistic model of one parameter – 2PL (a); Discrimination index using the logistic model of two parameter – 2PL (b) Evaluation of discrimination index by means of two models (c). Results considering the evaluating period by difficulty level (d) and discrimination index (e). ^aSignificant differences from question 1 and 2. [†]Significant differences from the period 2017-I. ^{*}Significant differences from the other evaluating periods. [¥]Significant differences from the other models. Data analyzed by one-way ANOVA and *t*-test by independent samples. Significance accepted $p<0.05$. Source: the author.

2.2.5 Statistical analysis - questionnaire 5: Alternating Current

One-way Anova for the alternating current questionnaire showed significant differences for questions 3, 5 and the general qualification ($F_{(3,245)}=4.015$; $F_{(3,245)}=5.459$ and $F_{(3,245)}=3.662$; $P<0.05$), without significant differences by questions 1, 2 and the time spent during the evaluation (Figure 19a-c). There was observed a consistent result regarding the difficulty level of the alternating current questionnaire when IRT was used. The three models (1PL: $F_{(4,19)}=11.320$; 2PL: $F_{(4,19)}=4.708$ and 3PL: $F_{(4,19)}=4.977$; $p<0.01$) revealed that questions 4 and 5 were the most difficult while questions 1 and 2 the easiest (Figure 19d-f). No significant differences were identified in other parameters of the IRT model as well as in the evaluating period ($p>0.05$).

Figure 19. Alternating Current Questionnaire



Result of specific questions by each period (a-c). Difficulty level using IRT model (d-f).

*Significant differences from the other evaluating periods. †Significant differences from the period's 2016-II and 2017-I. §Significant differences from question 1. ^aSignificant differences from questions 1 and 2. Data analyzed by one-way ANOVA. Significance accepted $p<0.05$.

Source: the author.

2.2.6 Statistical analysis - questionnaire 6: Effective Value

During the periods of 2016-II and 2017-I, there was a significant reduction in the number of hits by all the questions, except for question 6 ($F_{(3,262)}= 7.662$ - 22.097 ; $p<0.001$). Although in the period 2018-I the performance per question was better, the time used by the students was longer in comparison with the other periods ($F_{(3,262)}= 3.263$; $p<0.05$ - Table 10). This could suggest that time and final result are independent variables and could not be strictly related to student performance.

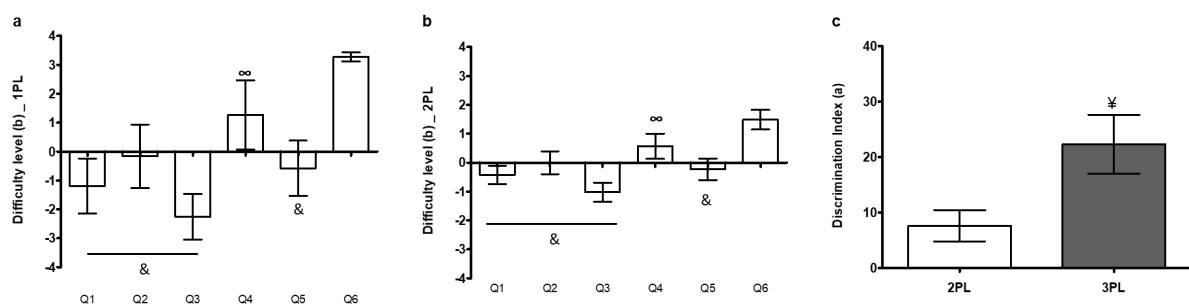
Table 10: Description of questionnaire result by each evaluating period.

Questionnaire 6	PERIOD			
	2016-II	2017-I	2017-II	2018-I
Q1	.86	.67	1.28†	1.43†
Q2	.47	.49	1.13†	1.34†
Q3	1.12	.97	1.42†	1.51†
Q4	.37	.21	.52	1.22*
Q5	.65	.55	1.28†	1.30†
Q6	.22	.21	.17	.29
Questionnaire Result	3.68	3.09	5.84†	7.07*
Questionnaire time	943.94	1132.88	680.12	1960.74*

[†]Significant differences from the period's 2016-II and 2017-I. *Significant differences from the other evaluating periods. Data analyzed by one-way ANOVA. Significance accepted p<0.05. Source: the author.

There was a similar result regarding the degree of difficulty when the 1PL and 2PL models were used ($F_{(5,23)}=4.511$; $F_{(5,23)}=5.634$ P<0.05, respectively). Both models indicating that question 1 to 3 were easy when compared to question 6 (Figure 20a-b). The analysis of the discrimination index using 2PL and 3PL models showed a significant difference between them, indicating that 3PL had an upper index ($t_{(46)}=2.447$, P<0.05 - Figure 20c). No significant differences were found when the evaluating period was considered or when the other parameters of the IRT model were included.

Figure 20. Effective Value Questionnaire - IRT Model



Difficulty level by each question using the logistic model of one parameter – 1PL (a); two parameter – 2PL (b). Evaluation of the discrimination index by means of two models (c). & Significant differences from question 6. *Significant differences from question 3. ¥Significant differences from the other model. Data analyzed by one-way ANOVA and t-test by independent samples. Significance accepted p<0.05. Source: the author.

2.2.7 Statistical analysis - questionnaire 7: Phasors

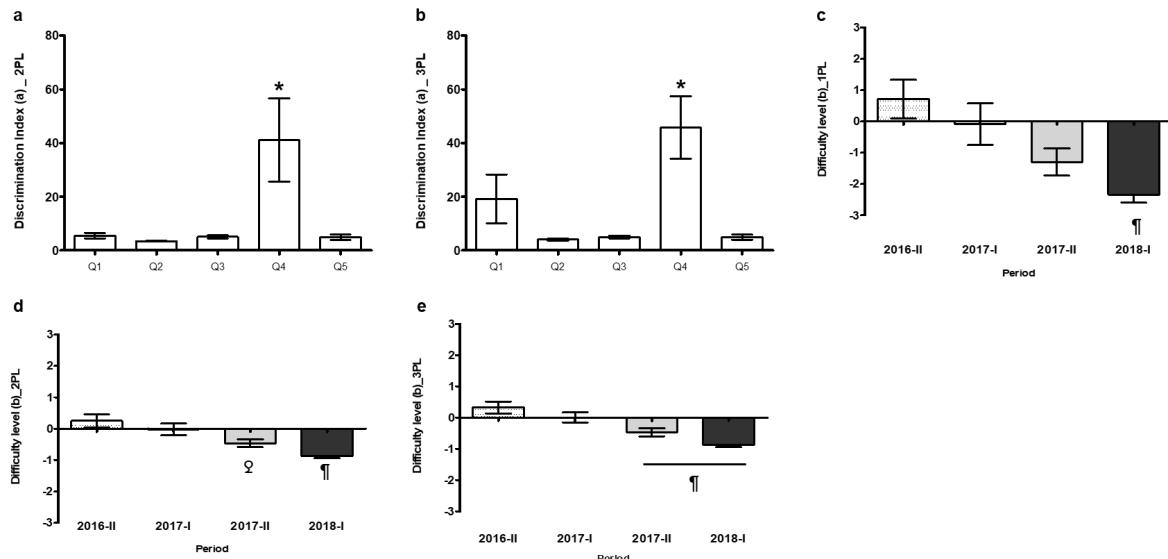
The analysis of each question of the Phasors questionnaire showed that, during the periods of 2017-II and 2018-I almost all the questions were resolved by students ($F_{(3,252)}=3.484$ -16.024, p< 0.05), being the questionnaire considered easy (Table 11). As observed in Figures 21c-e, this information was similar when the difficulty level was determined by means of the three IRT models (1P: $F_{(3,19)}=6.700$, p< 0.01; 2PL: $F_{(3,19)}=9.909$, p< 0.001 and 3PL: $F_{(3,19)}=13.681$, p< 0.0001), indicating that IRT is able to identify significant differences as observed through other methods. Interestingly, only one question (number 4) had a high discriminatory index for the Phasors questionnaire when analyzed through 2PL and 3PL ($F_{(4,19)}=5.452$ and $F_{(4,19)}=7.324$, p<0,01, respectively - Figure 21a-b).

Table 11. Description of questionnaire result by each evaluating period.

Questionnaire 7	PERIOD			
	2016-II Mean	2017-I Mean	2017-II Mean	2018-I Mean
Q1	1,22	1,36	1,51	1,57
Q2	1,04	1,29	1,41 [♀]	1,57 [♀]
Q3	,68	,86	1,05 [†]	1,43 [†]
Q4	,81	,93	1,36 [†]	1,67 [†]
Q5	,47	,64	1,18 [†]	1,52 [†]
Questionnaire Result	4,21	5,07	6,51 [†]	7,76 [†]
Questionnaire time	890,98	710,98	1006,87	546,85

[†]Significant differences from the period's 2016-II and 2017-I. [♀]Significant differences from the period 2016-II. Data analyzed by one-way ANOVA. Significance accepted p<0.05. Source: the author.

Figure 21. Phasors Questionnaire - IRT Model



Discrimination index by each question using the logistic model of one parameter – 1PL (a) and the two-parameter model – 2PL (b). Difficulty level using IRT model by each evaluating period (c-e). *Significant differences from the other questions. [†]Significant differences from the period's 2016-II and 2017-I. [♀]Significant differences from the period 2016-II. Data analyzed by one-way ANOVA. Significance accepted p<0.05. Source: the author.

2.2.8 Statistical analysis - questionnaire 8: Transformers

The analysis of each question using as a fixed factor the evaluating period revealed that during the periods 2017-II and 2018-I the students' performance was better when compared with previous periods ($F_{(3,248)}=5.286$ - 11.113 , $p<0.001$ - Table 12). Moreover, during the 2017-II period, students required very few minutes to complete the questionnaire ($F_{(3,248)}=2.729$, $p<0.05$).

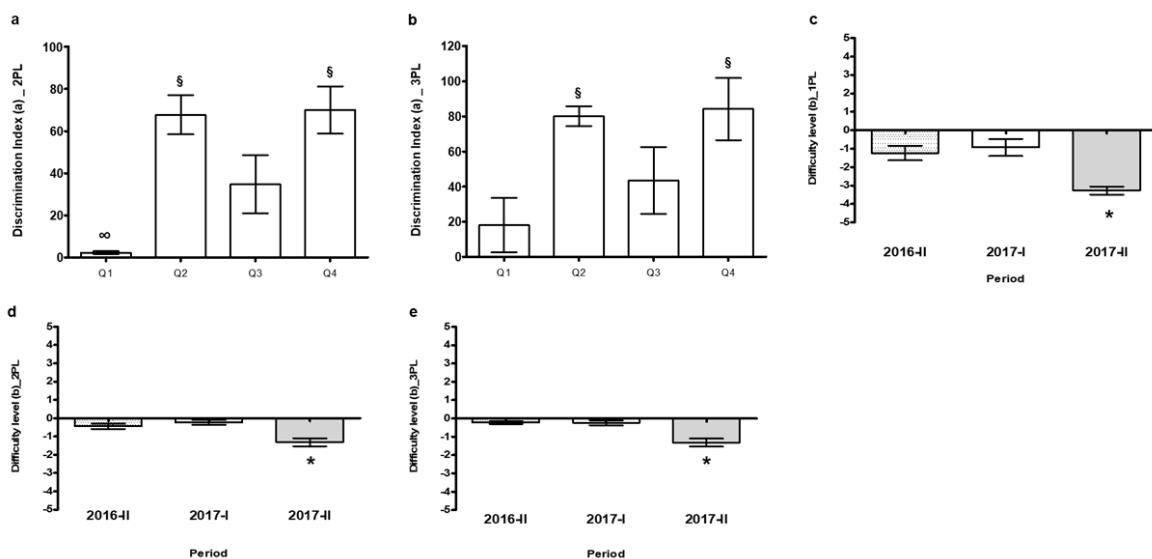
Table 12. Description of questionnaire result by each evaluating period.

Questionnaire 8	PERIOD			
	2016-II Mean	2017-I Mean	2017-II Mean	2018-I Mean
Q1	1,83	1,81	2,20 [¶]	2,50 [¶]
Q2	1,44	1,39	2,07 [¶]	2,38 [¶]
Q3	1,51	1,39	2,11 [¶]	1,71
Q4	1,47	1,39	2,04 [¶]	1,71
Questionnaire Result	6,25	5,97	8,42 [¶]	8,29 [¶]
Questionnaire time	933,06	768,89	255,24 [¤]	375,27

[¶]Significant differences from the period's 2016-II and 2017-I. [¤]Significant differences from the period 2016-II. Data analyzed by one-way ANOVA. Significance accepted p<0.05. Source: the author.

As depicted in Figures 22a-b, the discrimination index using 2PL and 3PL models showed that question 1 was the least discriminating when compared to the other points ($F_{(3,11)}=10.134$ and $F_{(3,11)}=4.161$, $p<0.05$ respectively). In the period 2018-I, it was not possible to use IRT due to the lower variability in the results. However, previous periods (2016-II to 2017-II) were considered. Thereby, it was observed that the difficulty level of the questionnaire was low in 2017-II, as mentioned above (1PL: $F_{(2,11)}=11.571$, 2PL: $F_{(2,11)}=11.176$ and 3PL: $F_{(2,11)}=16.500$, $p<0.01$ - Figures 22c-e). No additional differences were found considering IRT parameters.

Figure 22. Transformers Questionnaire - IRT Model



Discrimination index by each question using the logistic model of one parameter – 1PL (a) and the two-parameter mode – 2PL (b). Difficulty level using IRT model by each evaluating period (c-e). [§]Significant differences from question 1. [¤]Significant differences from question 3. ^{*}Significant differences from the other evaluating periods. Data analyzed by one-way ANOVA. Significance accepted p<0.05. Source: the author.

2.2.9 Statistical analysis - questionnaire 9: Transformers II

Table 13 describes the performance of the students over four different periods. Thus, it was observed that all the questions were resolved in the periods 2017-II and 2018-I ($F_{(3,245)}=8.824$ - 15.088 , $p< 0.05$). This result was in agreement with IRT analysis, using 1PL ($F_{(3,27)}=25.196$, $p< 0.0001$ - Figure 23b), 2PL ($F_{(3,27)}=47.009$, $p< 0.0001$ - Figure 23c) and 3PL models ($F_{(3,27)}=46.263$, $p< 0.0001$ - Figure 23d), indicating lower difficulty level in these two periods.

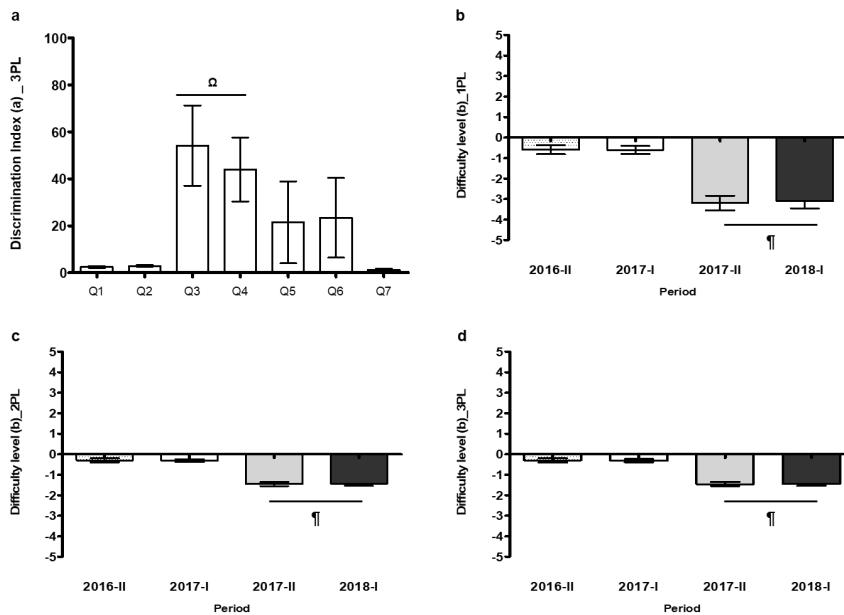
It is interesting to note that there were few questions with a high discrimination index, being the questions 3 and 4 the most significant in comparison with questions 1, 2 and 7 ($F_{(6,27)}=2.929$, $p< 0.05$). No significant differences were observed in questions 5 and 6, as shown in Figure 23a.

Table 13. Description of questionnaire result by each evaluating period.

Questionnaire 9	PERIOD			
	2016-II Mean	2017-I Mean	2017-II Mean	2018-I Mean
Q1	0.95	0.83	1.3 [¶]	1.32 [¶]
Q2	0.93	0.81	1.28 [¶]	1.32 [¶]
Q3	0.76	0.78	1.28 [¶]	1.17 [¶]
Q4	0.71	0.7	1.28 [¶]	1.17 [¶]
Q5	0.78	0.86	1.21 [¶]	1.25 [¶]
Q6	0.72	0.96 [¤]	1.21 [¶]	1.25 [¶]
Q7	1.01	0.96	1.12	1.17
Questionnaire Result	5.87	5.9	8.67 [¶]	8.65 [¶]
Questionnaire time	2052.58	1160.37	695.32 [¤]	487.06 [¤]

[¶]Significant differences from period's 2016-II and 2017-I. [¤]Significant differences from period 2016-II. Data analyzed by one-way ANOVA. Significance accepted $p<0.05$. Source: the author.

Figure 23. Transformers II Questionnaire - IRT Model



Discrimination index by each question using the logistic model of three parameter – 3PL (a). Difficulty level using IRT models by each evaluating period (b-de). *Significant differences from questions 1, 2 and 7. †Significant differences from periods 2016-II and 2017-I. Data analyzed by one-way ANOVA. Significance accepted $p<0.05$. Source: the author.

2.2.10 Statistical analysis - questionnaire 10: Three-phase Transformers

One-way Anova evidenced significant differences by each question when the evaluation period was considered ($F_{(3,245)}=3.703-26.624$, $p< 0.01$). Pairwise comparison indicated that during the 2016-II period students had the worst performance for the Three-Phase Transformer questionnaire. Peculiarly, during periods 2017-I, 2017-II and 2018-II the number of hits by each question as well as the general questionnaire results were relatively similar between them, as shown in Table 14. Nevertheless, on 2017-II, the time used to complete the questionnaire was the lowest in comparison with the other periods.

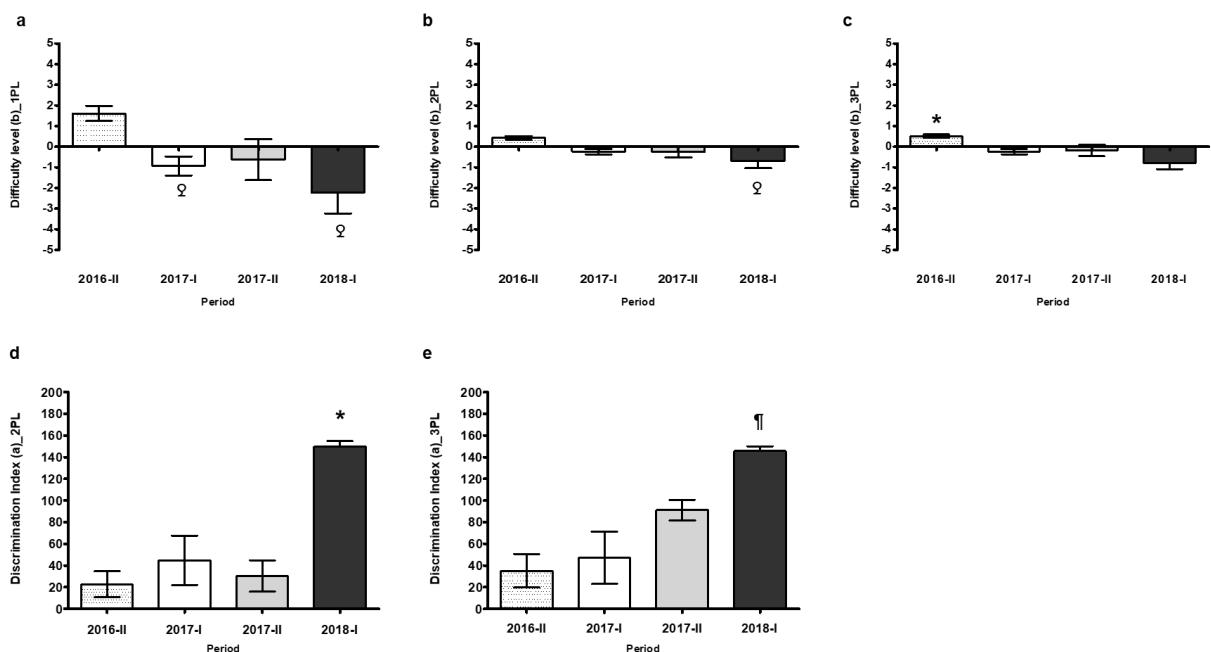
Table 14. Description of questionnaire result by each evaluating period.

Questionnaire 10	PERIOD			
	2016-II	2017-I	2017-II	2018-I
Q1	Mean	Mean	Mean	Mean
Q2	0.9	1.49 ^Φ	0.97	1.45 ^Φ
Q3	0.9	1.54 ^Ω	1.83 ^Ω	2.17 ^{††}
Q4	0.83	1.59 ^Φ	0.97	1.45 ^Φ
Questionnaire result	3.21*	6.01	5.77	7.24
Questionnaire time	1368.29	758.5	42.78 ^Ω	562.81

*Significant differences from periods 2016-II and 2017-II. †Significant differences from the periods 2016-II and 2017-I. ΩSignificant differences from the period 2016-II. Data analyzed by one-way ANOVA. Significance accepted $p<0.05$. Source: the author.

Using the parameter difficulty level of the three IRT models, it was observed that the Three-Phase Transformers questionnaire was perceived as more difficult on 2016-II, especially when it was compared with the periods of 2017-I and 2018-II (1PL: $F_{(3,15)}=4.348$, 2PL: $F_{(3,15)}=3.962$ and 3PL: $F_{(3,15)}=6.155$, $p < 0.05$ - Figures 24a-c). No significant differences were found when questions were used as a fixed variable after IRT analysis. There was a significant effect of the period in which the questionnaire was applied by the discriminatory index. The 2PL and 3PL models ($F_{(3,15)}=15.673$ and $F_{(3,15)}=10.812$, $p < 0.001$) showed a similar result, indicating a high discrimination on the 2018-I period, as indicated in Figure 24d-e.

Figure 24. Three Phase Transformers Questionnaire - IRT Model



Difficulty level using IRT model by each evaluating period (a-c). Discrimination index using the logistic model of two parameters – 2PL (d) and 3PL (e). *Significant differences from 2016-II. †Significant differences from 2016-II and 2017-I. *Significant differences from the other evaluating periods. Data analyzed by one-way ANOVA. Significance accepted $p < 0.05$. Source: the author.

2.2.11 Statistical analysis - questionnaire 11: Power Factor

The analysis of the Power factor questionnaire showed a similar pattern as observed in previous questionnaires (Table 15). In the period of 2018-I, there was a better student' performance for all the questions in comparison with 2016-II ($F_{(3,250)}=2.836-8.048$, $p < 0.05$). Moreover, some differences were observed between 2018-I and the periods of 2017-I and 2017-II, especially for questions 1 ($F_{(3,250)}=3.706$, $p < 0.05$) and 4 ($F_{(3,250)}=20.156$, $p < 0.001$).

One-way ANOVA evidenced a significant difference when the evaluation period was used as a fixed variable. The logistic model of one parameter (1PL) showed that the difficulty

level was low on 2018-I and high in 2017-II in comparison to the other periods ($F_{(3,15)}=10.580$ $p< 0.001$ -Figure 25a). The logistic model of three parameters (3PL) confirmed the significant differences between these two time points ($F_{(3,15)}=5.064$, $p< 0.05$ - Figure 25b).

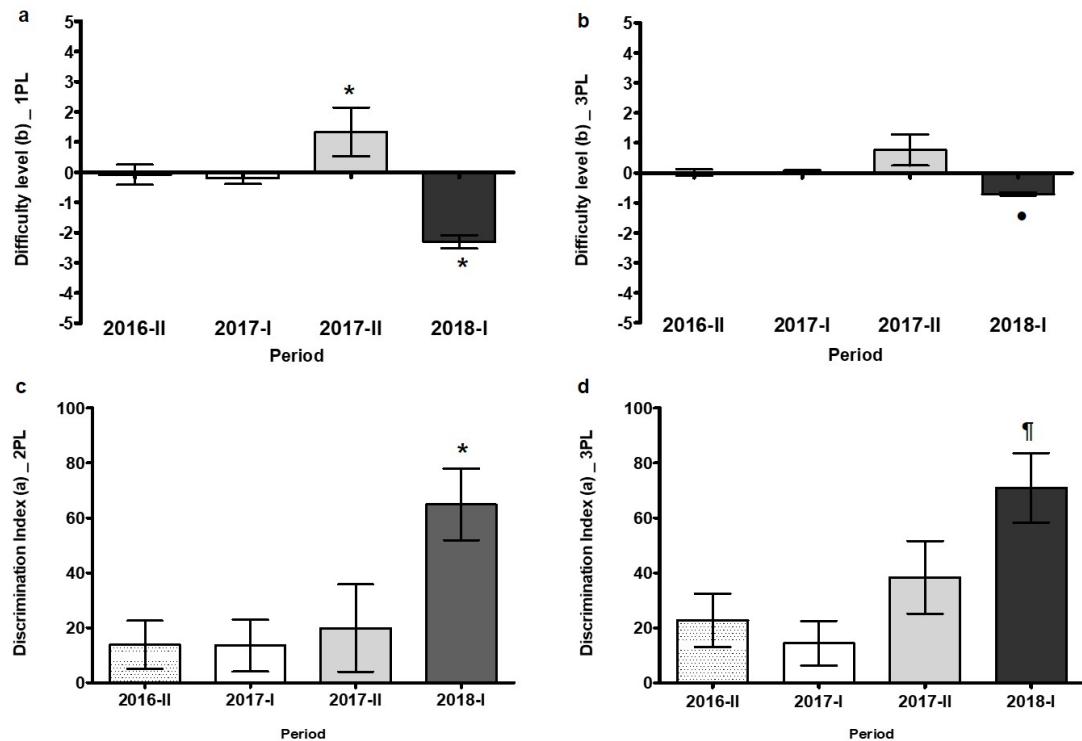
The discrimination index of the Power Factor questionnaire showed significant differences when the 2PL model was used, indicating a high index in the 2018-I period when compared to the other periods ($F_{(3,15)}=4.174$, $p< 0.05$ -Figure 25c). Model 3PL identified significant differences between 2018-I and 2017-I ($F_{(3,15)}=5.051$, $p< 0.05$ - Figure 25d). Thereby, these subtle differences among them could be related to the variables included by each model during IRT analysis. No significant differences were found when questions were used as a fixed variable.

Table 15. Description of questionnaire 11 results by each evaluating period.

Questionnaire 11	PERIOD			
	2016-II Mean	2017-I Mean	2017-II Mean	2018-I Mean
Q1	1,27	1,37	1,01	1,79 [◊]
Q2	1,49	1,42	1,30	1,96*
Q3	1,23	1,18	,97	1,85*
Q4	1,08	1,32	,29*	1,85 [¶]
Questionnaire result	5,06	5,28	3,57	7,44*
Questionnaire time	838,72	620,28	658,56	91,17

[◊]Significant differences from periods 2016-II and 2017-II. [¶]Significant differences from periods 2016-II and 2017-I. *Significant differences from the other evaluating periods. Data analyzed by one-way ANOVA. Significance accepted $p<0.05$. Source: the author.

Figure 25. Power Factor Questionnaire - IRT Model



Difficulty level using 1PL (a) and 2PL by each evaluating period (b). Discrimination index using 2PL (c) and 3PL (d). *Significant differences from the other evaluating periods.
•Significant difference from period 2017-II. †Significant differences from periods 2016-II and 2017-I. Data analyzed by one-way ANOVA. Significance accepted $p < 0.05$. Source: the author.

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APPENDIX <Details for Results of Experiment 2: “Electrical Engineering” course>

Experiment 2: “Electrical Engineering” course

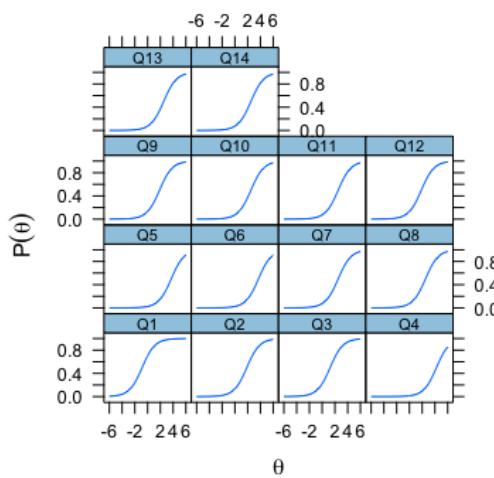
Graphical Analysis of IRT for Questionnaires from the “Electrical Engineering” Course

Detail information was described in the following tables (**Tables A to L**).

Graphical IRT Analysis: Questionnaire 1 - Kirchoff

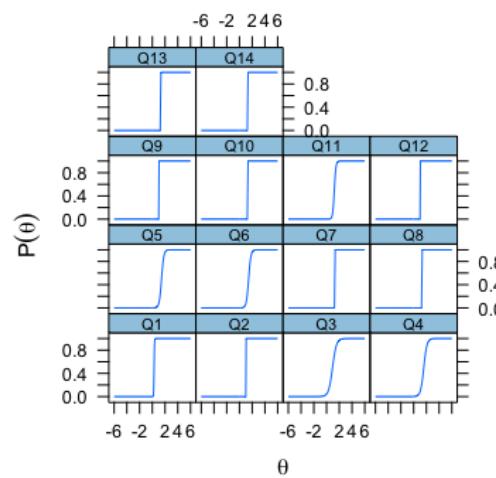
Period: 2016-2

Item trace lines



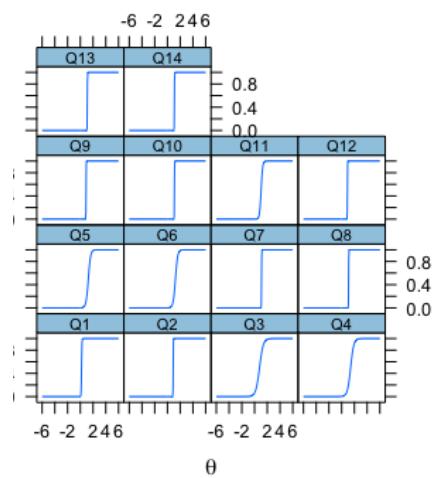
Rasch model
3PL

Item trace lines



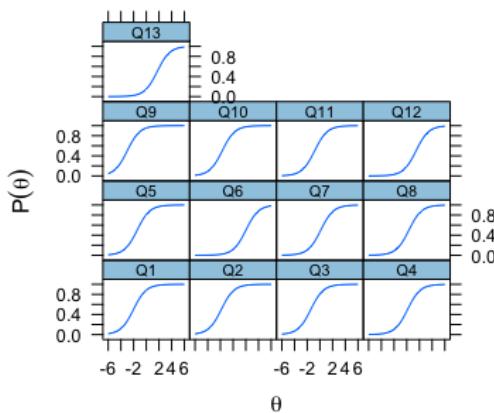
2PL

Item trace lines



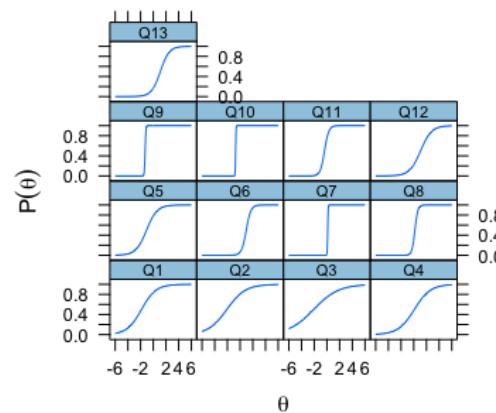
Period: 2017-1

Item trace lines



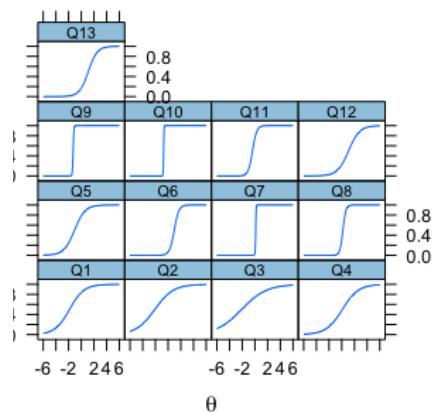
Rasch model
3PL

Item trace lines



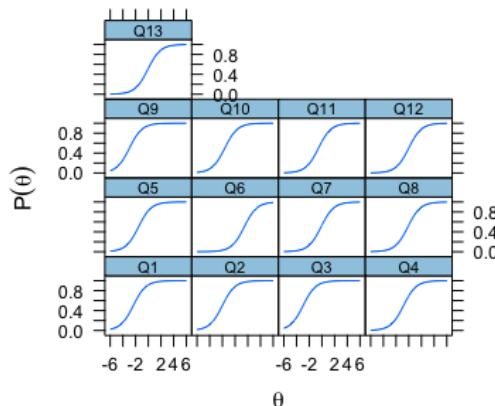
2PL

Item trace lines



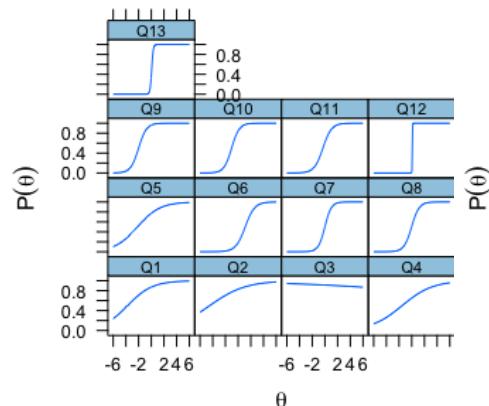
Period: 2017-2

Item trace lines



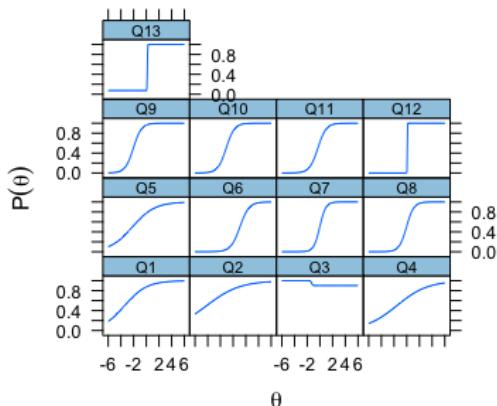
Rasch model
3PL

Item trace lines



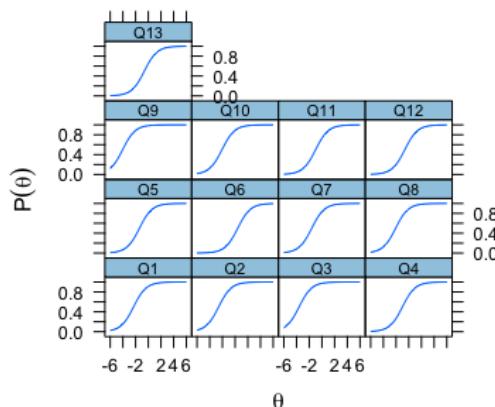
2PL

Item trace lines



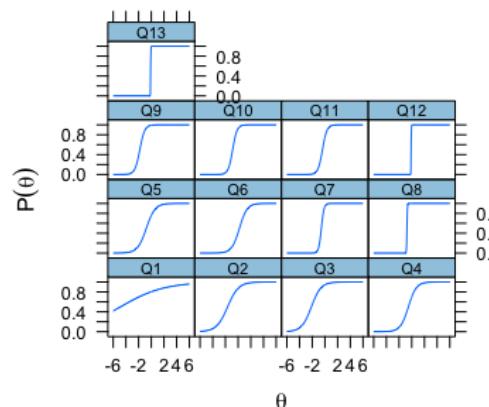
Period: 2018-1

Item trace lines



Rasch model
3PL

Item trace lines



2PL

Item trace lines

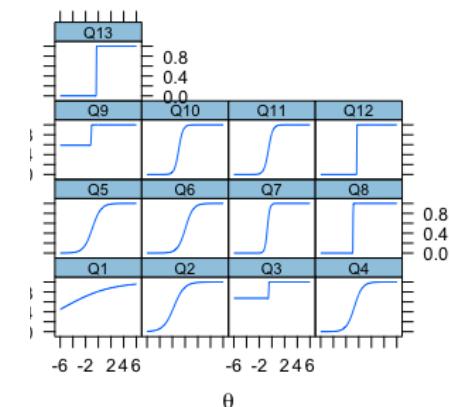
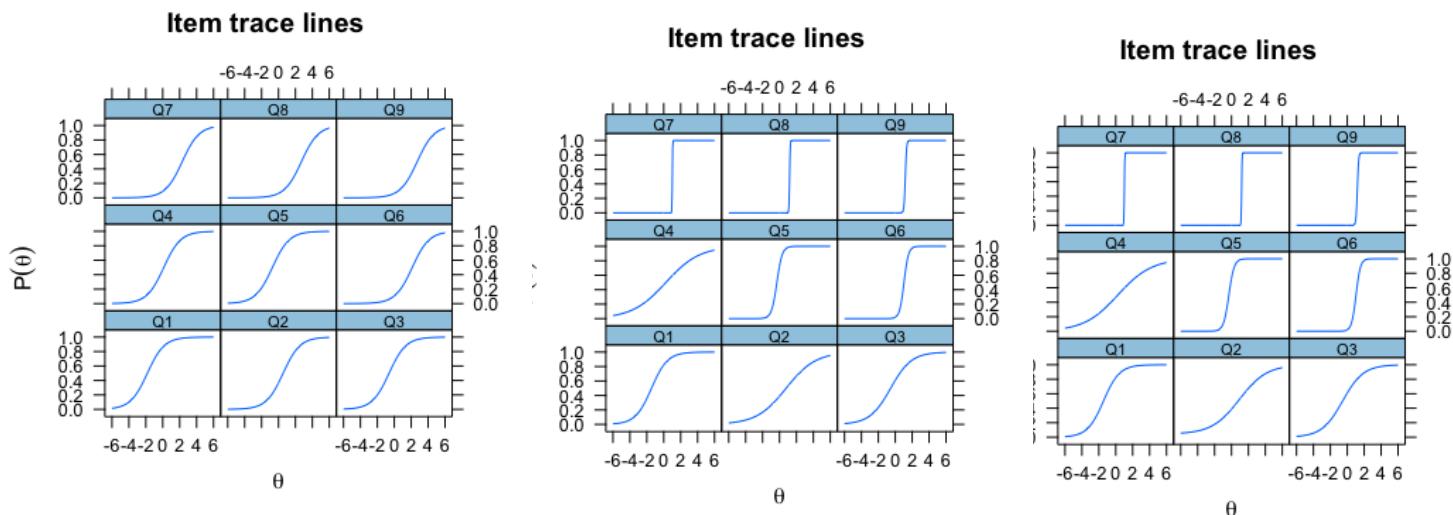


Table A: Coefficients of Logistic Models for kirchoff questionnaire

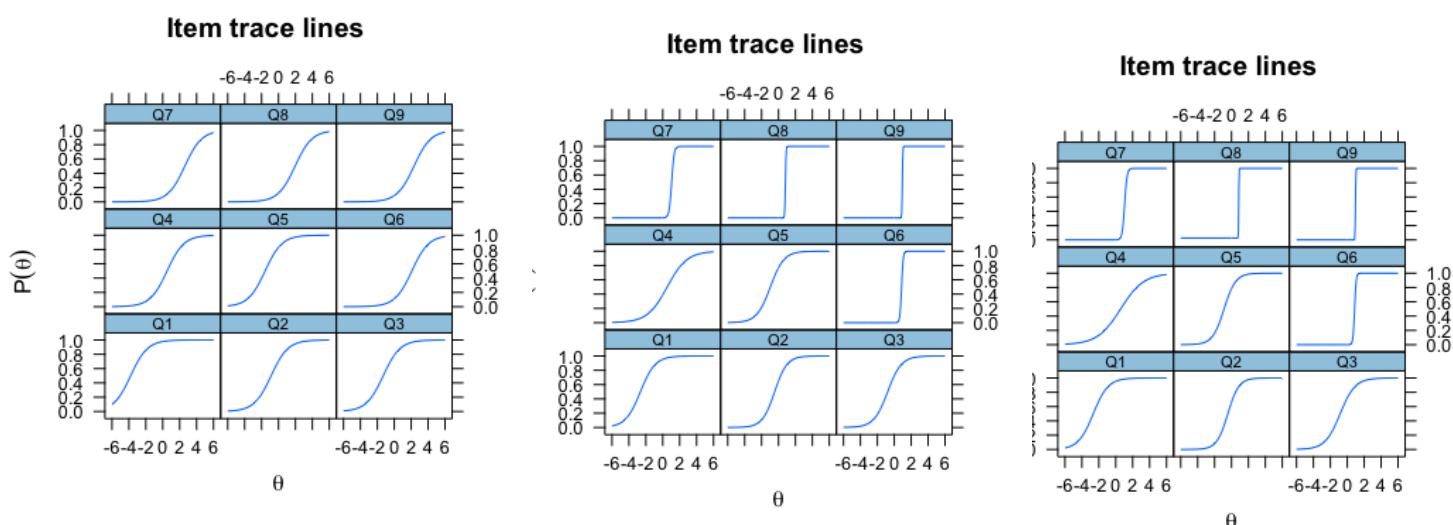
Kirchhoff							
QUESTION	PERIOD	mod1b	mod2a	mod2b	mod3a	mod3b	mod3c
Q1	2017-1	-2.012	879	-1.85	879	-1.851	0
Q2	2017-1	-1.856	684	-2.09	683	-2.092	0
Q3	2017-1	-1.435	512	-2.087	512	-2.087	0
Q4	2017-1	136	791	102	791	0.1	0
Q5	2017-1	-1.435	1.205	-1.058	1.205	-1.059	0
Q6	2017-1	2.018	2.746	972	2.745	0.97	0
Q7	2017-1	136	29.576	119	31.707	119	0
Q8	2017-1	344	4.264	182	4.272	181	0
Q9	2017-1	-2.997	16.73	-1.282	17.075	-1.282	0
Q10	2017-1	-1.709	33.197	-706	33.266	-707	0
Q11	2017-1	-828	3.02	-377	3.02	-378	0
Q12	2017-1	1.467	1.156	1.081	1.155	1.08	0
Q13	2017-1	1.73	1.436	1.117	1.434	1.116	0
Q1	2017-2	-2.363	511	-3.734	0.57	-3.398	1
Q2	2017-2	-2.013	353	-4.467	383	-4.126	6
Q3	2017-2	-2.965	-76	31.013	-11.793	-1.298	903
Q4	2017-2	-822	415	-1.509	408	-1.551	0
Q5	2017-2	-1.531	563	-2.168	0.57	-2.162	0
Q6	2017-2	1.445	1.345	1.124	1.395	1.081	0
Q7	2017-2	-134	1.962	-8	2.132	-0.02	0
Q8	2017-2	-134	1.674	-18	1.733	-34	0
Q9	2017-2	-2.965	1.609	-1.993	1.574	-2.037	0
Q10	2017-2	-1.621	1.663	-1.018	1.539	-1.085	0
Q11	2017-2	-0.54	1.476	-314	1.533	-324	0
Q12	2017-2	0	48.594	92	58.712	92	0
Q13	2017-2	-67	8.019	66	37.51	0.17	75
Q1	2018-1	-2.316	0.29	-4.852	276	-5.258	0
Q2	2018-1	-2.588	1.16	-1.654	1.219	-1.761	0
Q3	2018-1	-3.588	1.321	-2.132	95.815	-505	673
Q4	2018-1	-0.99	1.598	-527	1.599	-689	0
Q5	2018-1	-1.39	1.459	-777	1.47	-933	0
Q6	2018-1	416	1.66	213	1.647	54	0
Q7	2018-1	-1.603	4.797	-561	5.154	-718	0
Q8	2018-1	-2.064	29.768	-756	75.725	-894	0
Q9	2018-1	-4.036	2.611	-1.803	42.883	-1.111	587
Q10	2018-1	-2.064	2.912	-857	2.99	-1.006	0
Q11	2018-1	-0.99	2.875	-383	2.923	-549	0
Q12	2018-1	-617	76.599	-102	115.303	-299	0
Q13	2018-1	-617	76.599	-102	115.303	-299	0

Graphical IRT Analysis: Questionnaire 2 - Electrical Installations Concepts

Period: 2017-1

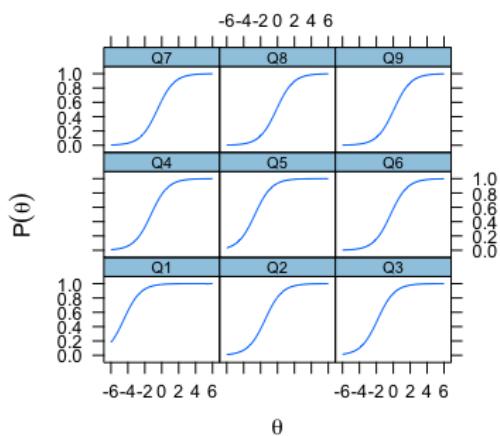


Period: 2017-2

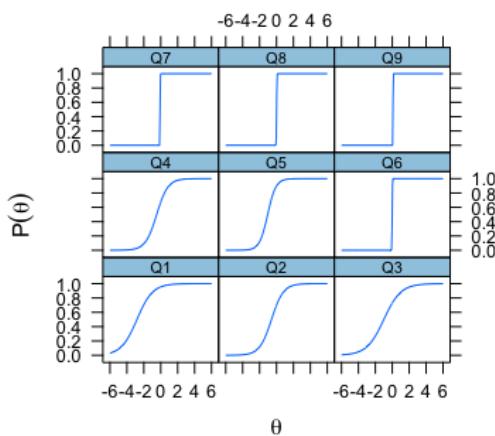


Period: 2018-1

Item trace lines



Item trace lines



Item trace lines

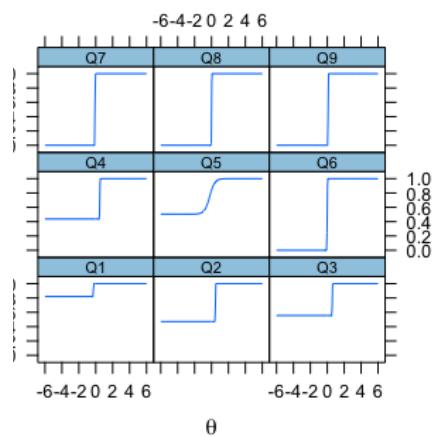


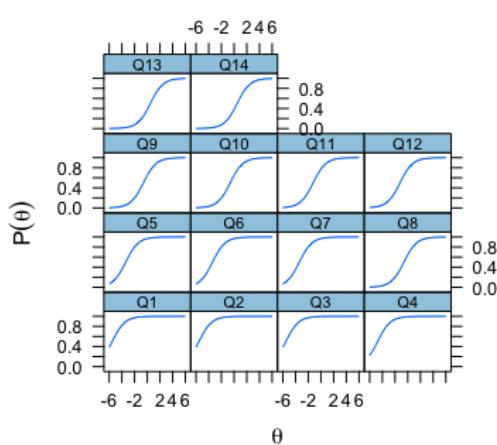
Table B: Coefficients of Logistic Models for Electrical Installations Concepts questionnaire

Electrical installations concepts							
QUESTION	PERIOD	mod1b	mod2a	mod2b	mod3a	mod3b	mod3c
Q1	2017-1	-1.817	1.059	-1.444	1.056	-1.447	0
Q2	2017-1	549	574	784	619	936	43
Q3	2017-1	-612	816	-545	817	-545	0
Q4	2017-1	122	502	254	501	254	0
Q5	2017-1	-0.72	3.189	-0.31	3.206	-0.31	0
Q6	2017-1	2.124	3.812	1.036	3.814	1.035	0
Q7	2017-1	2.303	50.979	1.013	43.612	1.015	0
Q8	2017-1	2.709	28.654	1.191	39.4	1.193	0
Q9	2017-1	2.709	13.502	1.19	13.226	1.19	0
Q1	2017-2	-3.793	1.141	-2.639	1.133	-2.656	0
Q2	2017-2	-873	1.369	-453	1.532	-432	0
Q3	2017-2	-1.305	1.23	-782	1.131	-838	0
Q4	2017-2	511	854	526	731	577	0
Q5	2017-2	-1.582	1.247	-963	1.468	-0.88	0
Q6	2017-2	2.078	10.33	864	10.779	863	0
Q7	2017-2	2.609	6.802	1.051	7.021	1.052	0
Q8	2017-2	1.959	25.554	815	54.628	856	27
Q9	2017-2	2.332	34.175	954	39.186	968	0
Q1	2018-1	-4.482	1.08	-2.813	63.801	-279	0.82
Q2	2018-1	-1.456	1.427	-591	66.222	462	471
Q3	2018-1	-1.839	994	-996	74.627	587	556
Q4	2018-1	-1.267	1.509	-479	70.669	479	436
Q5	2018-1	-2.667	2.074	-1.043	3.328	-213	505
Q6	2018-1	-317	54.189	-13	60.283	-11	0
Q7	2018-1	-0.51	97.367	-89	101.847	-94	0
Q8	2018-1	-121	53.548	13	94.048	7	0
Q9	2018-1	79	95.223	85	96.952	95	0

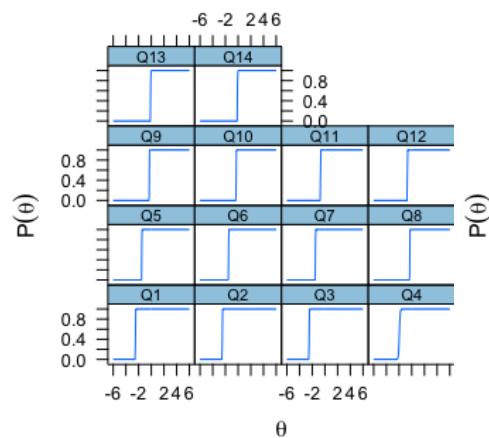
Graphical IRT Analysis: Questionnaire 3 - Resistive circuit resolution

Period: 2017-1

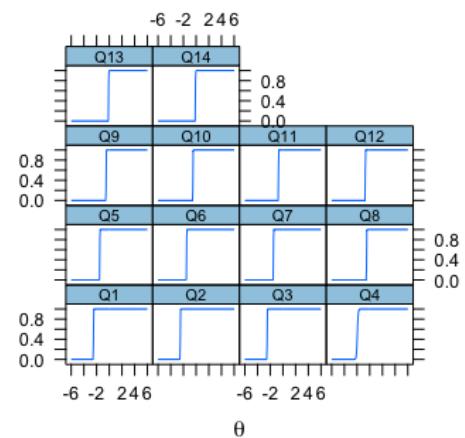
Item trace lines



Item trace lines

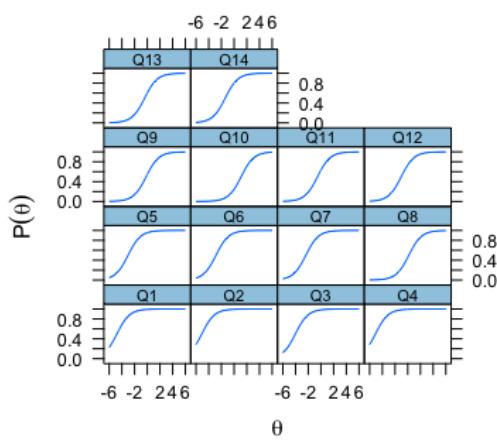


Item trace lines

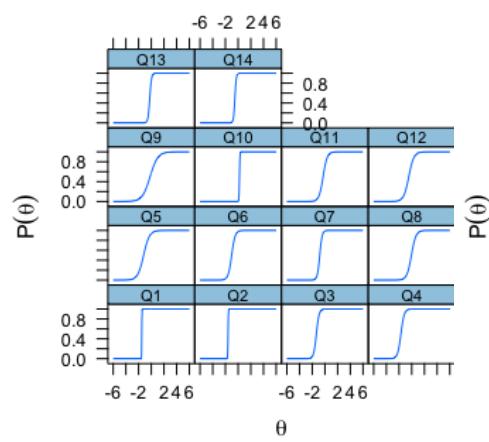


Period: 2017-2

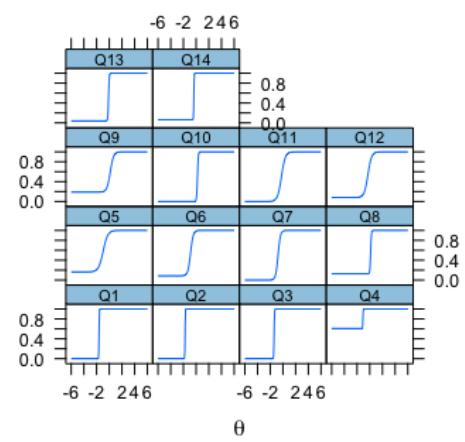
Item trace lines



Item trace lines



Item trace lines



Period: 2018-1

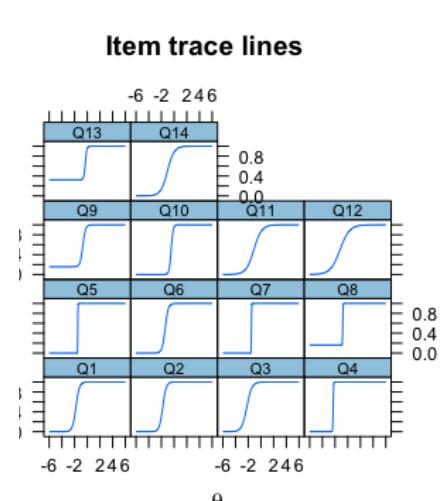
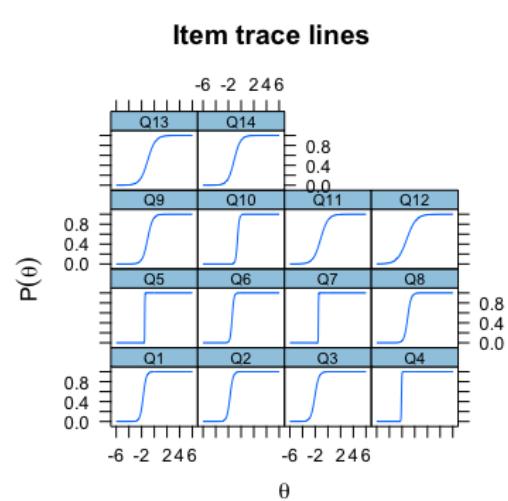
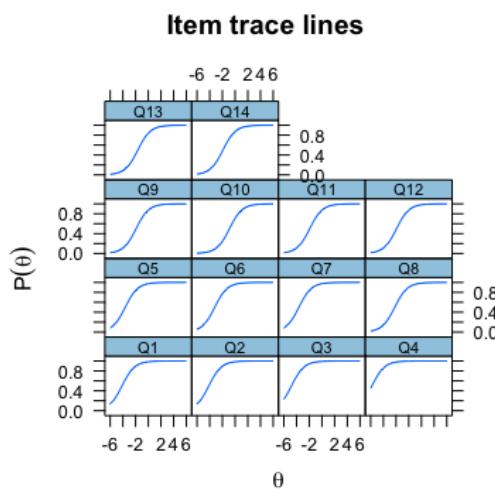


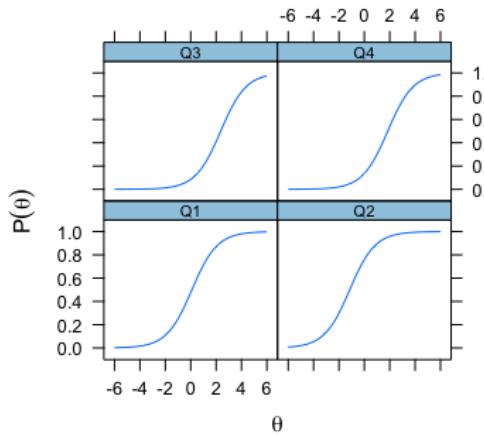
Table C: Coefficients of Logistic Models for Resistive Circuit Resolution questionnaire

Resistive circuit resolution							
QUESTION	PERIOD	mod1b	mod2a	mod2b	mod3a	mod3b	mod3c
Q1	2017-1	-5.518	78.524	-2.491	78.585	-2.491	0
Q2	2017-1	-5.518	78.523	-2.491	78.58	-2.491	0
Q3	2017-1	-5.518	78.521	-2.491	78.577	-2.491	0
Q4	2017-1	-4.741	15.337	-1.954	14.997	-1.954	0
Q5	2017-1	-3.399	95.565	-1.497	92.638	-1.496	0
Q6	2017-1	-3.399	95.47	-1.497	92.697	-1.496	0
Q7	2017-1	-3.399	95.558	-1.496	92.641	-1.496	0
Q8	2017-1	-607	106.322	-306	104.257	-499	0
Q9	2017-1	-607	106.322	-306	104.257	-499	0
Q10	2017-1	-607	106.322	-306	104.257	-499	0
Q11	2017-1	-1.215	100.411	-695	103.635	-699	0
Q12	2017-1	-1.215	100.411	-695	103.635	-699	0
Q13	2017-1	487	114.248	-101	110.95	-104	0
Q14	2017-1	487	114.248	-101	110.95	-104	0
Q1	2017-2	-4.777	65.878	-1.498	41.364	-1.612	0
Q2	2017-2	-5.082	40.637	-1.581	42.141	-1.737	0
Q3	2017-2	-4.018	4.703	-1.343	29.899	-1.389	0
Q4	2017-2	-5.082	3.885	-1.701	46.464	-1.077	608
Q5	2017-2	-3.028	2.184	-1.209	2.773	-961	165
Q6	2017-2	-2.856	3.656	-1.013	4.761	-876	85
Q7	2017-2	-2.375	5.33	-814	5.346	-769	0
Q8	2017-2	174	2.82	-0.05	16.983	142	126
Q9	2017-2	-177	1.656	-187	3.797	156	188
Q10	2017-2	1.118	27.772	213	15.43	214	0
Q11	2017-2	-531	3.128	-284	3.303	-234	0
Q12	2017-2	-1.017	2.511	-464	3.479	-286	81
Q13	2017-2	-412	7.322	-238	18.919	-116	0.04
Q14	2017-2	-1.397	9.376	-503	37.308	-357	64
Q1	2018-1	-4.136	4.102	-1.747	3.701	-1.785	0
Q2	2018-1	-4.136	4.102	-1.747	3.701	-1.785	0
Q3	2018-1	-4.795	3.178	-2.062	2.529	-2.218	0
Q4	2018-1	-5.796	31.915	-2.087	29.874	-2.3	0
Q5	2018-1	-3.629	72.885	-1.5	70.055	-1.498	0
Q6	2018-1	-3.208	6.772	-1.417	4.133	-1.403	0
Q7	2018-1	-3.629	72.885	-1.5	70.055	-1.498	0
Q8	2018-1	-2.203	3.641	-1.12	46.242	-787	164
Q9	2018-1	-1.916	2.464	-1.054	4.713	-702	155
Q10	2018-1	-881	7.051	-567	6.575	-463	0
Q11	2018-1	-1.916	1.72	-1.151	1.643	-1.11	0
Q12	2018-1	-1.916	1.373	-1.254	1.349	-1.212	0
Q13	2018-1	-1.644	1.663	-1.033	8.563	-308	324
Q14	2018-1	-1.916	2.01	-1.1	1.909	-1.049	0

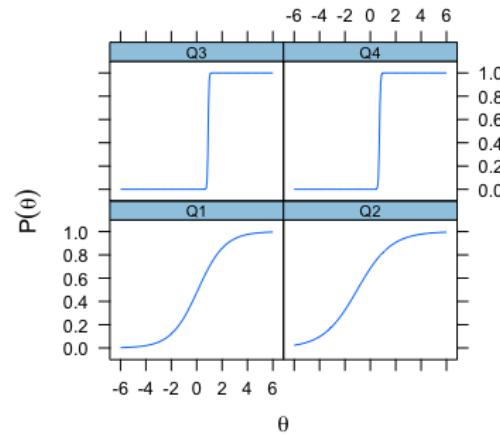
Graphical IRT Analysis: Questionnaire 4 - Systemic Circuit Resolution

Period: 2017-1

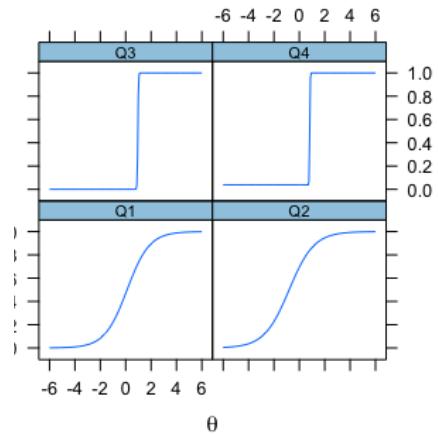
Item trace lines



Item trace lines

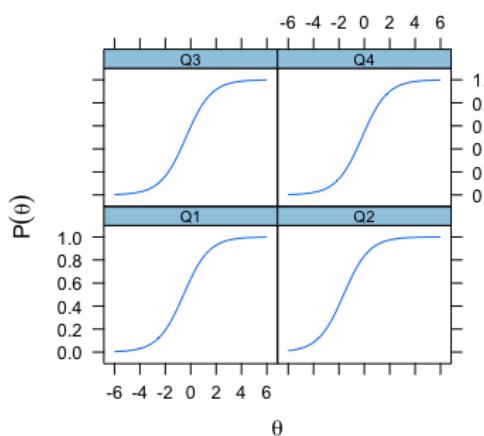


Item trace lines

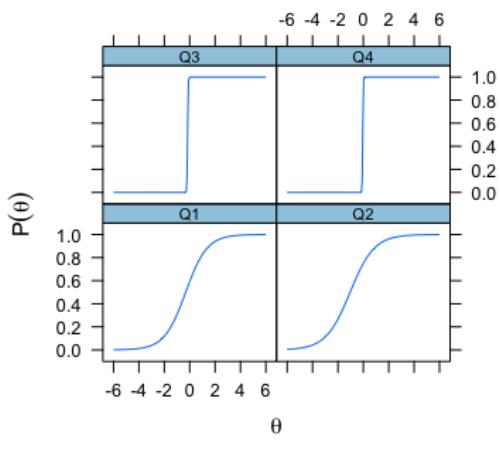


Period: 2017-2

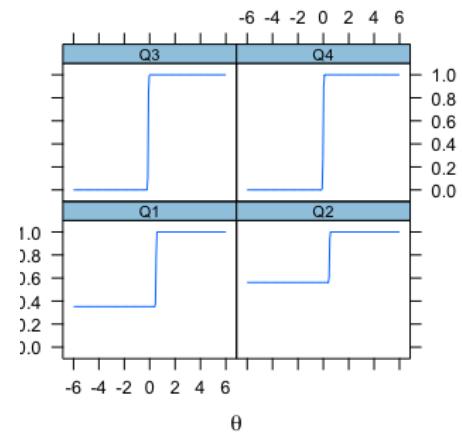
Item trace lines



Item trace lines



Item trace lines



Period: 2018-1

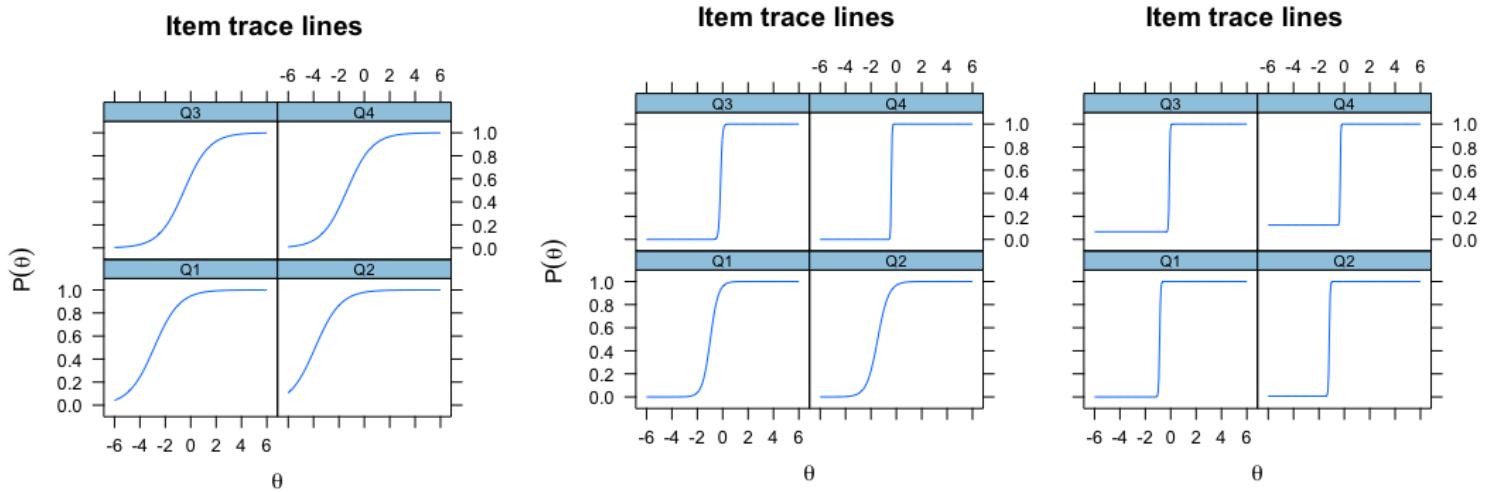


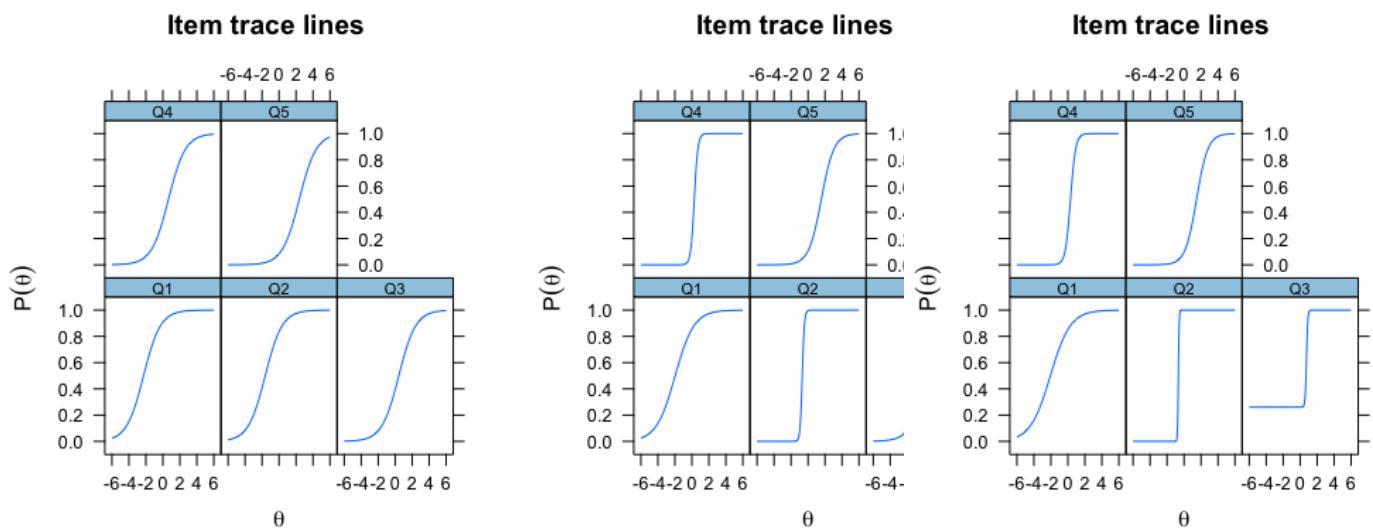
Table D: Coefficients of Logistic Models for Systemic Circuit Resolution questionnaire

Systematic circuit resolution

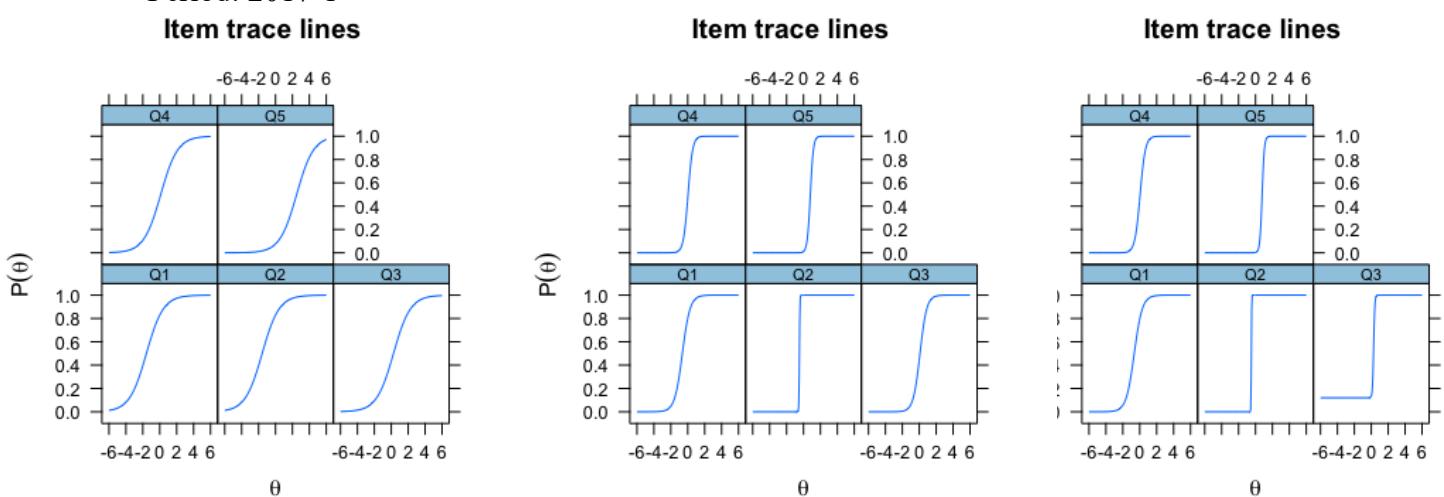
QUESTION	PERIOD	mod1b	mod2a	mod2b	mod3a	mod3b	mod3c
Q1	2017-1	97	942	102	1.133	109	0
Q2	2017-1	-1.149	0.75	-1.031	1.021	-802	0
Q3	2017-1	2.367	29.729	902	40.652	959	0
Q4	2017-1	1.843	24.79	719	54.95	819	39
Q1	2017-2	-555	1.187	-314	68.753	501	352
Q2	2017-2	-1.624	1.052	-1.042	68.317	485	562
Q3	2017-2	-369	44.085	-166	63.51	-118	0
Q4	2017-2	-184	46.321	-43	53.91	-12	0
Q1	2018-1	-2.875	3.175	-973	25.754	-0.87	0
Q2	2018-1	-3.867	2.313	-1.469	28.139	-1.186	7
Q3	2018-1	-0.51	13.75	-163	32.728	-107	67
Q4	2018-1	-1.367	35.632	-394	44.918	-322	124

Graphical IRT Analysis: Questionnaire 5 - Alternating Current

Period: 2016-2

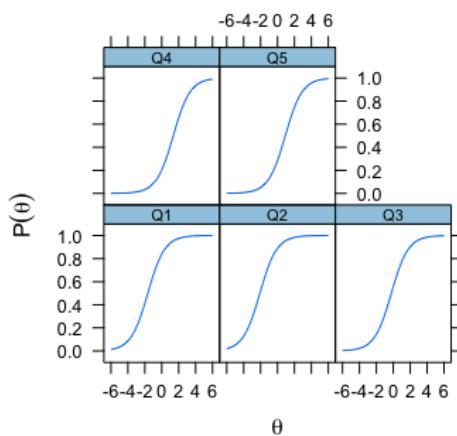


Period: 2017-1

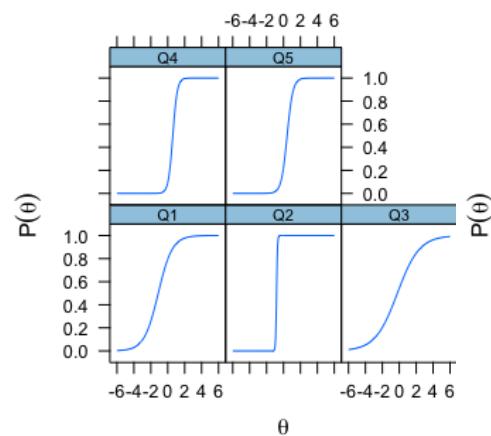


Period: 2017-2

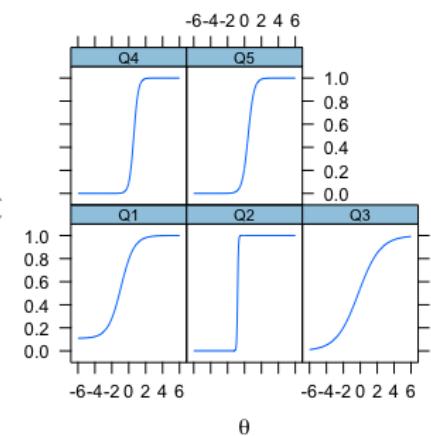
Item trace lines



Item trace lines

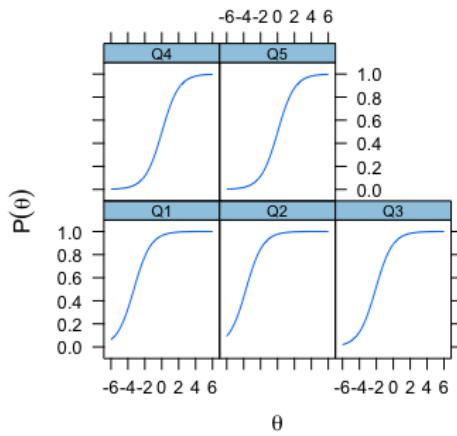


Item trace lines

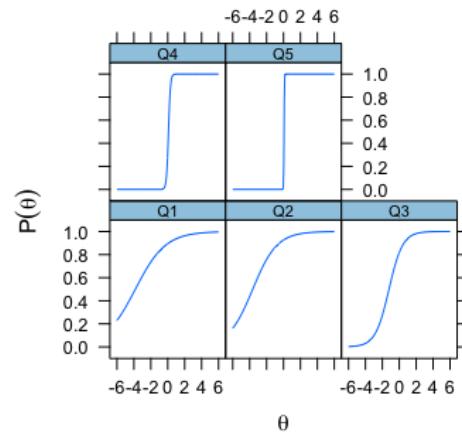


Period: 2018-1

Item trace lines



Item trace lines



Item trace lines

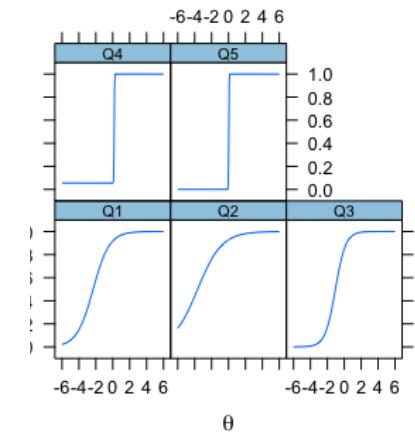


Table E: Coefficients of Logistic Models for Alternating current questionnaire

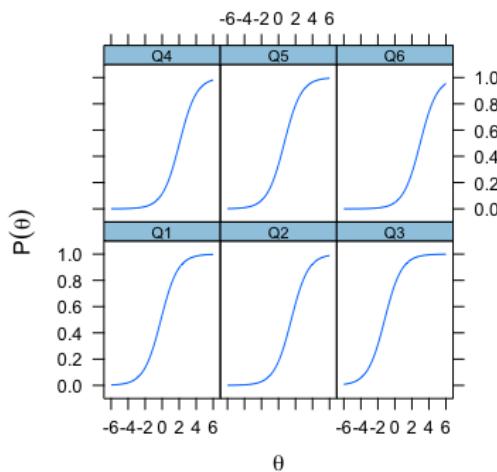
Alternating current

QUESTION	PERIOD	mod1b	mod2a	mod2b	mod3a	mod3b	mod3c
Q1	2016-2	-2.272	902	-1.965	0.85	-2.059	0
Q2	2016-2	-1.621	8.015	-675	21.951	-663	0
Q3	2016-2	0.43	1.031	331	13.021	746	261
Q4	2016-2	668	4.758	288	3.297	314	0
Q5	2016-2	2.396	1.352	1.575	1.502	1.483	0
Q1	2017-1	-1.576	2.198	-637	2.098	-0.65	0
Q2	2017-1	-1.576	35.442	-486	48.921	-493	0
Q3	2017-1	263	2.509	87	14.874	0.28	0.12
Q4	2017-1	117	3.66	33	3.213	44	0
Q5	2017-1	2.497	5.562	806	7.613	781	0
Q1	2017-2	-1.643	1.206	-1.123	1.304	-913	109
Q2	2017-2	-2.08	18.49	-821	19.967	-819	1
Q3	2017-2	-224	768	-225	773	-224	0
Q4	2017-2	1.367	3.793	597	3.777	597	0
Q5	2017-2	922	2.911	426	2.895	427	0
Q1	2018-1	-3.29	559	-3.829	1.039	-2.318	0
Q2	2018-1	-3.721	696	-3.636	0.7	-3.645	1
Q3	2018-1	-2.089	1.239	-1.214	1.659	-1.047	0
Q4	2018-1	27	8.597	85	45.986	171	56
Q5	2018-1	27	41.31	63	47.296	35	0

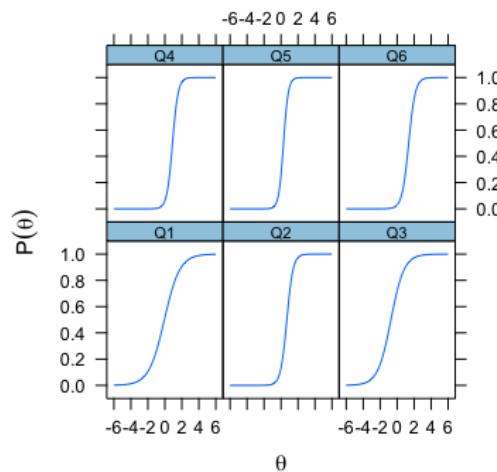
Graphical IRT Analysis: Questionnaire 6 - Effective Value

Period: 2016-2

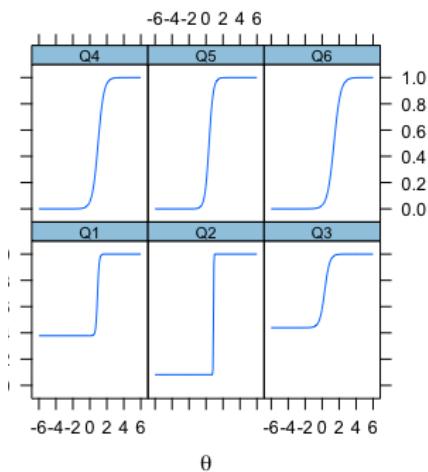
Item trace lines



Item trace lines

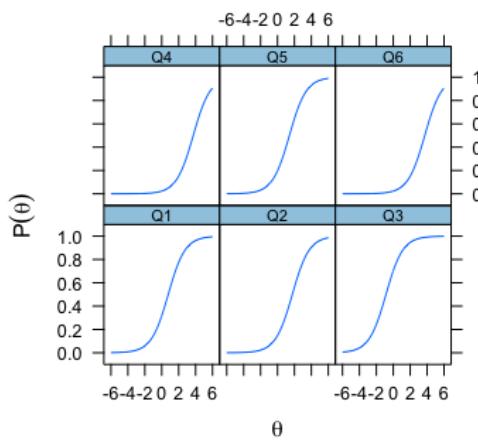


Item trace lines

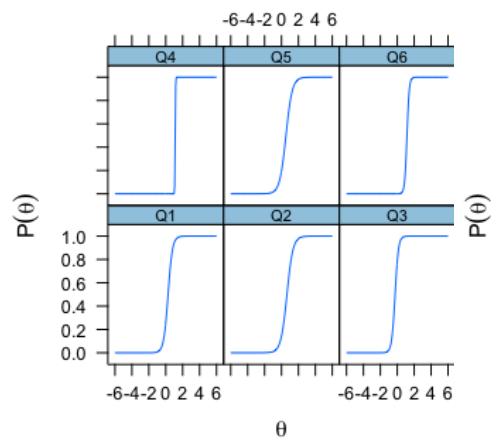


Period: 2017-1

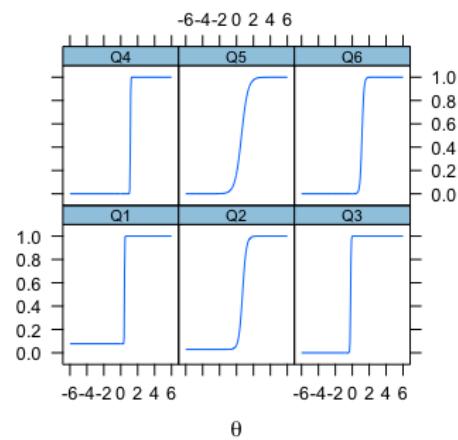
Item trace lines



Item trace lines

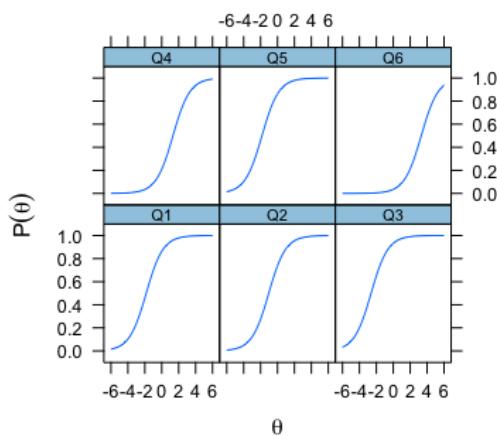


Item trace lines

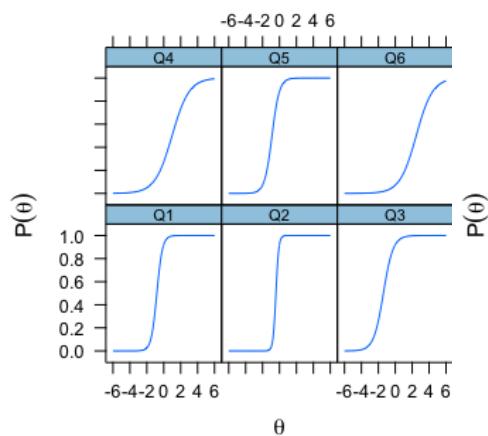


Period: 2017-2

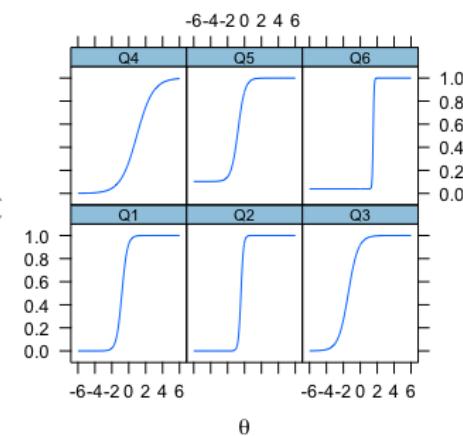
Item trace lines



Item trace lines

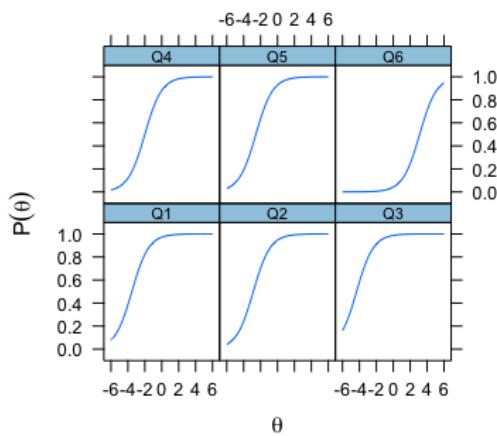


Item trace lines

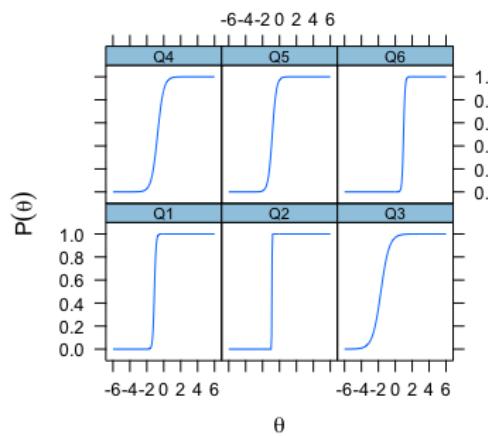


Period: 2018-1

Item trace lines



Item trace lines



Item trace lines

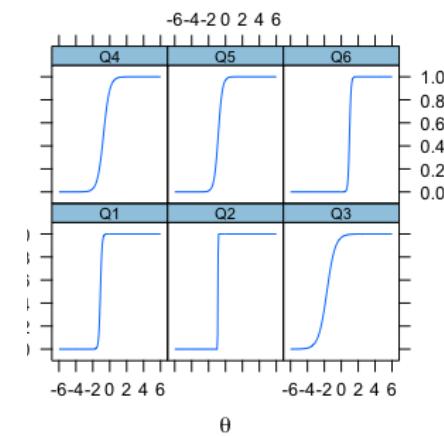


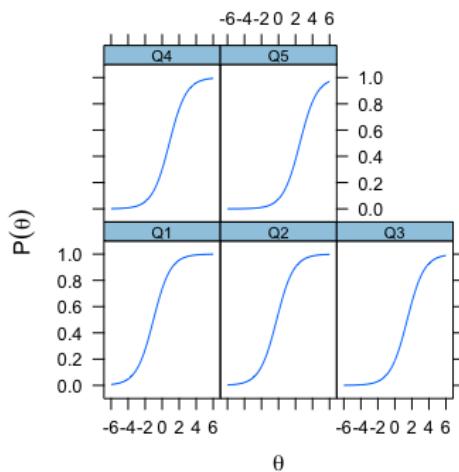
Table F: Coefficients of Logistic Models for Effective value questionnaire

QUESTION	PERIOD	Effective value					
		mod1b	mod2a	mod2b	mod3a	mod3b	mod3c
Q1	2016-2	-147	1.101	-0.06	10.013	0.9	378
Q2	2016-2	1.497	2.733	688	44.071	882	82
Q3	2016-2	-1.203	1.296	-728	3.419	302	439
Q4	2016-2	2.033	3.018	901	2.934	0.97	0
Q5	2016-2	0.67	3.581	295	4.072	363	0
Q6	2016-2	2.973	2.563	1.357	2.567	1.398	0
Q1	2017-1	765	3.857	274	59.482	0.44	77
Q2	2017-1	1.75	2.797	641	4.512	716	29
Q3	2017-1	-864	5.054	-258	30.559	-197	0
Q4	2017-1	3.722	42.343	1.116	44.965	1.133	0
Q5	2017-1	1.406	2.697	527	2.626	592	0
Q6	2017-1	3.722	7.509	1.145	8.611	1.149	0
Q1	2017-2	-1.836	3.028	-814	3.133	-807	0
Q2	2017-2	-1.033	5.959	-423	6.644	-418	0
Q3	2017-2	-2.619	1.745	-1.403	1.715	-1.415	0
Q4	2017-2	1.326	992	984	1.038	953	0
Q5	2017-2	-1.836	2.295	-886	2.467	-759	103
Q6	2017-2	3.307	1.035	2.475	18.7	1.524	39
Q1	2018-1	-3.533	10.11	-1.106	62.269	-914	249
Q2	2018-1	-2.859	59.328	-0.9	67.288	-892	0
Q3	2018-1	-4.337	2.027	-1.699	72.975	-0.71	607
Q4	2018-1	-1.997	2.786	-732	2.58	-781	0
Q5	2018-1	-2.555	4.124	-854	67.178	-688	116
Q6	2018-1	3.12	11.06	978	11.863	947	0

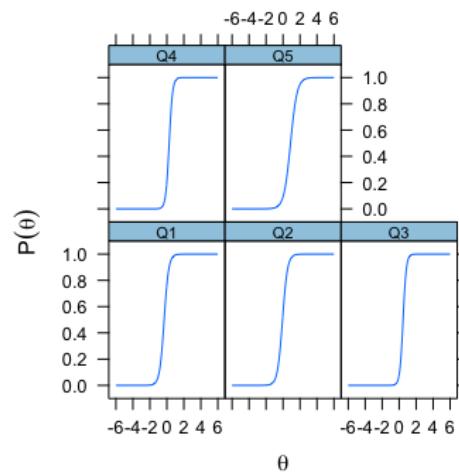
Graphical IRT Analysis: Questionnaire 7 - Phasors

Period: 2016-2

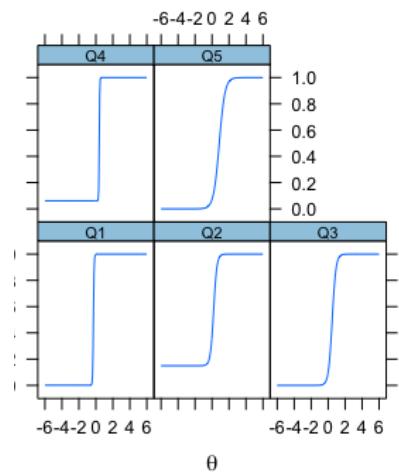
Item trace lines



Item trace lines

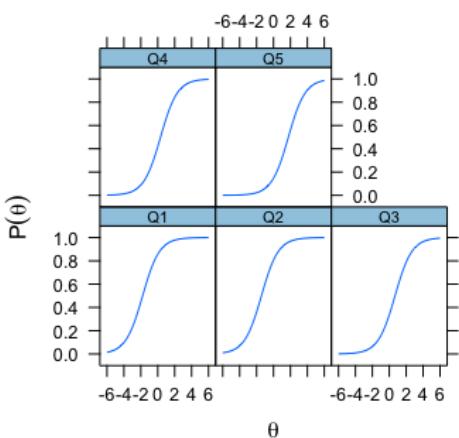


Item trace lines

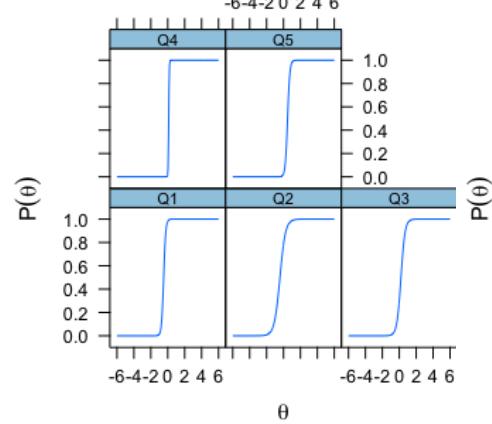


Period: 2017-1

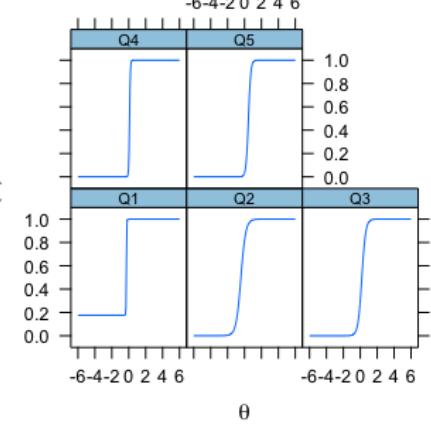
Item trace lines



Item trace lines

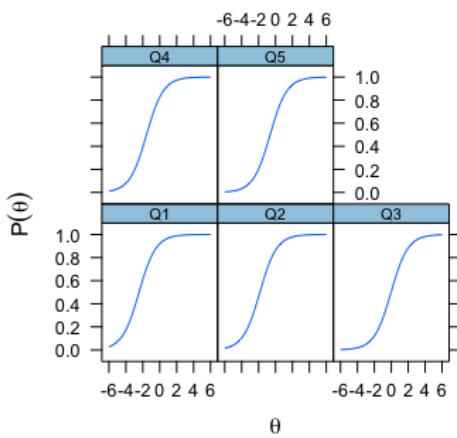


Item trace lines

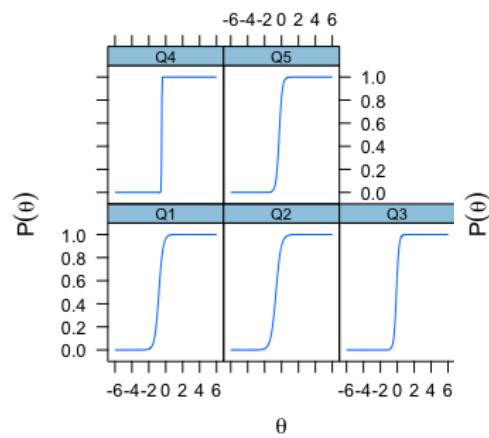


Period: 2017-2

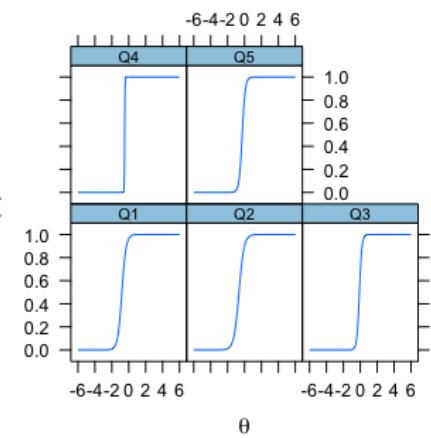
Item trace lines



Item trace lines

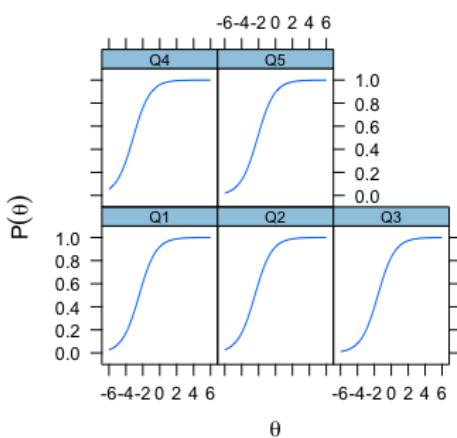


Item trace lines

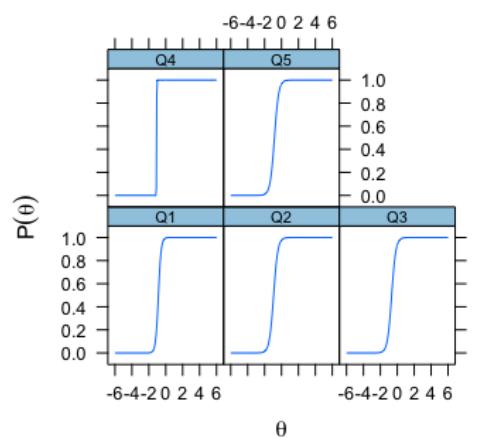


Period: 2018-1

Item trace lines



Item trace lines



Item trace lines

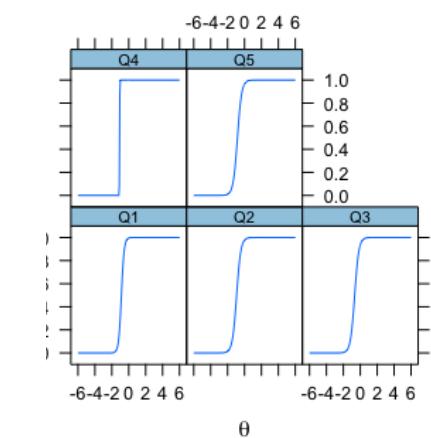


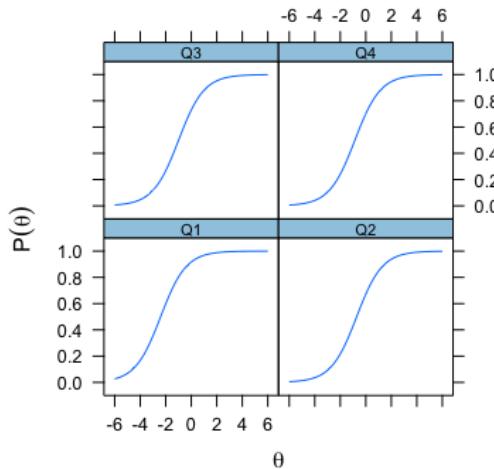
Table G: Coefficients of Logistic Models for Phasors questionnaire

Phasors							
QUESTION	PERIOD	mod1b	mod2a	mod2b	mod3a	mod3b	mod3c
Q1	2016-2	-1.024	3.738	-318	23.648	-289	1
Q2	2016-2	-217	3.404	-57	5.244	196	0.15
Q3	2016-2	1.453	5.28	462	4.571	479	0
Q4	2016-2	0.84	5.003	272	33.843	0.4	62
Q5	2016-2	2.509	2.591	886	2.988	857	0
Q1	2017-1	-1.786	8.202	-484	43.086	-277	176
Q2	2017-1	-1.426	3.042	-424	3.538	-424	0
Q3	2017-1	682	4.198	201	4.451	187	0
Q4	2017-1	0.33	30.703	115	20.548	96	0
Q5	2017-1	1.758	7.518	0.48	7.248	464	0
Q1	2017-2	-2.445	4.089	-807	4.088	-808	0
Q2	2017-2	-1.845	3.365	-654	3.364	-655	0
Q3	2017-2	-22	6.766	-102	6.756	-103	0
Q4	2017-2	-1.56	50.464	-484	55.498	-485	0
Q5	2017-2	-633	5.532	-271	5.54	-272	0
Q1	2018-1	-2.435	6.166	-868	6.17	-868	0
Q2	2018-1	-2.435	4.004	-932	4.005	-932	0
Q3	2018-1	-1.578	4.057	-662	4.057	-662	0
Q4	2018-1	-3.137	78.432	-1.08	73.159	-1.081	0
Q5	2018-1	-2.127	3.972	-836	3.972	-836	0

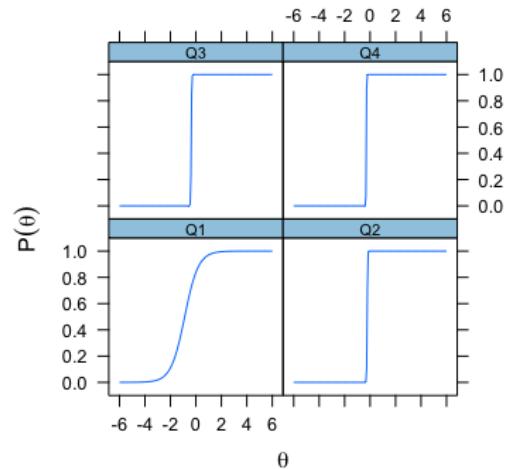
Graphical IRT Analysis: Questionnaire 8 - Transformers

Period: 2016-2

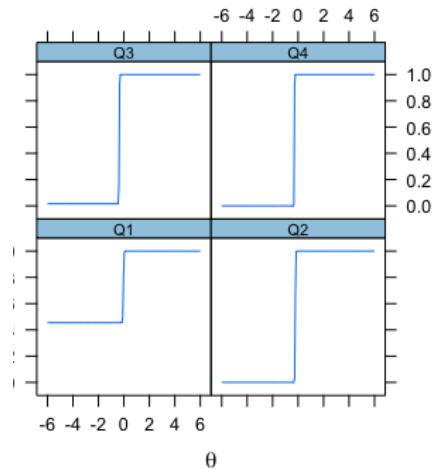
Item trace lines



Item trace lines

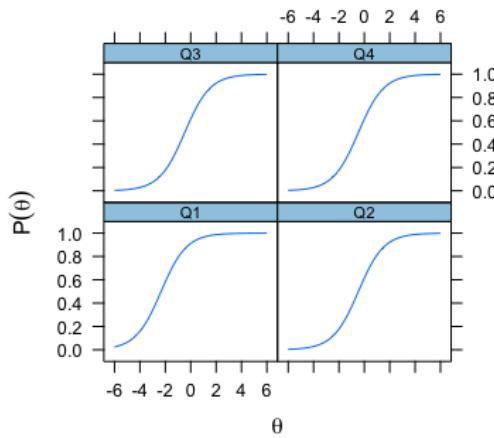


Item trace lines

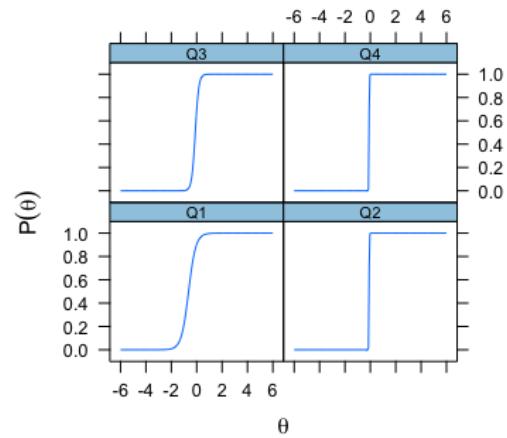


Period: 2017-1

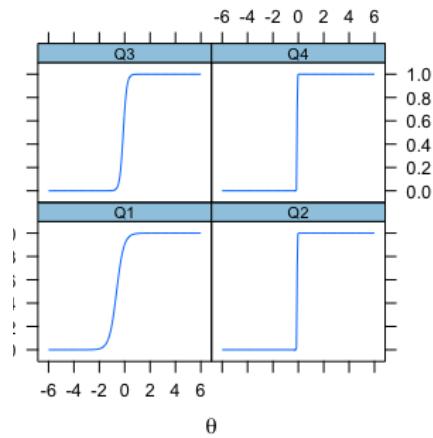
Item trace lines



Item trace lines

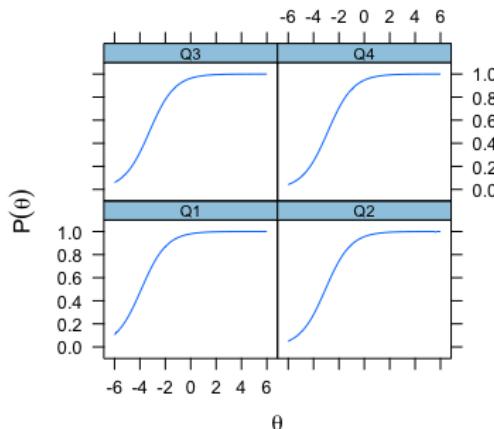


Item trace lines

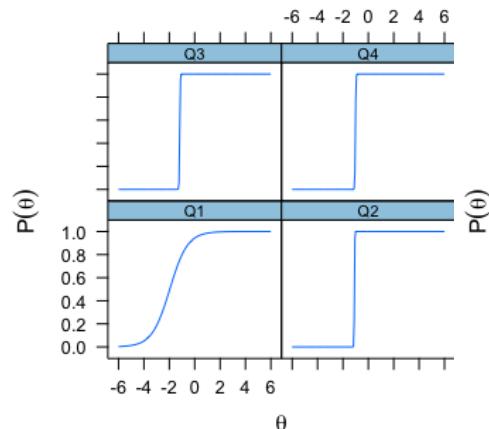


Period: 2017-2

Item trace lines



Item trace lines



Item trace lines

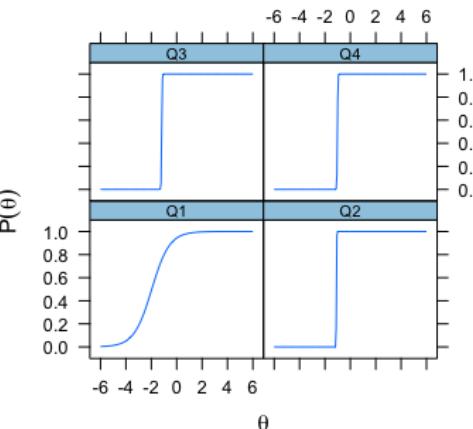


Table H: with coefficients of Logistic Models for Transformers questionnaire

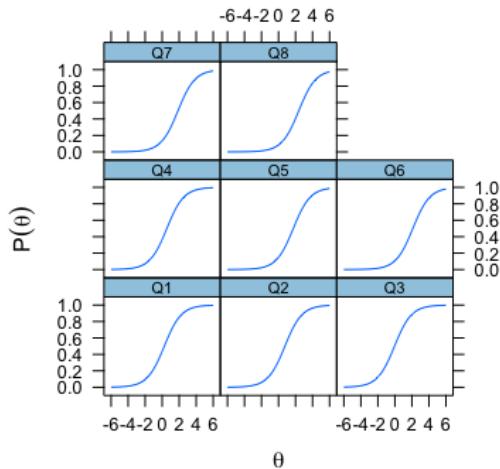
Transformers

QUESTION	PERIOD	mod1b	mod2a	mod2b	mod3a	mod3b	mod3c
Q1	2016-2	-2.4	1.863	-0.88	49.229	-41	455
Q2	2016-2	-716	52.073	-229	69.622	-223	0
Q3	2016-2	-993	50.063	-367	72.057	-367	15
Q4	2016-2	-854	77.952	-299	112.237	-294	0
Q1	2017-1	-2.332	3.508	-638	3.507	-639	0
Q2	2017-1	-469	84.197	-101	88.938	-0.1	0
Q3	2017-1	-469	7.258	-112	7.256	-112	0
Q4	2017-1	-469	84.197	-101	88.873	-0.1	0
Q1	2017-2	-3.891	1.428	-1.964	1.429	-1.964	0
Q2	2017-2	-3.062	66.766	-1.096	81.617	-1.096	0
Q3	2017-2	-3.253	46.997	-1.179	51.043	-1.181	0
Q4	2017-2	-2.878	47.803	-1.019	51.512	-1.018	0

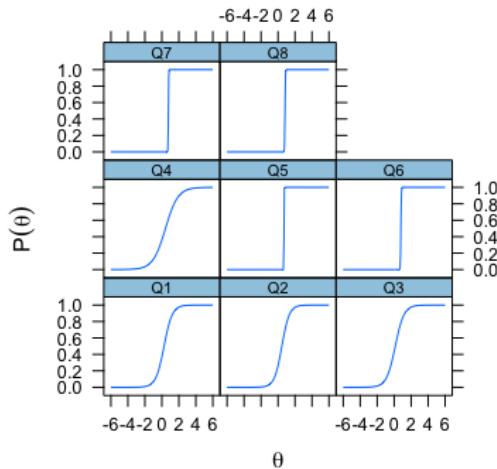
Graphical IRT Analysis: Questionnaire 9 - Multipole Alternator

Period: 2016-2

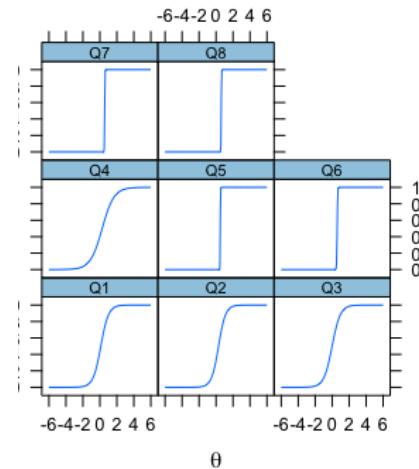
Item trace lines



Item trace lines

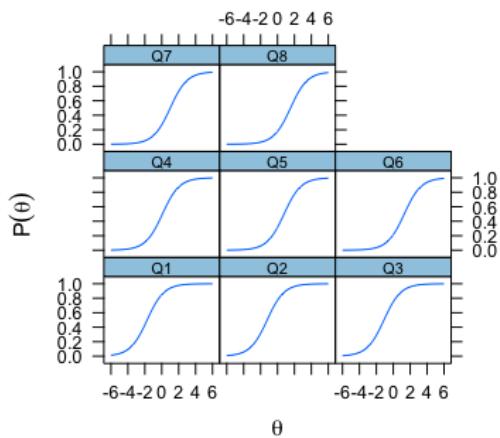


Item trace lines

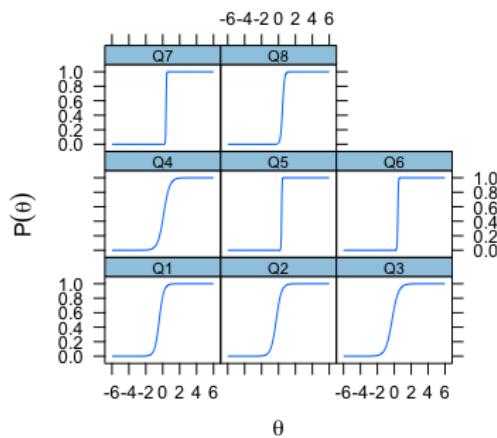


Period: 2017-1

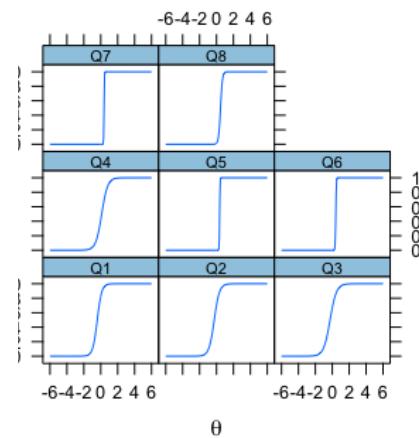
Item trace lines



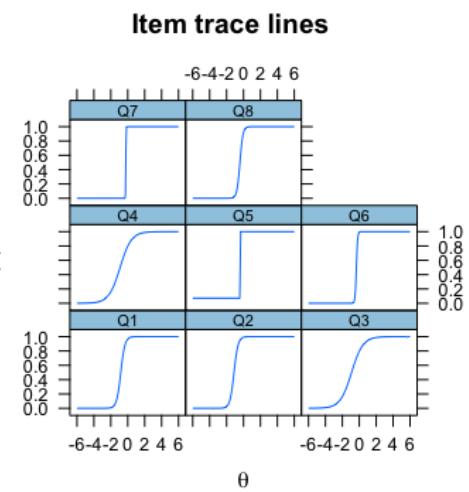
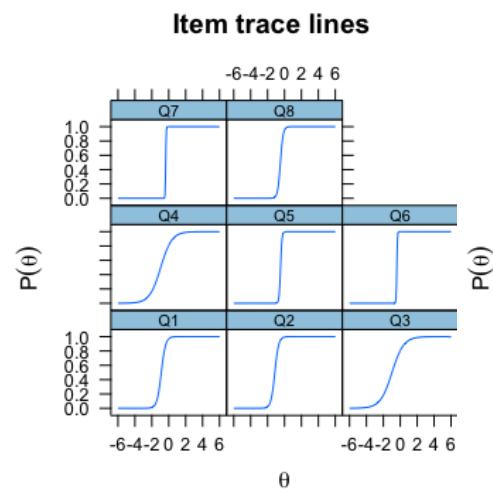
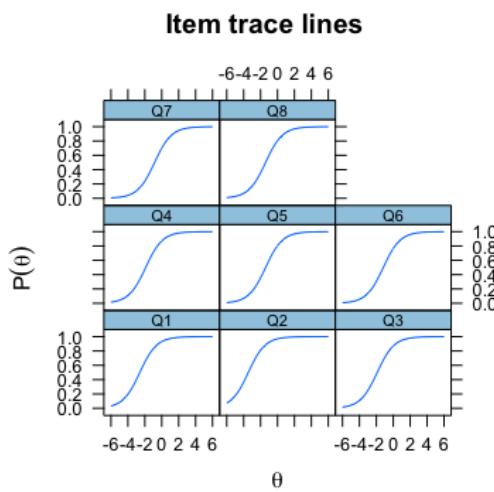
Item trace lines



Item trace lines



Period: 2017-2



Period: 2018-1

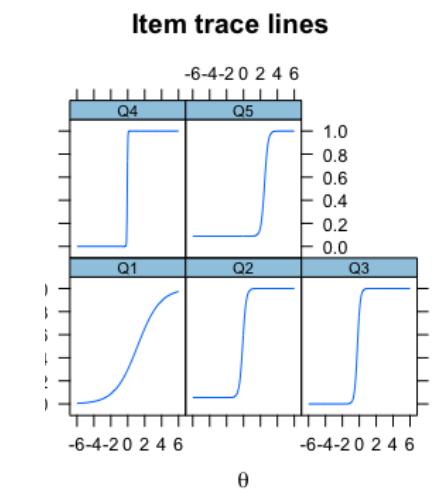
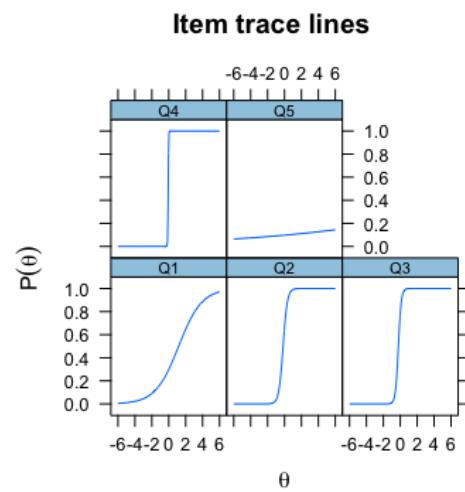
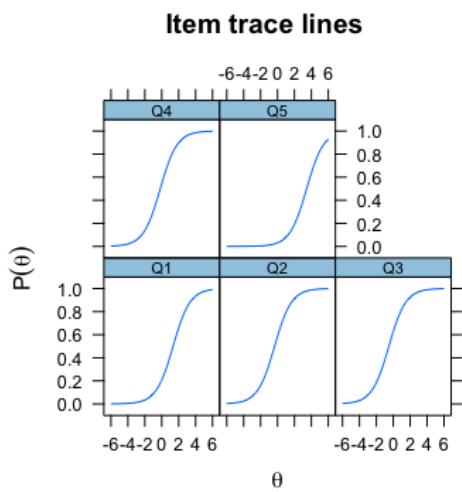


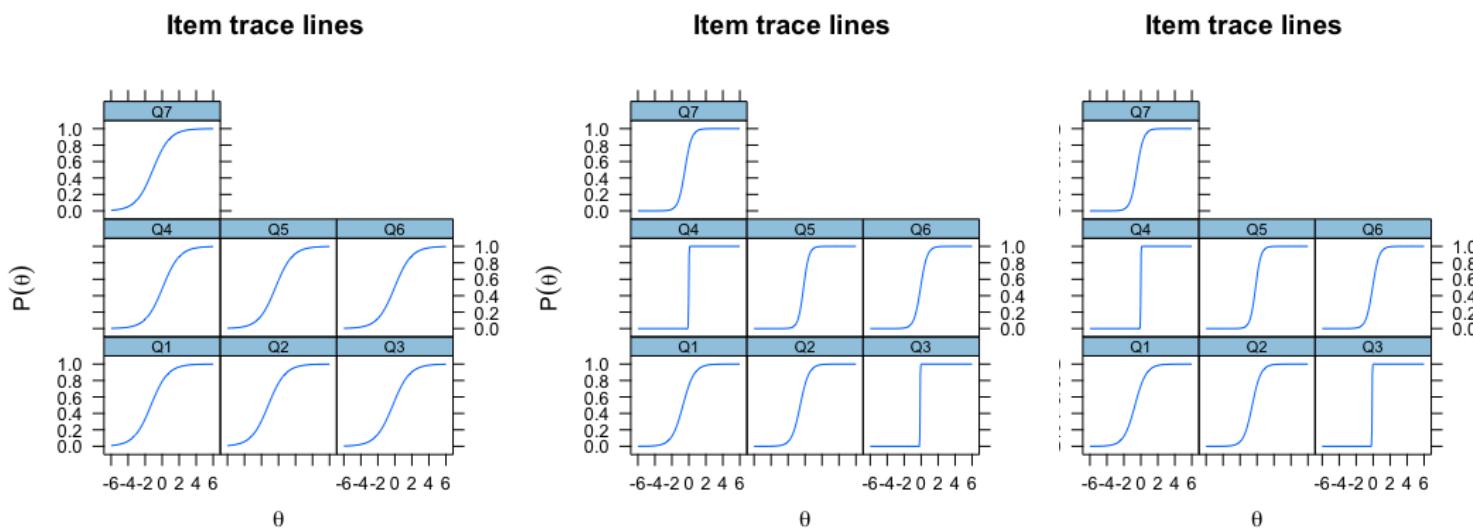
Table I: Coefficients of Logistic Models for Multi Pole alternator questionnaire

Multipole alternator circuit analysis

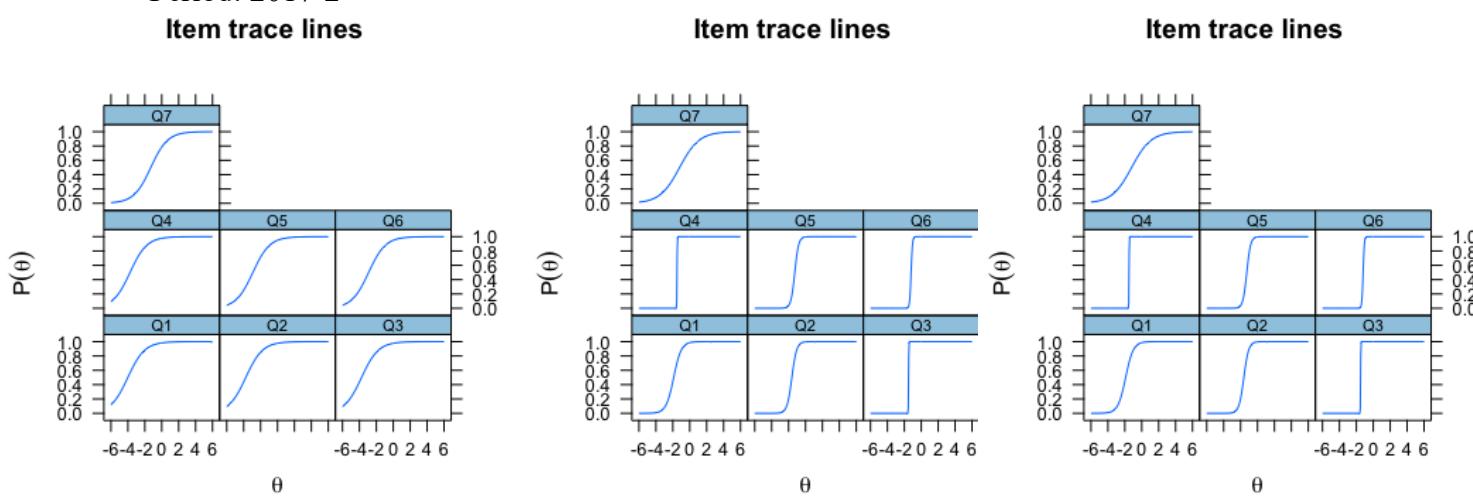
QUESTION	PERIOD	mod1b	mod2a	mod2b	mod3a	mod3b	mod3c
Q1	2016-2	252	2.079	259	2.207	115	0
Q2	2016-2	753	2.278	457	2.425	0.3	0
Q3	2016-2	-42	1.947	134	2.071	-2	0
Q4	2016-2	0.55	1.36	425	1.436	275	0
Q5	2016-2	1.738	79.74	703	79.877	502	0
Q6	2016-2	2.112	37.86	792	32.69	592	0
Q7	2016-2	1.859	55.466	768	58.725	0.57	0
Q8	2016-2	2.381	44.882	0.82	57.767	617	0
Q1	2017-1	-1.725	3.776	-413	3.775	-413	0
Q2	2017-1	-1.22	3.251	-269	3.251	-268	0
Q3	2017-1	-1.096	2.659	-261	2.66	-261	0
Q4	2017-1	85	2.873	115	2.874	115	0
Q5	2017-1	775	39.461	366	43.849	369	0
Q6	2017-1	1.299	29.147	414	30.648	413	0
Q7	2017-1	1.006	39.035	387	42.91	389	0
Q8	2017-1	1.537	8.838	473	8.878	473	0
Q1	2017-2	-2.592	3.928	-879	4.067	-822	0
Q2	2017-2	-3.451	4.441	-1.145	4.177	-1.121	0
Q3	2017-2	-1.898	1.455	-975	1.499	-909	0
Q4	2017-2	-1.898	1.527	-0.95	1.509	-906	0
Q5	2017-2	-1.409	11.934	-468	146.279	-391	72
Q6	2017-2	-1.179	26.36	-0.41	13.766	-343	0
Q7	2017-2	-844	34.151	-0.36	59.274	-225	0
Q8	2017-2	-1.409	6.159	-484	5.636	-424	0

Graphical IRT Analysis: Questionnaire 10 - Transformers II

Period: 2016-2

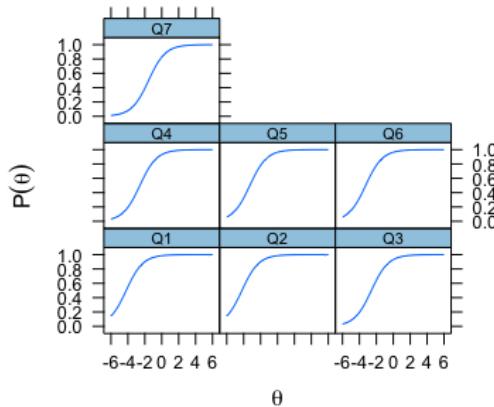


Period: 2017-2

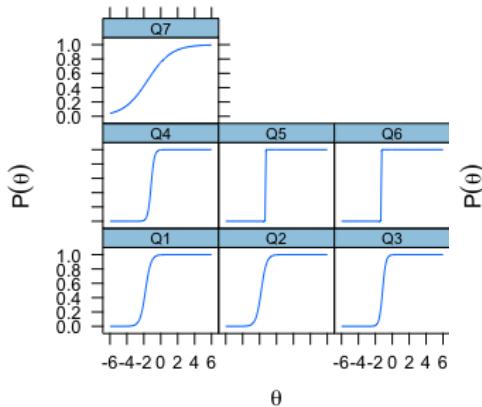


Period: 2018-1

Item trace lines



Item trace lines



Item trace lines

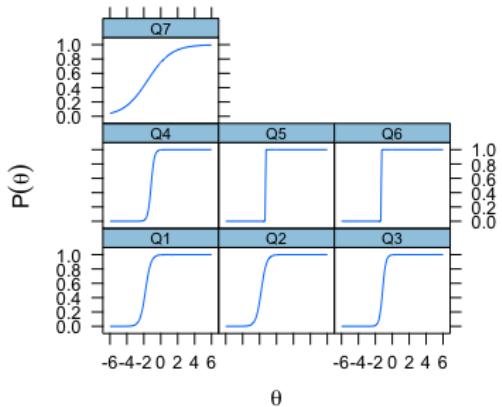


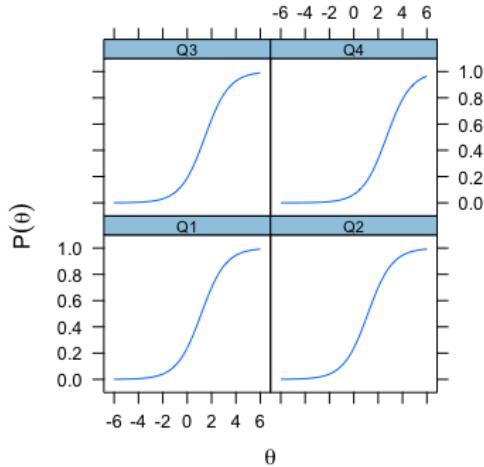
Table J: Coefficients of Logistic Models for Transformers II questionnaire

Transformers II

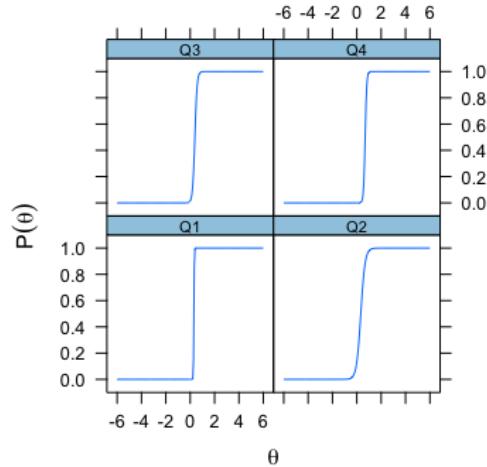
QUESTION	PERIOD	mod1b	mod2a	mod2b	mod3a	mod3b	mod3c
Q1	2016-2	-1.311	1.505	-688	1.506	-688	0
Q2	2016-2	-1.198	1.962	-556	1.963	-556	0
Q3	2016-2	-243	61.997	-123	59.907	-124	0
Q4	2016-2	65	48.653	-15	55.953	-14	0
Q5	2016-2	-346	3.136	-167	3.136	-168	0
Q6	2016-2	-37	2.581	-64	2.58	-64	0
Q7	2016-2	-1.087	2.516	-0.46	2.516	-0.46	0
Q1	2017-1	-681	2.993	-302	3.187	-317	0
Q2	2017-1	-0.39	2.963	-203	3.12	-219	0
Q3	2017-1	-246	30.514	-168	84.095	-0.11	55
Q4	2017-1	183	42.856	-27	47.162	-22	0
Q5	2017-1	-829	4.226	-326	4.531	-0.34	0
Q6	2017-1	-1.446	3	-564	3.321	-575	0
Q7	2017-1	-829	1.014	-571	1.1	-567	0
Q1	2017-2	-4.008	2.228	-1.898	2.213	-1.902	0
Q2	2017-2	-3.749	3.532	-1.611	3.501	-1.614	0
Q3	2017-2	-3.749	63.977	-1.498	67.516	-1.499	0
Q4	2017-2	-3.749	63.977	-1.498	67.516	-1.499	0
Q5	2017-2	-2.913	4.4	-1.269	4.422	-1.269	0
Q6	2017-2	-2.913	12.258	-1.203	13.979	-1.201	0
Q7	2017-2	-1.293	862	-1.196	861	-1.197	0
Q1	2018-1	-4.203	3.156	-1.8	3.154	-1.8	0
Q2	2018-1	-4.203	3.156	-1.8	3.154	-1.8	0
Q3	2018-1	-2.586	5.137	-1.142	5.134	-1.141	0
Q4	2018-1	-2.586	5.137	-1.142	5.134	-1.141	0
Q5	2018-1	-3.266	81.532	-1.299	73.764	-1.301	0
Q6	2018-1	-3.266	81.532	-1.299	73.764	-1.301	0
Q7	2018-1	-1.556	0.71	-1.563	0.71	-1.563	0

Period: 2016-2

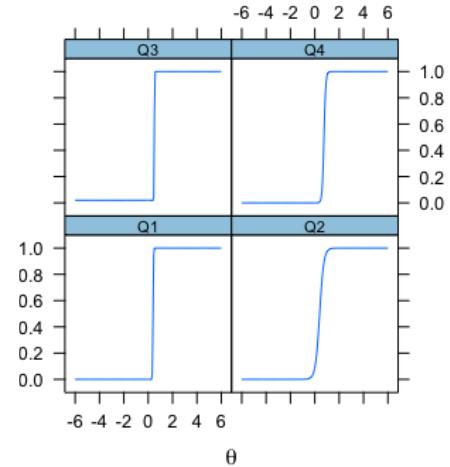
Item trace lines



Item trace lines

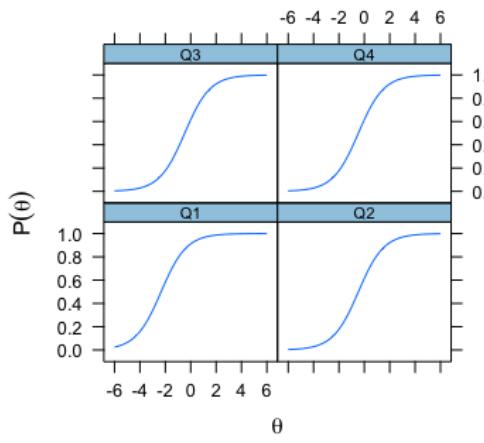


Item trace lines

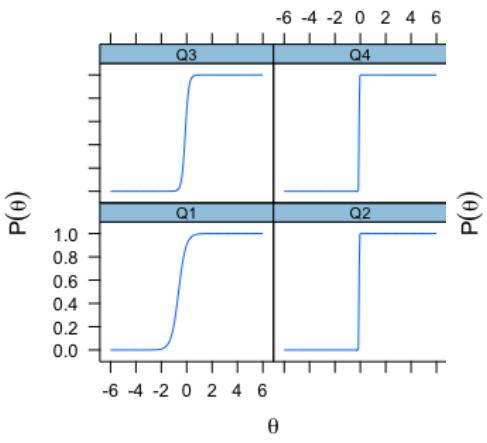


Period: 2017-1

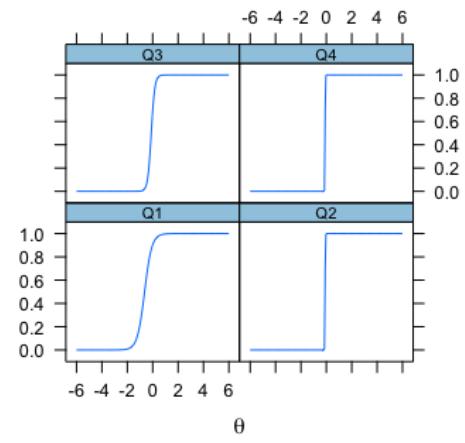
Item trace lines



Item trace lines

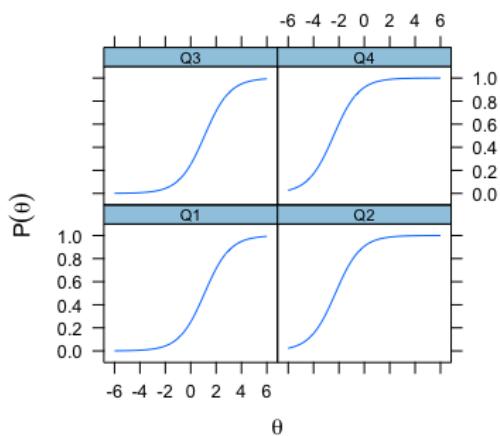


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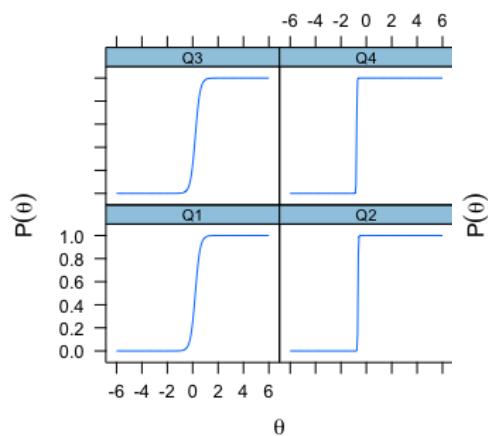


Period: 2017-2

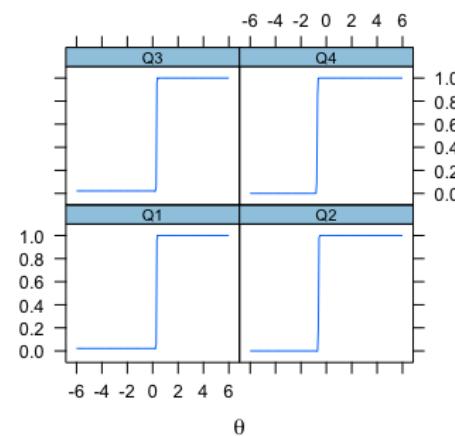
Item trace lines



Item trace lines

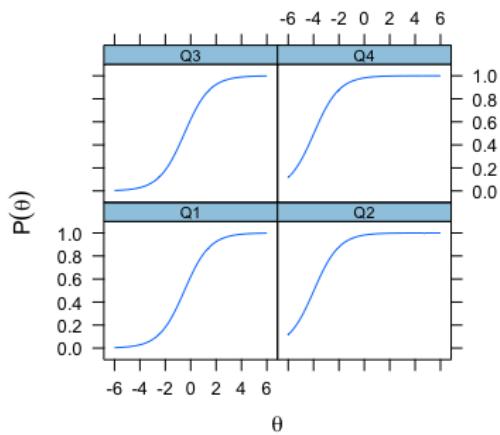


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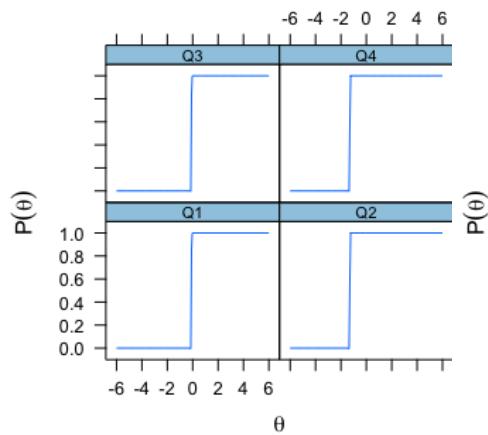


Period: 2018-1

Item trace lines



Item trace lines



Item trace lines

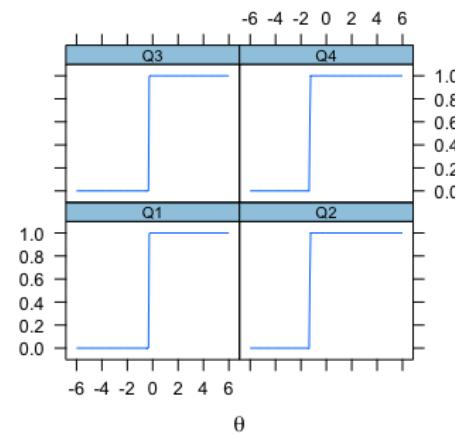


Table K: Coefficients of Logistic Models for Three phase transformers questionnaire

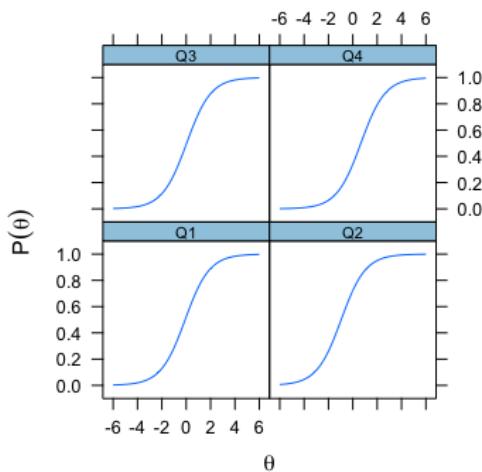
Three Phase Transformers

QUESTION	PERIOD	mod1b	mod2a	mod2b	mod3a	mod3b	mod3c
Q1	2016-2	1.157	58.115	301	49.992	394	0
Q2	2016-2	1.157	5.73	327	5.868	395	0
Q3	2016-2	1.447	10.956	382	71.033	502	0.02
Q4	2016-2	2.683	15.673	683	13.783	752	0
Q1	2017-1	-2.332	3.508	-638	3.507	-639	0
Q2	2017-1	-469	84.197	-101	88.938	-0.1	0
Q3	2017-1	-469	7.258	-112	7.256	-112	0
Q4	2017-1	-469	84.197	-101	88.873	-0.1	0
Q1	2017-2	1.092	5.3	208	105.885	302	22
Q2	2017-2	-2.277	57.122	-661	87.141	-616	0
Q3	2017-2	1.092	5.3	208	105.885	302	22
Q4	2017-2	-2.424	53.713	-766	66.015	-0.72	0
Q1	2018-1	-492	158.643	-102	153.432	-299	0
Q2	2018-1	-3.975	141.006	-1.299	137.898	-1.3	0
Q3	2018-1	-492	158.417	-101	153.124	-0.3	0
Q4	2018-1	-3.975	141.032	-1.299	137.898	-1.3	0

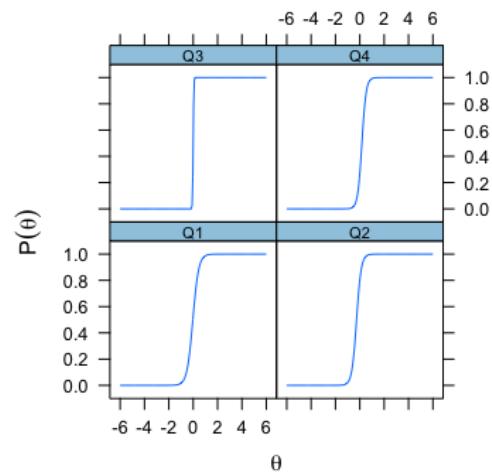
Graphical IRT Analysis: Questionnaire 12 - Power Factor

Period: 2016-2

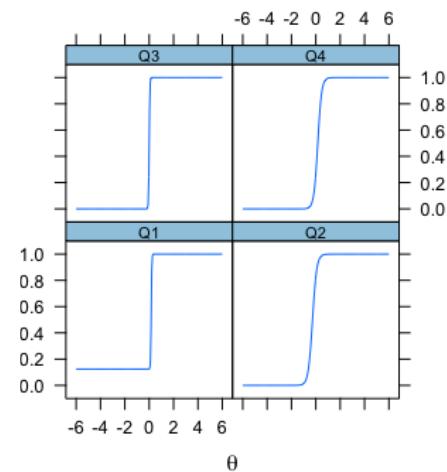
Item trace lines



Item trace lines

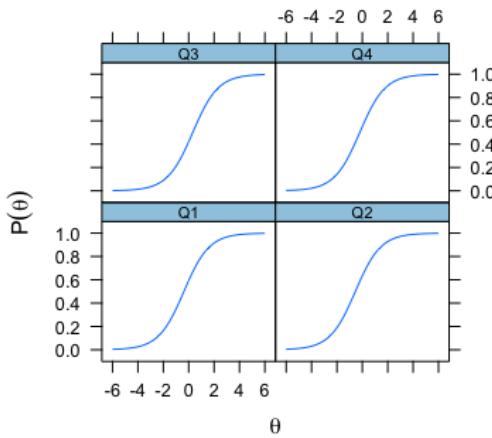


Item trace lines

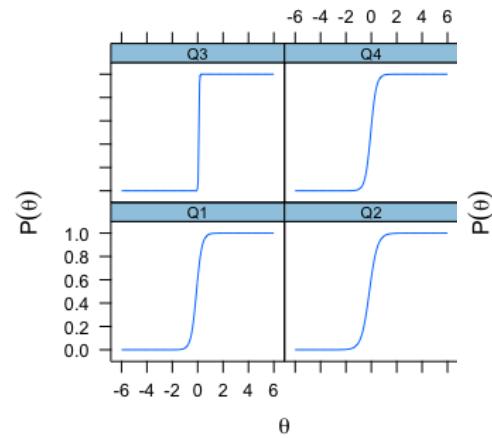


Period: 2017-1

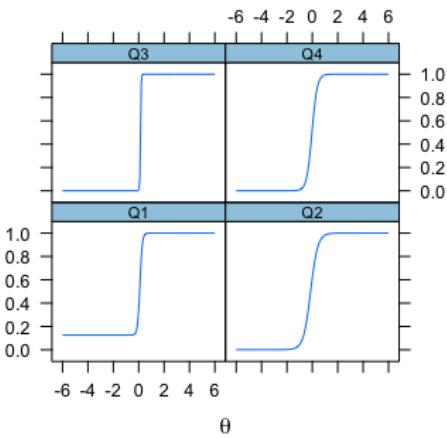
Item trace lines



Item trace lines

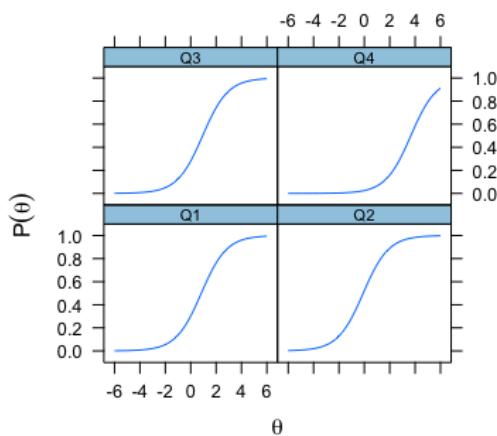


Item trace lines

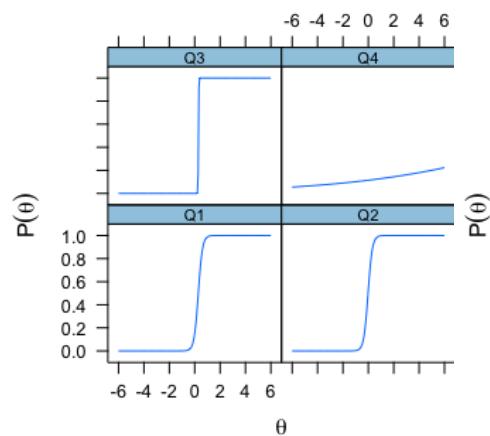


Period: 2017-2

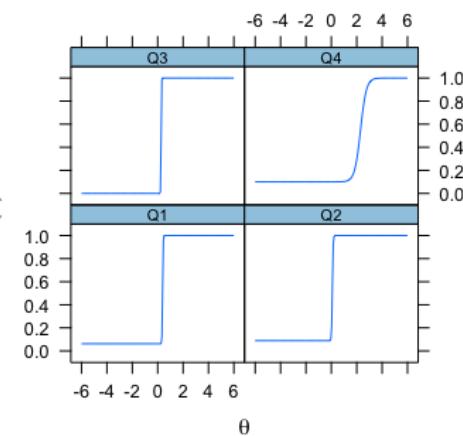
Item trace lines



Item trace lines

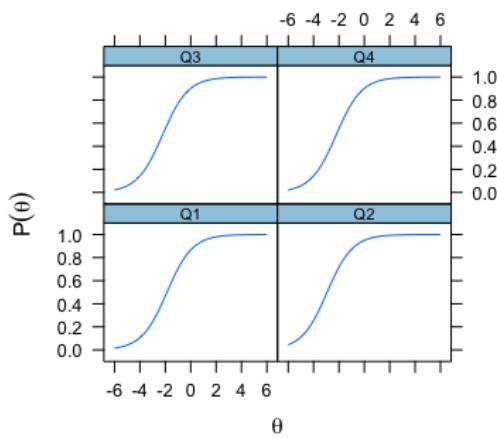


Item trace lines

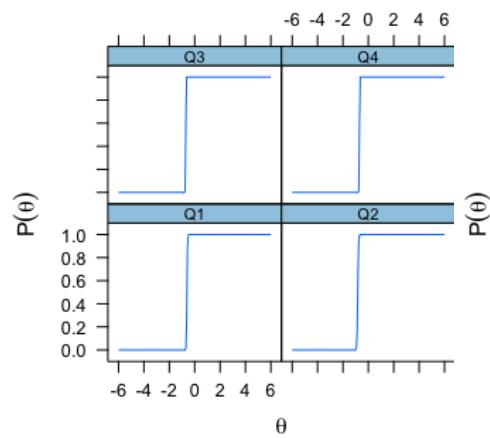


Period: 2018-1

Item trace lines



Item trace lines



Item trace lines

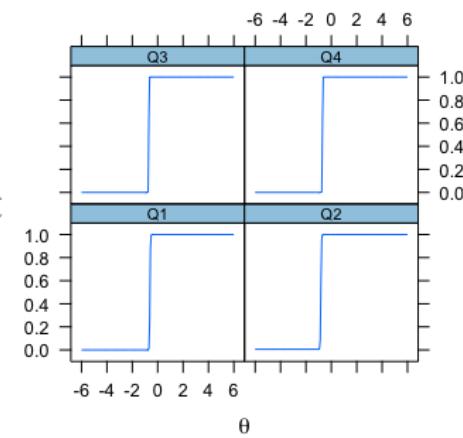


Table L: Coefficients of Logistic Models for Power factor questionnaire

Power factor							
QUESTION	PERIOD	mod1b	mod2a	mod2b	mod3a	mod3b	mod3c
Q1	2016-2	-88	4.19	-0.03	41.537	166	124
Q2	2016-2	-957	5.233	-268	5.795	-272	0
Q3	2016-2	37	40.056	-2	37.255	1	0
Q4	2016-2	663	5.834	172	6.293	0.16	0
Q1	2017-1	-377	4.645	-95	11.015	0.1	126
Q2	2017-1	-0.55	3.184	-152	3.544	-136	1
Q3	2017-1	319	41.788	89	38.187	145	0
Q4	2017-1	-203	4.601	-44	4.871	-28	0
Q1	2017-2	836	6.094	285	47.649	388	63
Q2	2017-2	-89	5.965	-21	33.993	81	89
Q3	2017-2	942	67.345	296	67.332	272	0
Q4	2017-2	3.663	133	15.418	4.356	2.3	0.1
Q1	2018-1	-1.868	49.831	-611	52.78	-0.61	0
Q2	2018-1	-2.927	35.991	-832	45.71	-823	5
Q3	2018-1	-2.208	86.833	-0.7	92.651	-0.7	0
Q4	2018-1	-2.208	86.833	-0.7	92.651	-0.7	0