Parameter Space Reasoning (PSR) Reports

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Executive Summary

The InquirySpace project has identified and theoretically characterized Parameter Space Reasoning (PSR) as the type of cognition necessary for students to successfully engage in inquiry-based experimentation. PSR is associated with planning experiments, operationalizing a set of parameters, navigating the parameter space through multiple experimental runs, identifying patterns in parameter space plots, and reflecting on sources of error. This theorization of the PSR construct was used to develop the PSR test. In this document, the construct validity of the PSR test was examined using the Rasch-Partial Credit Model which assumes single dimensionality among the items in the PSR test. The Rasch-PCM analysis results indicate that (1) the PSR test was highly reliable, (2) scoring rubrics reflected students' performance levels predicted by the underlying PSR construct, and (3) items in the PSR test were considered forming a uni-dimensional construct. Instructional sensitivity of the items on the PSR test was also examined. Students improved the most on the items addressing the experimentation context identical to the IS curriculum activities. The student improvement became less and less prominent as the item context was farther and farther removed from the IS curriculum contexts. The impact of the IS intervention on students' learning of PSR was compared across three teachers. The results indicated variations among three teachers in terms of how much students were impacted by the IS curriculum. Students in one teacher in particular were most impacted by the IS as compared to the other two teachers. This finding will guide the next stage of the research so as to describe how the IS curriculum activities were implemented across three teachers and explain why students in one teacher's class outperformed those in the other two teachers' classes as measured by the PSR test.

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Appendix

I. Parameter Space Reasoning Definition

Text below comes from Lee et al. (2014)'s paper presented at the ICLS in June, 2014.

A parameter is referred to as a measurable factor that defines a system or determines the conditions of a system's function. In science, a parameter space is defined as all possible combinations of values related to a set of parameters that define a system. A different set of parameters is used for a different system or a phenomenon under investigation. Parameter space also depends on the conceptualization of an experimenter or a modeler who studies a system. An experimental run can be described as a point in an *n*-dimensional parameter space where the number of parameters related to a system is *n*. Some parameters are salient to determine a given outcome while others are not. The range of a parameter can be plotted on one axis (typically, x) and the outcome of a system can be plotted on another axis (y, for example). In a spring-mass system, an outcome variable of interest such as period can be estimated from a sinusoidal graph between the distance from the center and time, instead of directly measuring it. We call a graph that shows changes in a variable over time as a time-series graph. If all other remaining parameters are kept constant, then a point representing (parameter space value, outcome value) can effectively summarize the result of an experimental run. We call this plot a parameter-outcome graph. It is quite possible that experimenting with different regions of the parameter space yields different results, e.g., a spring too stretched to lose its elasticity. Therefore, it is important to explore the adequate range of the parameter space to test a model or a relationship in experimentation.

An investigation includes multiple experimental runs, each of which is defined uniquely by a set of values chosen for the run (as one run sets a single value for each parameter, two values of the same parameter cannot be investigated simultaneously in a single run). The region of parameter space examined by students can be traced. Before experimental runs, students need to plan for which variables to vary and how to vary them. At the end of each experimental run, students must make decisions on their next step such as redoing the same experiment, varying parameter values, checking their equipment, and eventually concluding their investigation. After all the data are collected, students need to think about the quality of the data and recognize relationships between the parameters they manipulated and system outcomes they measured. PSR captures this array of cognitive processes as they relate to empirical inquiry, and entails, among other things, the ability to compare an experimental run to other runs that differ in the value of at least one parameter. Table 1 lists PSR in three phases of an investigation: parameter setting, data collection, and data analysis and describes the reasoning in each investigation step and how PSR can be observed.

<u>Table 1: Characterization of parameter space reasoning (PSR) during student investigation.</u>

Investigation phases	Investigation steps	PSR occurs as students:
Parameter setting	• Formulate a question with parameters and outcome variable • Identify parameters and outcome variables for an	• Set parameters for an investigation based on the question and the setup • Conduct test runs to build a mental model between the phenomenon under investigation and the data to be acquired

	experimental setup • Know how to vary parameters and measure outcome variables	• Describe which variables will be varied and how
Data collection	• Select a parameter set, carry out a run and measure the outcome variable • Reflect on the quality of the run. • Determine whether to rerun or stop data collection	• Make multiple runs purposefully to answer the question • Determine when to rerun, modify a run, or stop data collection • Select data for analysis
Data analysis	• Calculate a way to characterize a run with a single value, in order to compare runs • Create a parameter-outcome graph • Use a time series graph to obtain an outcome value • Identify patterns in a parameter-outcome graph • Reflect on quality of data • Answer the question using evidence generated from the investigation	• Calculate and incorporate outcome into analysis • Create and explain parameter-outcome graphs • Explain a point in the parameter space in connection to a time series graph of a run • Recognize the shape and important features parameter-outcome graphs (linear, nonlinear, periodic, etc. or break points where the nature of shape changes) • Identify and treat outliers • Identify and treat noise in the data and noise sources • Communicate conclusions using evidence

Inquiry-based investigations in science class have been promoted as an important pedagogical approach in science education reforms. PSR —the ability to think about the simulation runs as simply data points at a higher–level—can get confounded with other "inquiry skills" such as the ability to ask "interesting" questions, the ability to come up with experimental designs likely to shed light on a question, the ability to control potentially confounding variables, and the ability to reliably distinguish signal from noise. The science education literature refers to "systematicity" (often mindlessly recommending the "one size fits all" strategy of varying only one parameter at a time) or suggests as a normative standard that students exhaustively cover every region in the parameter space no matter what question they are trying to answer. Such supposed universal markers for PSR are clearly too simplistic to capture the richness of the phenomena under study. As more and more learning technologies are integrated to form powerful learning environments, it becomes necessary to reconceptualize student reasoning in a more nuanced and multi-faceted manner.

II. PSR Test Design and Specifications

Item Design Principles

Principle 1: The construct to assess is Parameter Space Reasoning. The following five PSR reasoning elements are tested.

- PSR1. Describe a scientific phenomenon using a primary graph (e.g., time series).
- PSR2. Set, measure or obtain a dependent variable from a primary graph (e.g., time series)
- PSR3. Make a parameter space graph using data from a primary graph.
- PSR4. Identify patterns represented in a parameter space graph and explain the patterns.
- PSR5. Treat, identify or explain outliers or errors in a primary or a parameter space graph

Principle 2: Make items accessible to students by using a minimum level of technology for the test so that not knowing technology does not become a main reason for students' performance on the test.

Principle 3: Address a particular aspect of PSR reasoning, not students' ability to conduct an investigation or use equipment or use technology.

Principle 4: Use contexts with varying degrees of transfer.

- The Mass set is identical to the IS curriculum context
- The Pendulum set is parallel to the spring/mass set and represents a near transfer from the IS curriculum context
- The Dash set is content lean but represents a physics context and thus a medium transfer from the IS curriculum context
- The Sarah set is content lean and represents a biological context involving multi-variate relationships. The Sarah set represents a far transfer context in terms of content and complexity.

Principle 5: Use both content-heavy and -lean item contexts from the IS curriculum to enhance interpretation of the IS curriculum impact on students.

- Include items addressing content-lean basic graphing knowledge and skill such as
  - representing a real-world factor on an axis and or y axis
  - scale axis
  - represent a point and multiple points
  - compare multiple points
  - identify overall trend and outliers
- Include items that can gain students' status of understanding of science contexts in content-heavy items such as pendulum and spring/mass systems.

PSR Test Specifications

- Four item contexts: Dash, Sarah, Pendulum, Mass
- Each item set has seven items.
- The PSR test consists of 28 items.
- The total score for the PSR test is 69.
- The recommended implementation time for the PSR test is one class period (40 to 45 minutes long).

- Both online and offline versions of the PSR are available.
- The PSR test is included in Appendix A.

III. PSR Test Construct Validity

The PSR test was taken by 415 students from five teacher in four high school settings.

- Njaa from Falmouth High School in Maine
- Chloe from Match High School in Boston, MA
- Macuk and Andrus from Arlington High School in Arlington, MA
- Weathers from North Reading High School in Reading, MA

All five teachers' students (N=415) took the PSR pretest. Three teachers' students (N=241) took the PSR posttest. These three teachers whose students completed both pre and posttests were Njaa, Andrus, and Weathers. A total of 656 students' PSR prepost test data were scored. Higher scores in open-ended items represented more complete and sophisticated answers. Higher scores in multiple-choice, short-answer, or plotting items represented complete and correct answers. The same type of scoring rubrics and the same score ranges were applied to items with the same PSR type. For details, see scoring rubrics included in Appendix B. See Appendix C for item and scoring specifications across PSR types.

In order to test the construct validity of the PSR test, we used the student data from PSR pre and posttests. We eliminated students who responded less than 50 percent of the PSR test. After elimination, we had a database of 631 student records. We applied the Rasch analysis based on the Partial Credit Model (PCM) to the database to examine the construct validity of the PSR test. The PSR test showed an excellent reliability of .87. Consider that instruments with reliabilities higher than .70 are generally accepted for research use in education. This indicates that the PSR is acceptable to use in the IS curriculum intervention research. The actual output for the Rasch-PCM analysis results is available in Appendix D.

Table 2 shows a summary of Rasch PCM analysis results. To see whether all items fit the Rasch-PCM model, take a look at the Fit statistics columns (unweighted and weighted). The acceptable value ranges for fit statistics is between 0.7 and 1.3. According to the unweighted fit statistics, there were four items that were outside of this acceptable range. For the weighted fit statistics, only one item, D7, was outside of the acceptable range. Other than these items, all items were within the acceptable range of fit statistics. For the item-test correlations, the acceptable values are above .30. In the PSR test, all except P1 were larger than .30.

Table 2. Rasch Analysis Results of the PSR Test (N=631)

Item ID	Item stem	PSR Type	Max score	Item difficulty	Fit unweighted mnsq	Fit weighted mnsq	Item-test Correlation
D1	Read time series graph	1	2	-.68	1.28	1.16	.39
D2	Treat outlier	5	1	.51	1.04	1.04	.31
D3	Identify outlier	5	4	.38	1.32	1.23	.39
D4	Calculate dep variable	2	3	-.55	1.04	1.04	.38

D5	Plot dep on POP	3	1	-.79	1.01	.97	.36
D6	Find patterns on POP	4	2	.10	1.07	1.08	.30
D7	Explain patterns on POP	4	4	.39	1.38	1.39	.33
S1	Identify dep variable	2	1	-1.07	.94	.97	.35
S2	Control variable	5	4	-.65	1.27	1.14	.53
S3	Read time series	1	4	-.57	1.22	1.20	.41
S4	Calculate dep on time series	2	2	-1.02	1.50	1.05	.36
S5	Plot dep on POP	3	2	.17	1.00	1.00	.54
S6	Find patterns on POP	4	2	.43	.90	.90	.55
S7	Explain patterns on POP	4	4	1.34	1.09	1.06	.57
P1	Read time series graph	1	1	-2.98	1.28	1.00	.13
P2	Describe time series graph	1	4	1.00	1.01	1.01	.41
P3	Calculate dep variable from time series	2	1	-1.40	.65	.84	.54
P4	Explain how dep variable is calculated	2	3	-.40	.93	.93	.61
P5	Plot on POP	3	2	-.01	.82	.84	.64
P6	Find patterns on POP	4	2	1.56	.73	.86	.53
P7	Explain patterns on POP	4	4	.66	.90	.96	.64
M1	Read time series graph	1	1	-.27	.91	.94	.43
M2	Describe time series graph	1	4	1.62	.93	.94	.59
M3	Calculate dep variable from time series	2	1	-.05	.84	.87	.54
M4	Explain how dep variable is calculated	2	3	.22	.92	.94	.65
M5	Plot on POP	3	2	.58	.85	.87	.65
M6	Find patterns on POP	4	1	.43	.76	.79	.64
M7	Explain patterns on POP	4	4	1.13	.85	.85	.69

Note. POP refers to the parameter space-system-outcome graph. For example, a plot between pendulum length (parameter space when all other variables were constant) and period (system outcome) is a POP. A plot between the displacement from the equilibrium position over time is a time-series graph for a pendulum.

Reliability of the entire test= .867

Figure 1 shows a Wright Map which graphically represent student distributions and item difficulty distributions on the same PSR construct. The higher the student's location on the construct, the more capable the student on the PSR construct. The higher the item's location on the construct, the more difficult the item on the PSR construct. Figure 1 can show whether scoring levels used to score student responses were adequate. If adequate, the item threshold values on the PSR construct should increase as the scores increase within each item. To check whether scoring levels for each item indeed coincides with the order of students' performances predicted on the PSR construct, take an item such as S7 and follow the four scoring levels: S7.1, S7.2, S7.3, and S7.4. Note that S7.1 on the Wright Map indicates the location of the item threshold value for the score of "1" in the item S7. They were placed higher and higher as scores increase. All other score levels in each item followed the same pattern, indicating scoring levels reflect the increasing levels of student performance on the underlying PSR construct.

Figure 1. Wright Map

(increasing item difficulties and increasing student abilities from bottom to up)

Student distributions   Item difficulty distributions

```
-------------------------------------------------------------------------------------
                                              |             S7.4           P2.4 P6.2     M2.4
                                              |
                                              |                            P7.4
                                              |
                                              |D7.4
                                              |
                                              |                                          M7.4
                                              |
   3                                          |
                                              |
                                              |
                                             X|D3.4
                                             X|                                          M2.3
                                           XXX|
                                            XX|
                                          XXXX|
                                          XXXX|
   2                                    XXXXXX|                            P2.3
                                 XXXXXXXXXXXXX|
                                  XXXXXXXXXXXX|D4.3 D6.2    S6.2
                              XXXXXXXXXXXXXXXX|
                        XXXXXXXXXXXXXXXXXXXXXX|
                 XXXXXXXXXXXXXXXXXXXXXXXXXXXXX|
                     XXXXXXXXXXXXXXXXXXXXXXXXX|D3.3         S3.4
                XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|                                          M7.3
      XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|
           XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|             S7.3                         M4.3
   1    XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|
         XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|
           XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|                            P4.3
              XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|             S3.3                         M5.2 M7.2
            XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|             S2.4
                XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|D2           S5.2                         M5.1 M6
            XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|D3.2                        P7.3
                      XXXXXXXXXXXXXXXXXXXXXXXX|             S7.2
                                 XXXXXXXXXXXXX|D7.3                        P5.2          M4.2
                         XXXXXXXXXXXXXXXXXXXXX|
   0                             XXXXXXXXXXXXX|                                          M3
                           XXXXXXXXXXXXXXXXXXX|             S2.3 S5.1                    M2.2
                                 XXXXXXXXXXXXX|                            P7.2          M1
                                 XXXXXXXXXXXXX|
                              XXXXXXXXXXXXXXXX|                            P4.2 P5.1
                                     XXXXXXXXX|D1.2 D7.2
                                         XXXXX|                                          M4.1 M7.1
                                        XXXXXX|D1.1 D5
                                        XXXXXX|             S4.2 S7.1                    M2.1
  -1                                         X|             S2.2 S6.1      P7.1
                                         XXXXX|             S1
                                           XXX|             S4.1
                                          XXXX|
                                             X|D4.2                        P2.2 P3
                                              |D7.1         S3.2           P2.1
                                              |D6.1                        P6.1
                                              |
                                            XX|
                                              |
  -2                                          |             S2.1
                                              |D4.1
                                              |
                                              |D3.1         S3.1           P1 P4.1
=====================================================================================
Each 'X' represents 1.0 cases
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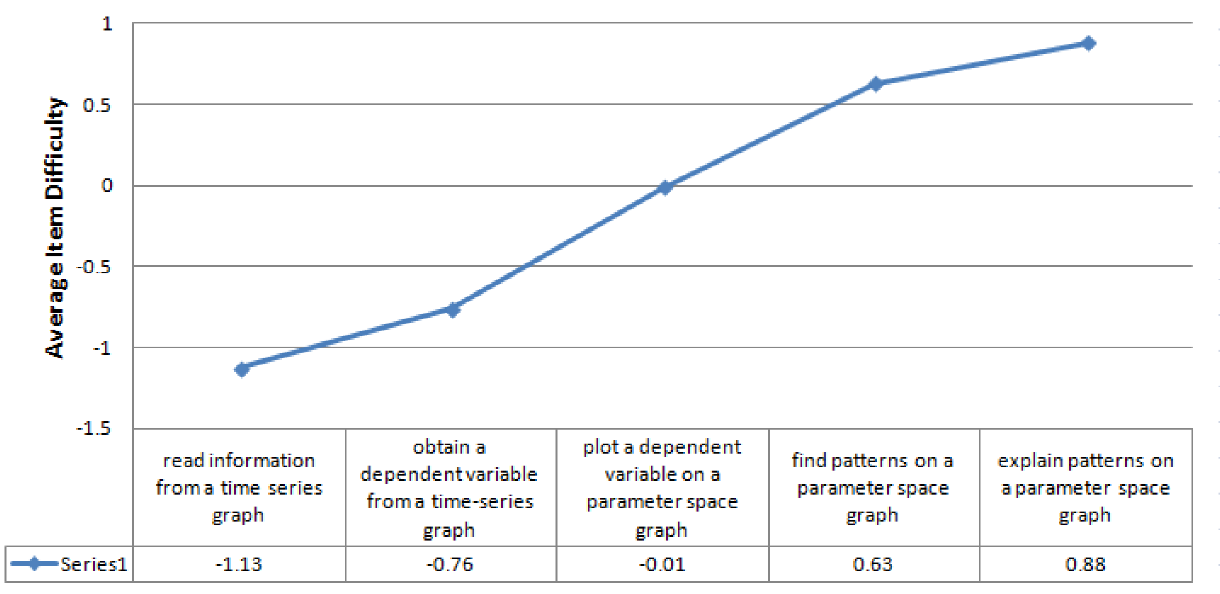
Taken together, the PSR test was highly reliable and scoring rubrics reflected students' performance levels predicted by the PSR construct. The PSR construct measured with the items in the PSR test can be considered as a uni-dimensional construct responsible for the underlying cognition across the items.

In addition, item difficulty values across items show another interesting trend. The average item difficulty value increases in the order of:

- easiest: read information from a time series graph
- obtain a dependent variable from a time-series graph
- plot a dependent variable on a parameter space graph (POP)
- find patterns on a parameter space graph (POP)
- most difficult: explain patterns on a parameter space graph (POP)

This indicates that more advanced PSR reasoning is necessary for students to move from reading information on a time series graph, to explaining patterns on a parameter space graph. This was anticipated as the latter step relies on the completion and mastery of the former step. This can serve as a model for an instructional game to teach PSR in five steps!

Figure 2. Average Item Difficulty Values Increase from Left to Right.



IV. Instructional Sensitivity of the PSR Test

In order to examine the instructional sensitivity of the PSR test, we examined how students' performances changed between pre and post tests on the same items. Instructional sensitivity in this study is defined as “the tendency for an item to vary in difficulty as a function of instruction” (Haladyna & Roid, 1981, p. 40). If the instrument was sensitive to the IS curriculum intervention, students' performance would increase before and after the IS intervention on items targetted by the IS curricular activities.

We examined 231 students who completed both pre and post tests. These students received the IS curricular intervention. We applied the Wilcoxon-Mann-Whitney test to each of the 28 items in the PSR test to see on which items students showed significant improvement. The Wilconxon-Mann-Whitney test was chosen because the scores assigned to student responses to the items were on an ordinal scale. The Wilcoxon-Mann-Whitney test results are shown in Z scores. Positive Z scores mean posttest scores were higher than pretest scores. Negative Z scores mean pretest scores were higher than posttest scores. p-values indicate whether changes between pre and posttests were significant.

Table 3. Instructional Sensitivity of the Items in the PSR Test

	Item stem	PSR Type	Max score	Wilcoxon-Mann-Whitney Test	
				Z	p
D1	Read time series graph	1	2	2.02	*
D2	Treat outlier	5	1	4.18	***
D3	Identify outlier	5	4	2.16	*
D4	Calculate dep variable	2	3	2.32	*
D5	Plot dep on POP	3	1	.75	.46
D6	Find patterns on POP	4	2	-1.37	.17
D7	Explain patterns on POP	4	4	-1.57	.12
S1	Identify dep variable	2	1	-.51	.61
S2	Control variable	5	4	-.67	.51
S3	Read time series	1	4	-2.52	*
S4	Calculate dep on time series	2	2	1.07	.29
S5	Plot dep on POP	3	2	.59	.55
S6	Find patterns on POP	4	2	-.63	.53
S7	Explain patterns on POP	4	4	-2.32	*
P1	Read time series graph	1	1	-.58	.56
P2	Describe time series graph	1	4	3.16	**
P3	Calculate dep variable from time series	2	1	1.04	.30
P4	Explain how dep variable is calculated	2	3	1.60	.11
P5	Plot on POP	3	2	1.49	.14
P6	Find patterns on POP	4	2	-.96	.34
P7	Explain patterns on POP	4	4	2.20	*
M1	Read time series graph	1	1	.29	.77
M2	Describe time series graph	1	4	2.41	*
M3	Calculate dep variable from time series	2	1	-.37	.71
M4	Explain how dep variable is calculated	2	3	2.73	**
M5	Plot on POP	3	2	3.50	***
M6	Find patterns on POP	4	1	3.85	***
M7	Explain patterns on POP	4	4	4.33	***

Note. Green cells indicate significant improvements from pre to post. Orange cells indicate significant decreases from pre to post.

According to Table 3, 11 out of 28 items were associated with significant positive gains before and after the IS intervention. These items were associated with Dash, Pendulum, and Mass sets. In particular, the largest gains were observed in the items of the Mass set, the identical transfer context. On the other hand, students regressed significantly on two items of the Sarah set related to reading time series graph and explaining patterns on POP. The Sarah set involved a biological context with multi-variate relationships which were not explicitly dealt in the IS intervention.

Finding patterns on POP in three of the four item sets were associated with negative changes. These items addressed non-linear relationships between a parameter and an outcome variable. For example, in the Dash set, the time to complete a dash increases at an increasing rate as the length of the dash gets longer. In the Sarah set, two variables affect the rose production: one linearly and the other curvilinear. In the Pendulum set, the period increases at a slower rate as the length of the pendulum increases. This indicates that pattern recognition beyond linear relationships needs to be addressed in the IS curriculum materials.

Explaining patterns on POP results indicate that explanations involve both content knowledge and practice. The identical and near transfer contexts (pendulum and mass systems) provided opportunities for students and teachers to talk about science beyond the experimentations resulting in significant improvement on explaining patterns. However, in the medium and far transfer contexts, students did not likely encounter such opportunities to learn science behind phenomena during the IS intervention, resulting in no gains. This indicates that PSR operates in two spheres: content and practice. Content knowledge requirement involved in item contexts obscures the transferability of the PSR from one context (Mass set) to another (Sarah set), for example. As a result, students' changes from pre to posttests varied as a function of the degree of transfer: from identical, near, medium, to far, even though the same aspect of PSR was involved.

V. InquirySpace Impact on Students' Changes in PSR

To examine how much changes occurred in PSR before and after the IS curriculum materials were implemented, we compared students of three teachers who completed both PSR pre and post tests. We calculated means of the entire test and the mechanics portion of the test (Table 4). We also broke down the scores by the item set (Table 5) and by the PSR type (Table 6). We used repeated measures ANOVA to investigate three effects: (1) whether prepost changes were significant (C), (2) whether there were teacher effects (T), and (3) whether changes were significantly different across teachers (C x T).

Table 4. Pre-post mean comparisons across teachers with repeated measures ANOVA results

	Njaa (N=67)		Andrus (n=88)		Weathers (n=78)		All (n=231)		Repeated measures ANOVA: F, p
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Total (Dash+Sarah+ Pendulum+Mass)	48.8	51.8	45.4	46.7	42.7	42.8	45.5	46.9	C: F(1,228)=14.56*** T: F(2,228)=22.48*** C x T: F(2,228)=4.24*
Mechanics (Dash+Pendulum +Mass)	33.8	37.3	31.8	33.2	29.8	30.6	31.7	33.5	C: F(1,228)=33.3*** T: F(2,228)=21.5*** C x T: F(2,228)=6.15**

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

Table 4 shows that students significantly improved from pre to post on the entire PSR test as well as the mechanics sections of the PSR test. There were significant differences in students' overall PSR abilities across teachers. Significant interaction effects indicate that the amount of improvements were different across three teachers: Njaa's class posted the largest gain, followed by Andrus's class. Weather's class did not change much.

Table 5. Pre-post mean comparisons by item set across teachers with repeated measures ANOVA results

	Njaa (N=67)		Andrus (n=88)		Weathers (n=78)		All (n=231)		Repeated measures ANOVA: F, p
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Dash	12.2	13.1	10.3	10.6	10.8	10.6	11.0	11.3	C: F(1,228)=4.62* T: F(2,228)=26.47*** C x T: F(2,228)=3.86*
Sarah	15.0	14.6	13.6	13.6	12.9	12.3	13.8	13.4	C: F(1,228)=5.19* T: F(2,228)=14.5*** C x T: F(2,228)=1.29, p=.28
Pendulum	11.8	12.7	12.0	11.9	10.6	11.2	11.4	11.9	C: F(1,228)=14.57*** T: F(2,228)=12.66*** C x T: F(2,228)=4.78***
Mass	9.8	11.5	9.5	10.6	8.4	8.7	9.2	9.7	C: F(1,228)=24.70*** T: F(2,228)=13.40*** C x T: F(2,228)=3.35*

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

Table 5 shows that students significantly improved on Dash, Pendulum, and Mass sets while they significantly regressed on the Sarah set. The reduction on the Sarah set was omnipresent across four teachers. The improvement on the other three sets was significantly different across teachers: largest gains by Njaa's class, followed by Andrus's class on the Dash and Mass sets. For the Pendulum set, largest gains were achieved by Njaa's class, followed by Weather's class. There were significant differences in PSR abilities on each of the four item sets across teachers.

Table 6. Pre-post mean comparisons by PSR type across teachers with repeated measures ANOVA results

	Njaa (N=67)		Andrus (n=88)		Weathers (n=78)		All (n=231)		Repeated measures ANOVA: F, p
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
PSR1	10.8	11.5	10.7	10.5	9.7	9.9	10.4	10.6	C: F(1,228)=2.78, p=.10 T: F(2,228)=17.3*** C x T: F(2,228)=4.41*
PSR2	11.2	12.5	11.5	11.8	10.7	10.4	11.1	11.5	C: F(1,228)=12.32*** T: F(2,228)=14.64*** C x T: F(2,228)=12.78***
PSR3	5.6	6.1	5.1	5.4	4.5	4.7	5.0	5.4	C: F(1,228)=10.8***

									T: F(2,228)=12.13*** C x T: F(2,228)=.28, p=.76
PSR4	14.4	14.8	12.9	13.3	12.5	12.2	13.2	13.4	C: F(1,228)=1.16, p=.28 T: F(2,228)=12.22*** C x T: F(2,228)=1.11, p=.33
PSR5	6.8	6.9	5.3	5.7	5.4	5.5	5.8	6.0	C: F(1,228)=5.05* T: F(2,228)=20.34*** C x T: F(2,228)=.73, p=.48

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

Table 6 indicates that students made overall significant changes on PSR2, PSR3, and PSR5. There were significant teacher effects on all five PSR types. For PSR1 and PSR2, the significant interaction effects between change and teacher indicate that the amount of changes on PSR1 and PSR2 were different from teacher to teacher. Again, Njaa's class posted the largest gain on PSR1 and PSR2. On PSR3 and PSR5, there were no significant interaction effects, indicating improvements occurred in all three teachers' classes. On PSR4, there were no significant changes before and after IS across all three teachers.

In summary, students' overall PSR abilities were different across three teachers. This indicates that students were not sampled from the same population. Overall, students improved mostly from pre to post in PSR measured as a whole or broken down by the PSR type or the Item context. Exceptions were found with the far transfer context and PSR1 and PSR4. Njaa's class was impacted by the IS the most positively while Weather's and Andrus's classes were not much impacted. This will lead to our next research efforts to describe how Njaa's curriculum implementation was different from the other teachers and explain why Njaa's students appeared to benefit from the IS the most as measured by the PSR test.

InquirySpace Instructional Questionnaire

Date: ____________

Name: _____________________ Teacher Name: __________________
Gender: __ Male __ Female Grade Level: _______
Do you speak English as your first language? __ Yes __ No
Do you often use computers for science learning? __ Yes __ No

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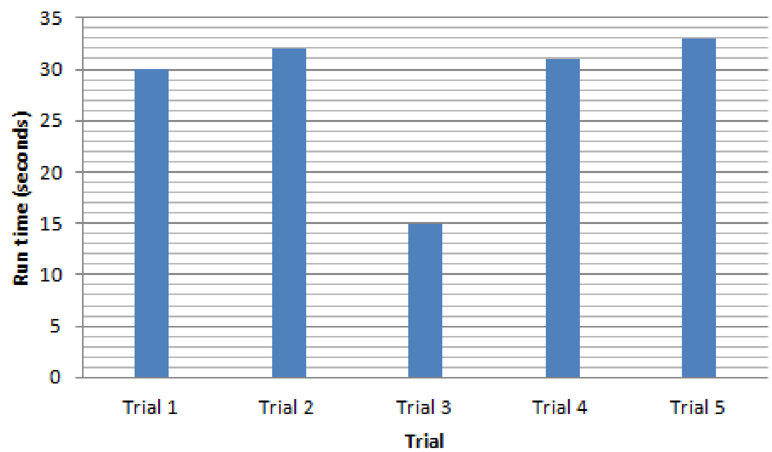
Please try your best to answer all of the questions.

Dash Trials
Tom wanted to find out how fast he could run for various distances. He ran five trials for each of 100, 200, 400, and 800-meter dashes. Tom asked Maria to measure the amount of time needed to finish a run.

1. Using a stopwatch, Maria kept Tom's records and drew the graph for Tom's 200-meter dash trials.

According to the graph, what was Tom's fastest and slowest records for the 200-meter dash?



Fastest: ______ seconds in trial ______

Slowest: ______ seconds in trial ______

2. Tom became curious about his 200-meter dash record related to Trial 3. Which of the following should Tom do?

(a) discard the record
(b) keep the record

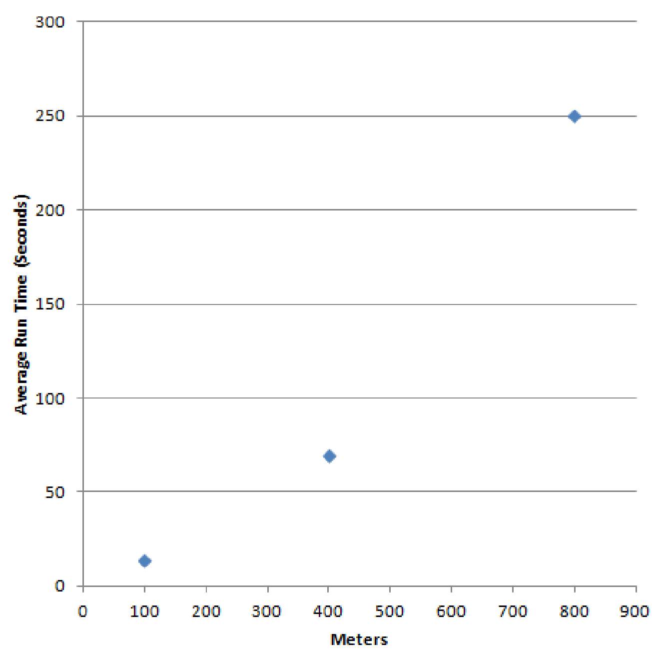
Explain your answer.

3. Tom wanted to represent his overall performance on the 200-meter dash using an average record across trials. What is an average time for Tom's 200-meter dash? Use the graph on the first page.

Average time for Tom's 200-meter dash: _______ seconds

Explain how you obtained the average time.

4. Maria drew a graph on the right to compare Tom's average time records across 100, 200, 400, and 800-meter dashes. Put a dot (●) for Tom's average record on the 200-meter dash.



5. What pattern can you identify from the graph above?

As Tom runs longer distances, ________________________________

Explain your answer.

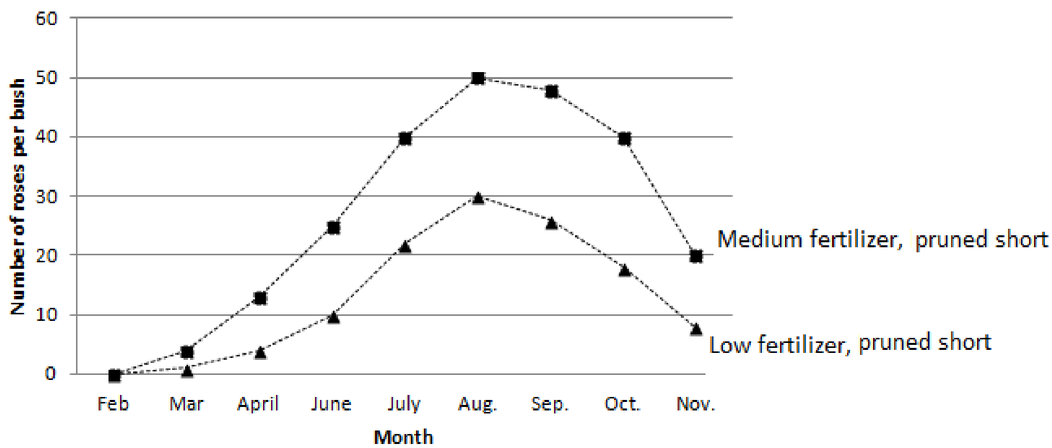
Sarah's Garden Experiment

Sarah wanted to figure out the best combination of fertilizer amount and pruning length that would produce the largest number of roses in her garden. In order to experiment, she divided her garden into many sections and gave each section a unique combination of fertilizer and pruning.

1. In Sara's experiment, which of the following variables was the outcome Sarah needed to collect for each of her combinations?
   (a) fertilizer amount
   (b) pruning length
   (c) the number of roses

2. Before her experiment, Sarah realized that the amount of water could also affect the growth of rose bushes. To conduct an accurate experiment to find out the best combination of fertilizer and pruning, what should Sarah do about watering and why?

3. The graph below shows Sarah's records of the average number of roses per bush from February to November for two fertilizer/pruning combinations.



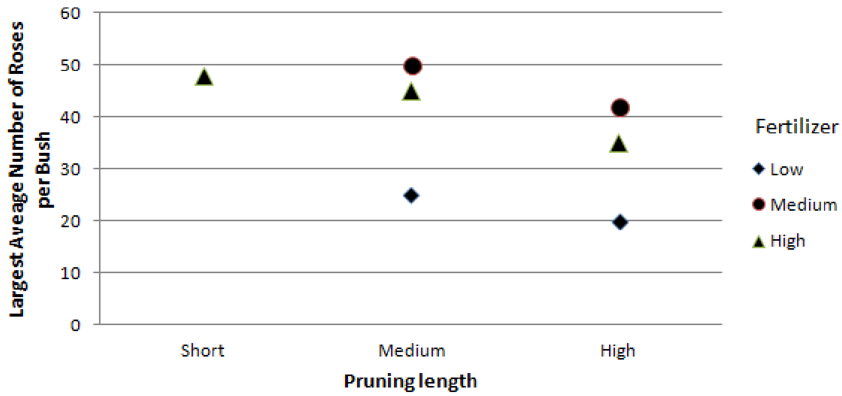
What does this graph tell about the two combinations related to rose production?

4. In determining the best fertilizer/pruning combination, Sarah decided to *compare* <u>the largest number of roses produced in any month</u>. Use the graph on the previous page to answer:

For the low fertilizer and pruned short combination,
the largest average number of roses per bush = ________ in the month of ________

For the medium fertilizer and pruned short combination,
the largest average number of roses per bush = ________ in the month of ________

5. Sara created nine combinations of fertilizer (low, medium, and high) and pruning (short, medium, and high). She drew a graph for the largest average number of roses per bush across combinations. Seven of the nine combinations are plotted below. **Put two additional points for the low fertilizer/pruned short and medium fertilizer/pruned short combinations.**

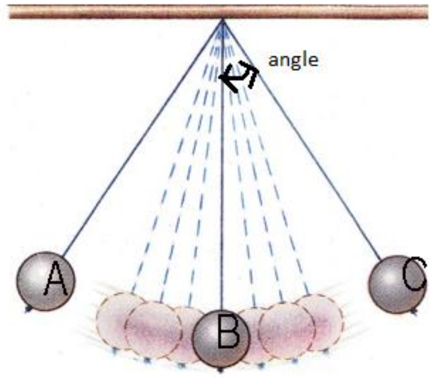


6. What pattern can you identify from the graph above?

As the fertilizer amount increases, ____

As the pruning length increases, ____

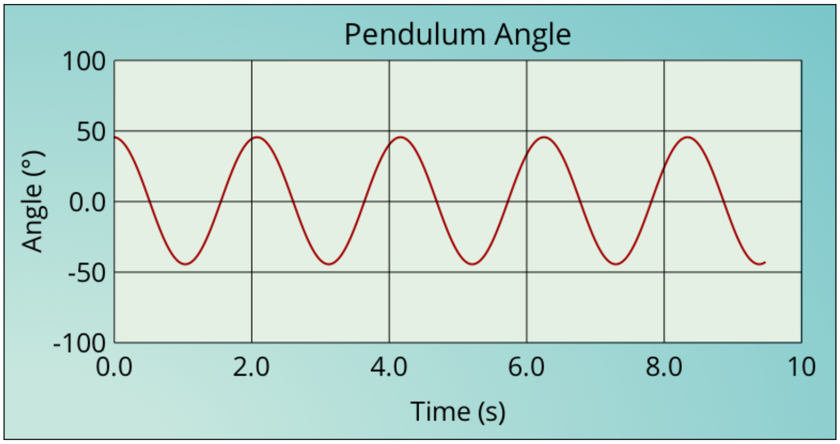
Explain your answers.



Pendulum

A mass was hanging from a ceiling. Sue pulled the mass to the position C and let it go. The mass was swinging back and forth. Consider that there was no friction between the mass and the air as well as between the string and the ceiling. The angle between the string and the central vertical line was continuously measured over time.

1. After one trial, Sue drew a graph below to show how the angle changed over time.



Based on this graph, at what angle did the pendulum start? _________ degrees

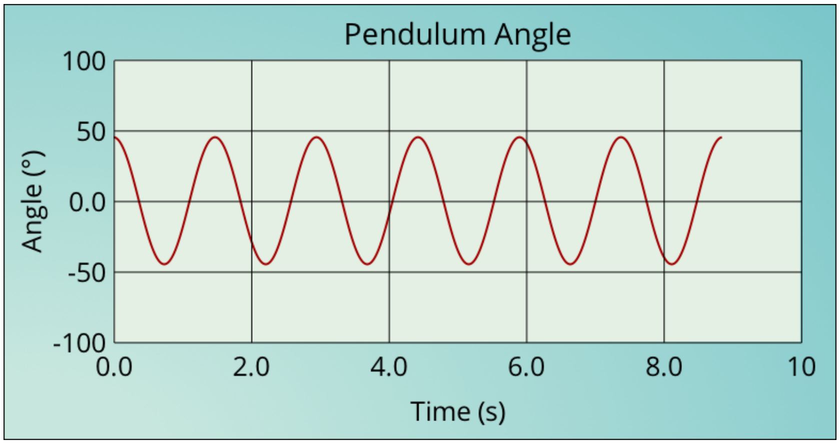
2. Describe what the graph tells about the pendulum's motion.

3. A period represents the amount of time necessary for the pendulum to come back to the same exact position where it started. Using the graph above, estimate the period of this pendulum.

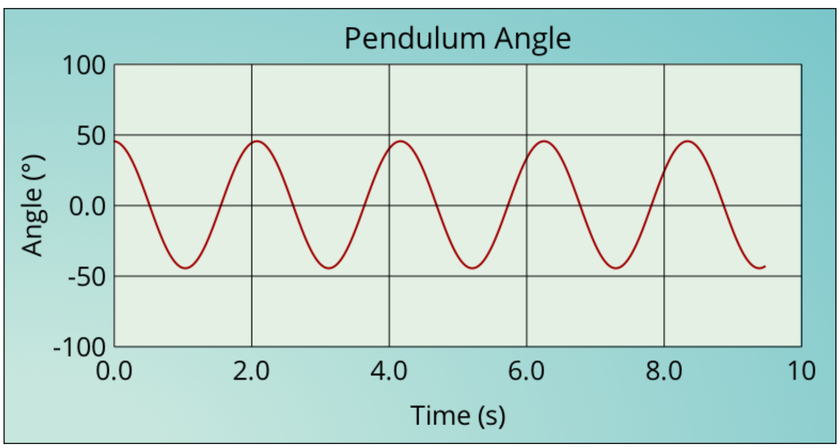
Period: __________ seconds

Explain how you obtained the period.

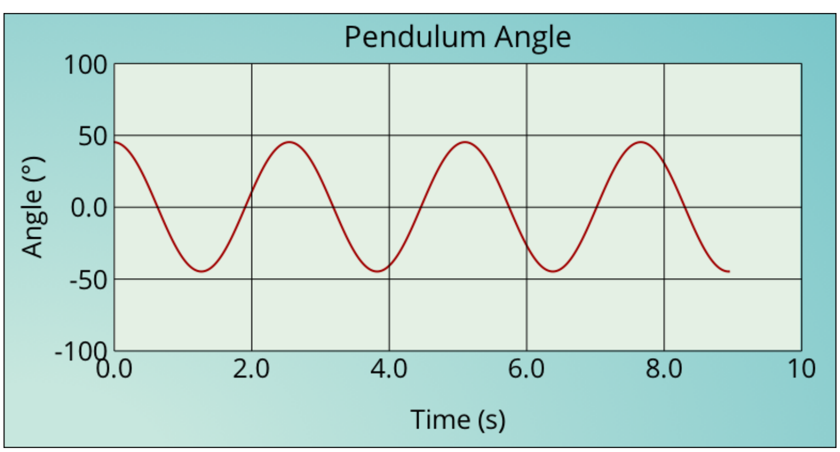
4. Sue repeated the pendulum trials three times by varying the length of the pendulum. She obtained three graphs shown below.



length=50 cm

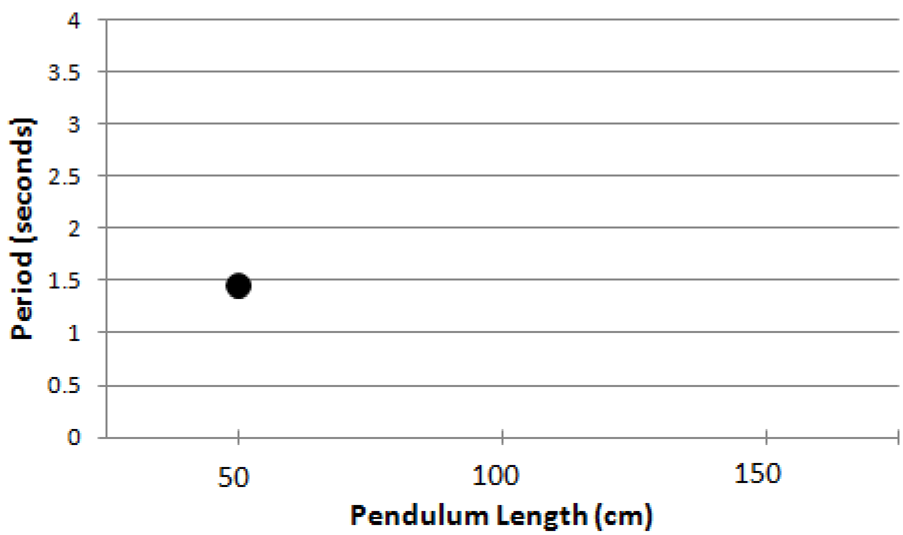


length=100 cm



length=150 cm

Sue drew a graph to compare periods among these three trials. A point for the 50 cm pendulum is already plotted. **Draw points for pendulum lengths of 100 cm and 150 cm.**



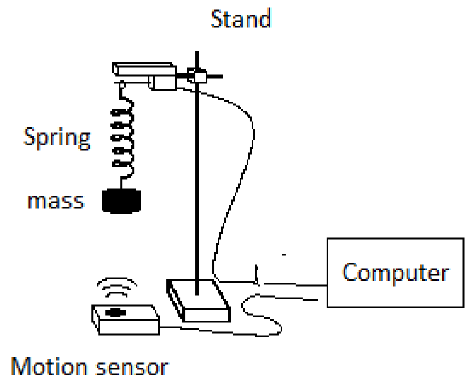
5. What pattern can you identify from the graph above?

As the pendulum length increases, ____

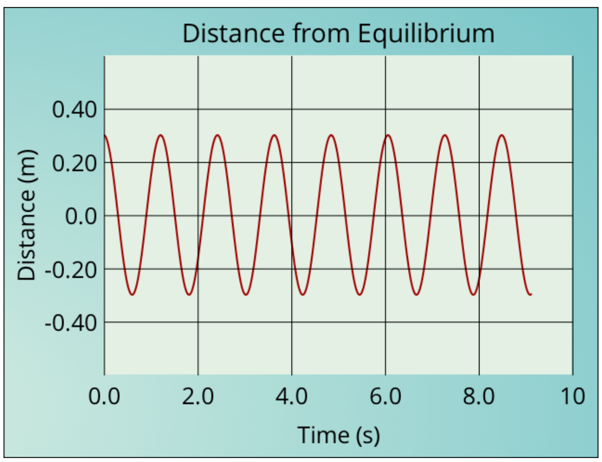
Explain your answer.

Spring/Mass System

Zachery was investigating a mass attached to a spring. This spring/mass system was hanging from a stand. Directly below, a motion sensor was placed so that the distance between the mass and the motion sensor could be measured. The motion sensor sent distance signals to the computer screen.



1. When Zachery stretched and let go of the mass in the first trial, he obtained the following graph.



According to this graph, how far was the mass stretched from the equilibrium position?

_____ meters

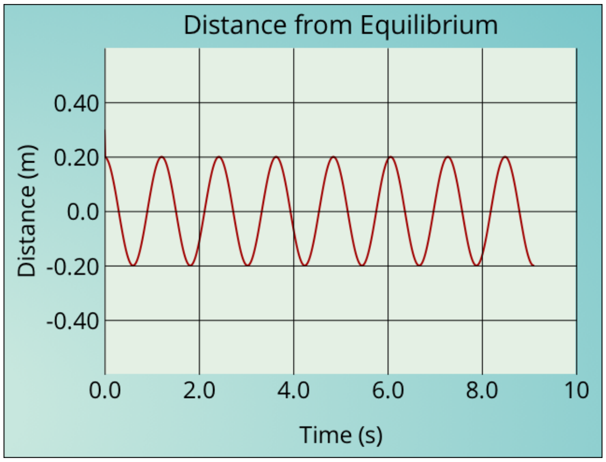
2. Describe what the graph tells about the motion of the mass.

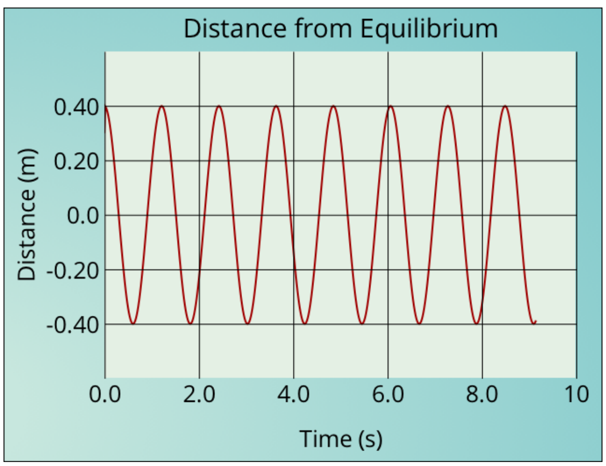
3. A period represents the amount of time necessary for the mass to come back to the same exact position where it started. Using the graph above, estimate the period of this mass.

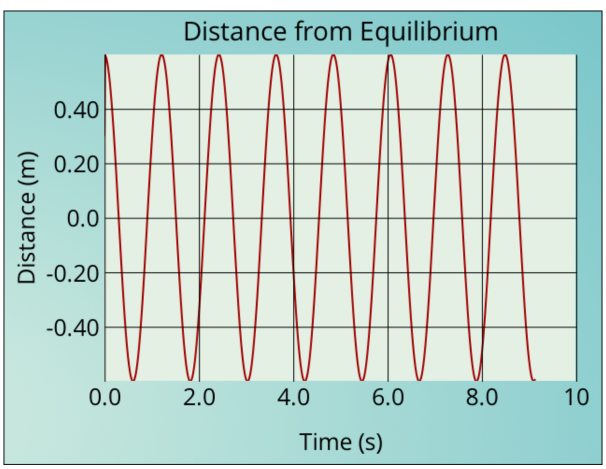
Period: _________ seconds

Explain how you obtained the period.

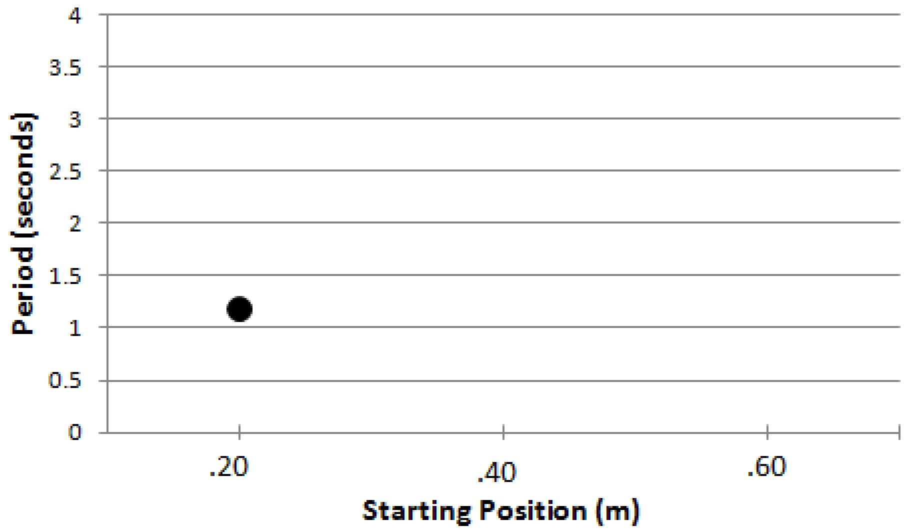
4. Zachery ran the spring/mass system three times by varying the starting position. He obtained the three graphs shown below:







Zachery drew a graph to compare periods among the three starting positions. A point for the starting position of .20 meter is already drawn for you. **Draw points for the starting positions of .40 meter and .60 meter.**



5. What pattern can you identify from the graph above?

As the starting position of the mass increases, ___________________________________

Explain your answer.

Appendix B. PSR Scoring Rubrics

Date: ____________

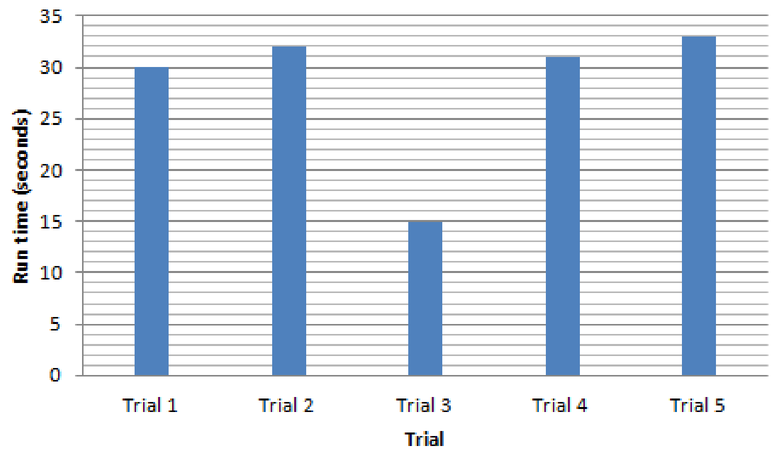
Name: ______________________ Teacher Name: ___________________
Gender: __ Male __ Female Grade Level: _______
Do you speak English as your first language? __ Yes __ No
Do you often use computers for science learning? __ Yes __ No
----
Please try your best to answer all of the questions.

Dash Trials

Tom wanted to find out how fast he could run for various distances. He ran five trials for each of 100, 200, 400, and 800-meter dashes. Tom asked Maria to measure the amount of time needed to finish a run.

1. Using a stopwatch, Maria kept Tom's records and drew the graph for Tom's 200-meter dash trials.

According to the graph, what was Tom's fastest and slowest records for the 200-meter dash?



Fastest: ______ seconds in trial ______
Slowest: ______ seconds in trial ______

correct (15 in trial 3) or (3 in 15)
correct (33 in trial 5) or (5 in 33)

(blank) no answer
(0) Both incorrect=0
(1) One correct =1
(2) Both correct=2

2. Tom became curious about his 200-meter dash record related to Trial 3. Which of the following should Tom do?

(a) discard the record
(b) keep the record

(blank) no answer
(0) incorrect
(1) correct choosing (a)

Explain your answer.

(blank) no answer
(0) offtask, I don't know...
(1) incorrect: because all data should be included in the analysis regardless: the data is his fastest record
(2) Recognizing as a measurement err OR suggest remedies: do more trials
(3) outlier relative to other points based on data (bring average down, for example)
(4) explain why: outlier because this is too low (humans cannot do this)

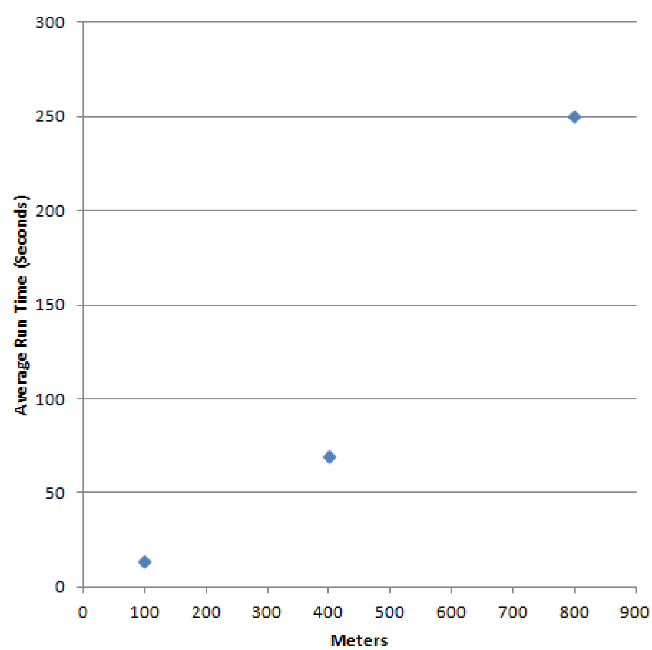
3. Tom wanted to represent his overall performance on the 200-meter dash using an average record across trials. What is an average time for Tom's 200-meter dash? Use the graph on the first page.

Average time for Tom's 200-meter dash: _______ seconds

Explain how you obtained the average time.

(blank) no answer
(0) offtask, I don't know...
(1) incorrect: outlier was not eliminated and cal wrong
(2) outlier was not eliminated but cal correct
(3) outlier eliminated and cal correct

4. Maria drew a graph on the right to compare Tom's average time records across 100, 200, 400, and 800-meter dashes. Put a dot (●) for Tom's average record on the 200-meter dash.



x should be 200 meters
y should be consistent with their calculation

(blank) no answer
(0) incorrect
(1) correct

5. What pattern can you identify from the graph above?

As Tom runs longer distances, ______________________________

(blank) no answer
(0) offtask and incorrect
(1) time increases (linear) (constant rate)

(2) time exponentially increases or takes longer and longer time (increasing rate)

Explain your answer.

(blank) no answer
(0) offtask
(1) wrong interpretations or explanations
(2) correctly describing what happens to y or x (time, dependent variable or distance, indep variable), no connection to x (distances he needed to run) OR mention correlation between x and y (x and y are related but do not mention how they are related)
(3) mention the type of relationship (correlation) between x and y (the longer he runs the longer it took for him to finish dash) OR the type of correlation between speed (slope, time difference) and distance (*slope rises as meters increase; not increasing at a steady rate (exponential); matches exponential function time gets bigger)
(4) Explain science behind the pattern

Sarah's Garden Experiment
Sarah wanted to figure out the best combination of fertilizer amount and pruning length that would produce the largest number of roses in her garden. In order to experiment, she divided her garden into many sections and gave each section a unique combination of fertilizer and pruning.

1. In Sara's experiment, which of the following variables was the outcome Sarah needed to collect for each of her combinations?
(a) fertilizer amount
(b) pruning length
(c) the number of roses

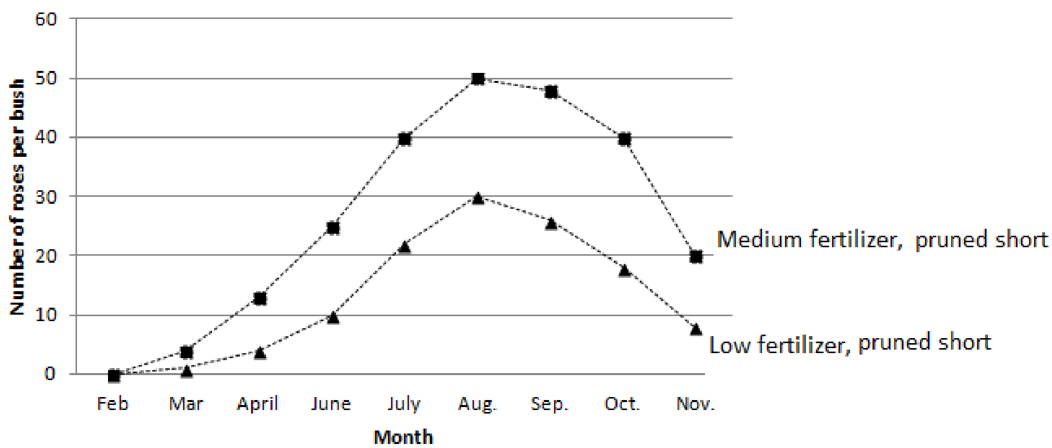
(blank) no answer
(0) incorrect
(1) correct (c)

2. Before her experiment, Sarah realized that the amount of water could also affect the growth of rose bushes. To conduct an accurate experiment to find out the best combination of fertilizer and pruning, what should Sarah do about watering and why?

(blank) no answer
(0) off task
(1) incorrect judgment antd rationale
(2) would like to measure water amount as well
(3) correct judgement (water amount should be kept constant) without rationale
(4) correct judgment (water amount should be kept constant) with rationale
- if not, the outcome is also dependent on water amount
- if not, then the water amount would be another variable to consider

3. The graph below shows Sarah's records of the average number of roses per bush from

February to November for two fertilizer/pruning combinations.



What does this graph tell about the two combinations related to rose production?

(blank) no answer
(0) off task
(1) incorrect
(2) focusing on one graph, medium fertilizer only or low fertilizer only, OR talking about short prune short OR fertilizer and rose production are correlated. or talking about one combination
(3) medium fertilizer produces more roses than low fertilizer
(4) medium fertilizer produces more roses than low fertilizer when prune length is short

4. In determining the best fertilizer/pruning combination, Sarah decided to *compare* the largest number of roses produced in any month. Use the graph on the previous page to answer:

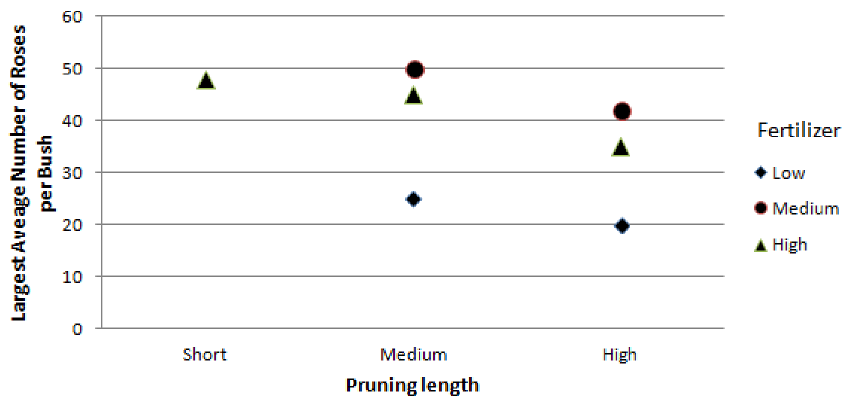
For the low fertilizer and pruned short combination,
the largest average number of roses per bush = ________ in the month of ________

For the medium fertilizer and pruned short combination,
the largest average number of roses per bush = ________ in the month of ________

first one correct: (30, aug)
second one correct: (50, aug)

(blank) no answer
(0) incorrect
(1) one correct
(2) both correct

5. Sara created nine combinations of fertilizer (low, medium, and high) and pruning (short, medium, and high). She drew a graph for the largest average number of roses per bush across combinations. Seven of the nine combinations are plotted below. **Put two additional points for the low fertilizer/pruned short and medium fertilizer/pruned short combinations.**



(blank) no answer
(0) incorrect
(1) one correct
(2) both correct

Explain how you determined the points for the two combinations on the graph above.
DO NOT CODE

6. What pattern can you identify from the graph above?

As the fertilizer amount increases, ______________________________________

As the pruning length increases, ______________________________________

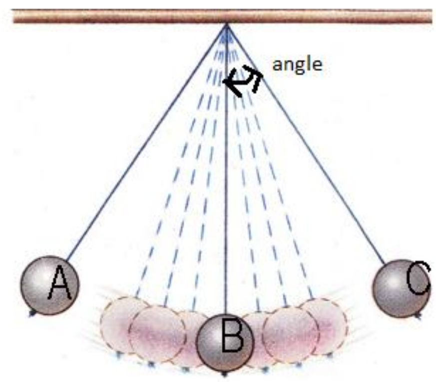
first one correct: increase and decrease
second one correct: decrease

(blank) no answer
(0) incorrect
(1) one correct
(2) both correct

Explain your answers.

(blank) no answer
(0) off task
(1) wrong OR just says graph without specifics
(2) description based on one variable OR fertilizer and rose production are correlated. OR prune length and rose production are correlated. (focusing one correct correlation) OR one combination without comparison
(3) one correct relationship: medium fertilizer is best for rose production OR prune short is best for rose production OR two correct relationships: medium fertilizer is best for rose production AND prune short is best for rose production

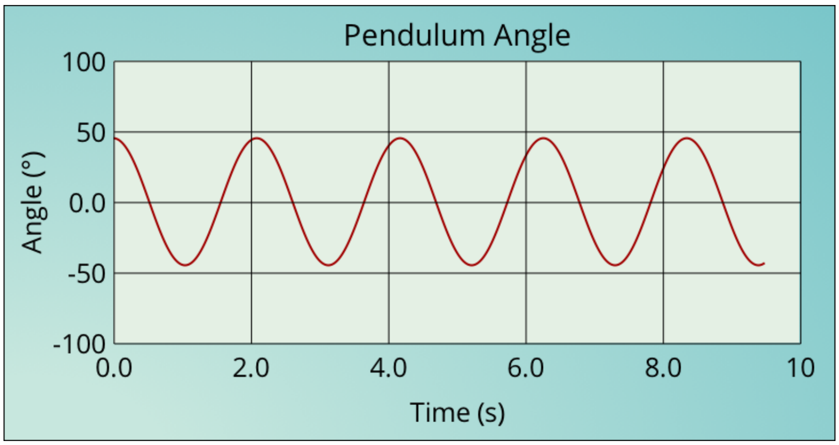
(4) Explain science behind the phenomenon



Pendulum

A mass was hanging from a ceiling. Sue pulled the mass to the position C and let it go. The mass was swinging back and forth. Consider that there was no friction between the mass and the air as well as between the string and the ceiling. The angle between the string and the central vertical line was continuously measured over time.

1. After one trial, Sue drew a graph below to show how the angle changed over time.



Based on this graph, at what angle did the pendulum start? _________ degrees

(blank) no answer
(0) incorrect
(1) correct: 45 - 50

2. Describe what the graph tells about the pendulum's motion.

periodicity (time -related statement of wave)
shape of the wave (wavelength/amp)
no friction/damping

(blank) no answer
(0) offtask
(1) incorrect
(2) mention one out of three above
(3) mention two out of three
(4) mention all three

(Check for pendulum Column AV)

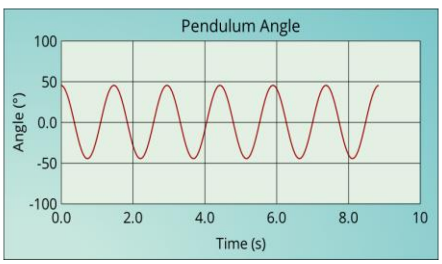
3. A period represents the amount of time necessary for the pendulum to come back to the same exact position where it started. Using the graph above, estimate the period of this pendulum.

Period: _________ seconds

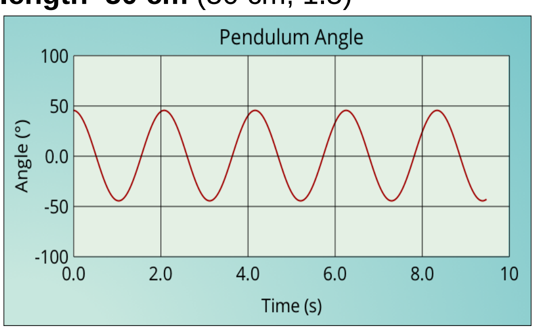
(0) incorrect
(1) correct: 2 - 2.3

Explain how you obtained the period.
(blank) no answer
(0) off task
(1) incorrect descriptions
(2) mention amplitude (reaching the same amplitude position from the graph) OR period (time taken between the two positions)
(3) mention both amplitude AND period

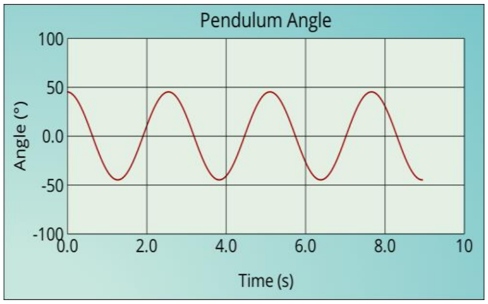
4. Sue repeated the pendulum trials three times by varying the length of the pendulum. She obtained three graphs shown below.



length=50 cm (50 cm, 1.5)

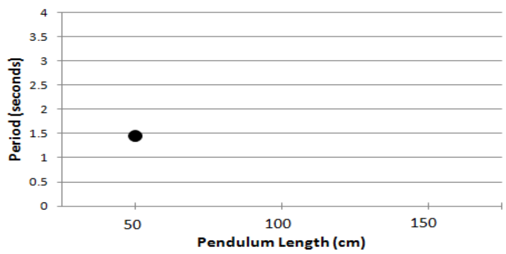


length=100 cm (100 cm, 2.0 to 2.2)



length=150 cm (150 cm, 2.4 to 2.6)

Sue drew a graph to compare periods among these three trials. A point for the 50 cm pendulum is already plotted. **Draw points for pendulum lengths of 100 cm and 150 cm.**



(100 cm, 2-2.2 seconds)
(150 cm, 2.4-2.6 seconds)

(blank) no answer
(0) incorrect
(1) one correct
(2) both correct

5. What pattern can you identify from the graph above?

As the pendulum length increases, ____

(blank) no answer
(0) incorrect
(1) correct: a period increasing

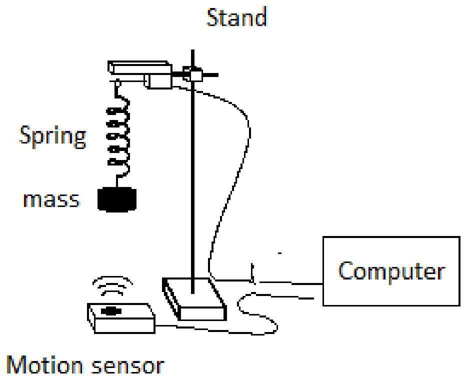
Explain your answer.

(blank) no answer
(0) off task/I think so, this is rule, I know it, I don't know
(1) incorrect
(2) describe one variable.

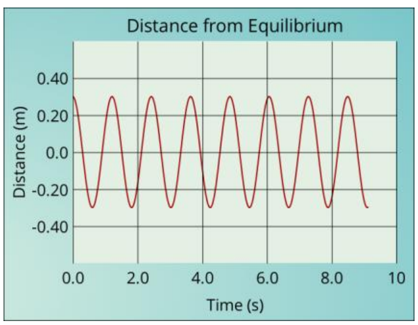
(3) describe the quantitative relationship between the two
(4) explain science behind the phenomenon

Spring/Mass System

Zachery was investigating a mass attached to a spring. This spring/mass system was hanging from a stand. Directly below, a motion sensor was placed so that the distance between the mass and the motion sensor could be measured. The motion sensor sent distance signals to the computer screen.



1. When Zachery stretched and let go of the mass in the first trial, he obtained the following graph.



According to this graph, how far was the mass stretched from the equilibrium position?
_____ meters

(blank) no answer
(0) incorrect
(1) correct: .25 to .35 meters or 25-35 centimeters

2. Describe what the graph tells about the motion of the mass.

periodicity (time -related statement of wave)
shape of the wave (wavelength/amp)
no friction/damping

(blank) no answer
(0) offtask
(1) incorrect
(2) mention one out of three above
(3) mention two out of three
(4) mention all three

3. A period represents the amount of time necessary for the mass to come back to the same exact position where it started. Using the graph above, estimate the period of this mass.

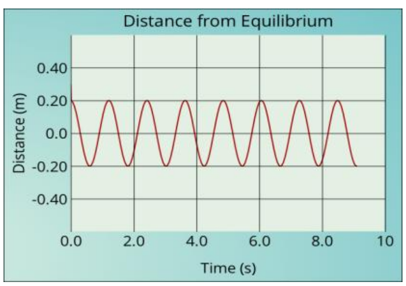
Period: __________ seconds

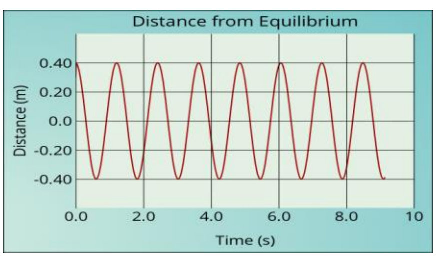
(blank) no answer
(0) incorrect
(1) correct: 1-1.5 seconds

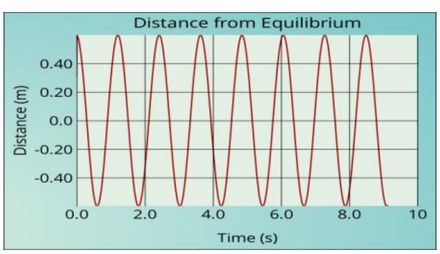
Explain how you obtained the period.

(blank) no answer
(0) off task
(1) incorrect/no reasoning provided
(2) wavelength or amplitude (some repeated points) OR time off the repeated points
(3) wavelength, amplitude + time off the repeated points (time difference), calculated period

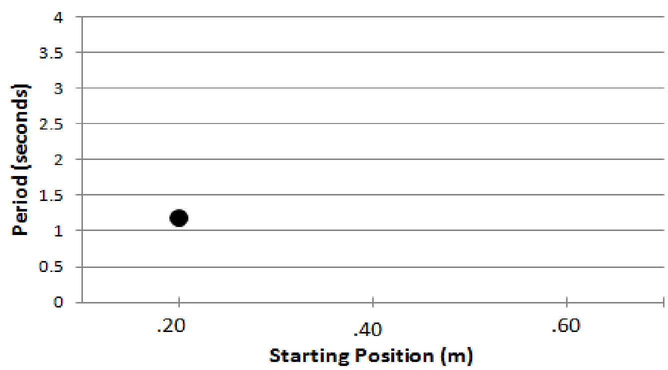
4. Zachery ran the spring/mass system three times by varying the starting position. He obtained the three graphs shown below:







Zachery drew a graph to compare periods among the three starting positions. A point for the starting position of .20 meter is already drawn for you. **Draw points for the starting positions of .40 meter and .60 meter.**



(.40 meter, 1.2ish 1.1-1.3 seconds)
(.60 meter, 1.2ish 1.1 - 1.3 seconds)

(blank) no answer
(0) both incorrect
(1) one correct
(2) both correct

5. What pattern can you identify from the graph above?

As the starting position of the mass increases, ________________________________

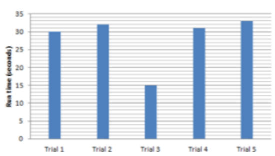
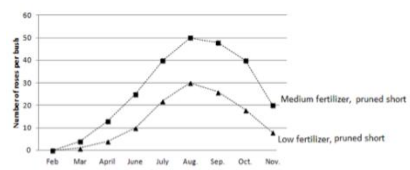
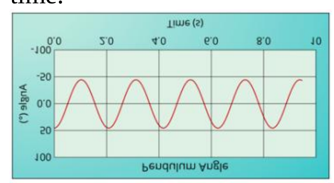
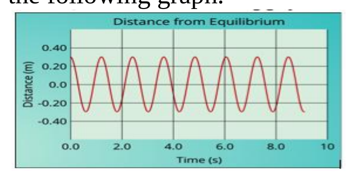
(blank) no answer
(0) incorrect
(1) correct: period stays constant

Explain your answer.

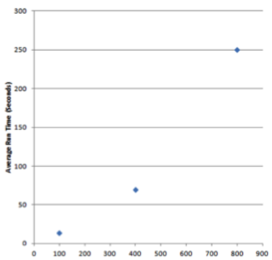
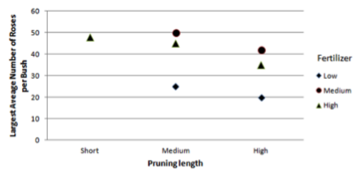
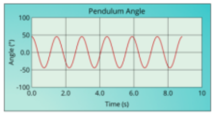
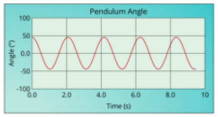
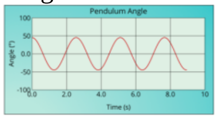
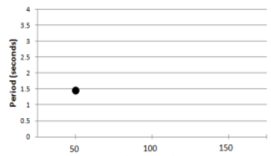
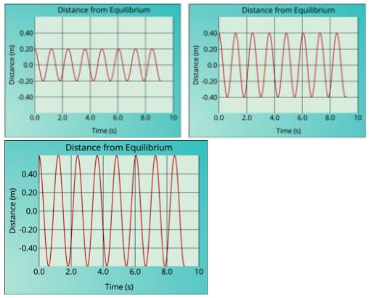
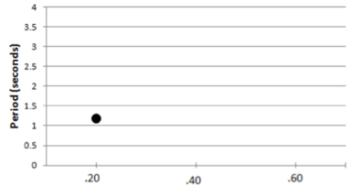
(blank) no answer
(0) off task/I think so, this is rule, I know it, I don't know
(1) incorrect or vaguely says I got it from the graph OR says specifically what they don't know. Restatement of the claim
(2) describe one variable.
(3) describe the quantitative relationship between the two
(4) explain science behind the phenomenon

Appendix C

Parameter Space Reasoning (PSR) Test: Item Specifications and Rubrics

	Dash: Tom wanted to find out how fast he could run for various distances. He ran five trials for each of 100, 200, 400, and 800-meter dashes. Tom asked Maria to measure the amount of time needed to finish a run.	**Rose Garden:** Sarah wanted to figure out the best combination of fertilizer amount and pruning length that would produce the largest number of roses in her garden. In order to experiment, she divided her garden into many sections and gave each section a unique combination of fertilizer and pruning.	**Pendulum:** A mass was hanging from a ceiling. Sue pulled the mass to the position C and let it go. The mass was swinging back and forth. Consider that there was no friction between the mass and the air as well as between the string and the ceiling. The angle between the string and the central vertical line was continuously measured over time.	**Spring/Mass:** Zachery was investigating a mass attached to a spring. This spring/mass system was hanging from a stand. Directly below, a motion sensor was placed so that the distance between the mass and the motion sensor could be measured. The motion sensor sent distance signals to the computer screen.
PSR1 Describe a scientific phenomenon using a primary graph (e.g. time series)	Using a stopwatch, Maria kept Tom's records and drew the graph for Tom's <u>200-meter</u> dash trials.  D1: According to the graph, what was Tom's fastest and slowest records for the 200-meter dash? Fastest: ___ seconds in trial _. Slowest: __ seconds in trial _. (0) Both incorrect (1) One correct (2) Both correct	The graph below shows Sarah's records of the average number of roses per bush from February to November for two fertilizer/pruning combinations.  S3: What does this graph tell about the two combinations related to rose production? (0) off task (1) incorrect (2) focusing on one graph, medium fertilizer only or low fertilizer only, OR talking about short prune short OR fertilizer and rose production are correlated. or talking about one	After one trial, Sue drew a graph below to show how the angle changed over time.  P1: Based on this graph, at what angle did the pendulum start? _________ Degrees (0) incorrect (1) correct: 45 - 50 degrees P2: Describe what the graph tells about the pendulum's motion. (0) offtask (1) incorrect (2) mention one out of three above	When Zachery stretched and let go of the mass in the first trial, he obtained the following graph.  M1: According to this graph, how far was the mass stretched from the equilibrium position? ______ Meters (0) incorrect (1) correct: .25 to .35 meters or 25-35 centimeters M2: Describe what the graph tells about the motion of the mass. (0) offtask (1) incorrect

		combination (3) medium fertilizer produces more roses than low fertilizer (4) medium fertilizer produces more roses than low fertilizer when prune length is short	(3) mention two out of three (4) mention all three	(2) mention one out of three above (3) mention two out of three (4) mention all three
PSR2 Measure or obtain a dependent variable from primary (e.g. time-series) graphs	Tom wanted to represent his overall performance on the 200-meter dash using an average record across trials. What is an average time for Tom's 200-meter dash? Use the graph on the first page. Average time for Tom's 200-meter dash: _______ seconds D4: Explain how you obtained the average time. (0) offtask, I don't know... (1) incorrect: outlier was not eliminated and cal wrong (2) outlier was not eliminated but cal correct (3) outlier eliminated and cal correct	S1: In Sara's experiment, which of the following variables was the outcome Sarah needed to collect for each of her combinations? (a) Fertilizer amount (b) Pruning length (c) The number of roses (0) incorrect (1) correct (c) In determining the best fertilizer/pruning combination, Sarah decided to *compare* <u>the largest number of roses produced in any month</u>. Use the graph on the previous page to answer: S4: For the <u>low fertilizer</u> and <u>pruned short</u> combination, the largest average number of roses per bush = __ in the month of ___ For the <u>medium fertilizer</u> and <u>pruned short</u> combination, the largest average number of roses per bush = __ in the month of ___ (0) incorrect (1) one correct (2) both correct	A period represents the amount of time necessary for the pendulum to come back to the same exact position where it started. Using the graph above, estimate the period of this pendulum. P3: Period: _________ seconds (0) incorrect (1) correct: 2 - 2.3 P4: Explain how you obtained the period. (0) off task (1) incorrect descriptions (2) mention amplitude (reaching the same amplitude position from the graph) OR period (time taken between the two positions) (3) mention both amplitude AND period	A period represents the amount of time necessary for the mass to come back to the same exact position where it started. Using the graph above, estimate the period of this mass. M3: Period: _________ seconds (blank) no answer (0) incorrect (1) correct: 1-1.5 seconds M4: Explain how you obtained the period. (0) off task (1) incorrect/no reasoning provided (2) wavelength or amplitude (some repeated points) OR time off the repeated points (3) wavelength, amplitude + time off the repeated points (time difference), calculated period
PSR3 Making a	D5. Maria drew a graph on the right to compare Tom's average	S5: Sara created nine combinations of fertilizer (low, medium, and high) and	P5. Sue repeated the pendulum trials three times by varying the length of the	M5. Zachery ran the spring/mass system three times by varying the

parameter space graph using data from primary graphs.	time records across 100, 200, 400, and 800-meter dashes. Put a dot (●) for Tom's average record on the 200-meter dash.  (0) incorrect (1) correct	pruning (short, medium, and high). She drew a graph for the largest average number of roses per bush across combinations. Seven of the nine combinations are plotted below. Put two additional points for the low fertilizer/pruned short and medium fertilizer/pruned short combinations.  (0) incorrect (1) one correct (2) both correct	pendulum. She obtained three graphs shown below.  Length=50 cm  Length=100 cm  Length=150 cm Sue drew a graph to compare periods among these three trials. A point for the 50 cm pendulum is already plotted. Draw points for pendulum lengths of 100 cm and 150 cm  (0) incorrect (1) one correct (2) both correct	starting position. He obtained the three graphs shown below:  Zachery drew a graph to compare periods among the three starting positions. A point for the starting position of .20 meter is already drawn for you. Draw points for the starting positions of .40 meter and .60 meter.  (0) both incorrect (1) one correct (2) both correct
PSR4 Identifying patterns represented in a parameter space graph	What pattern can you identify from the graph above? D6: As Tom runs longer distances, ________________ (0) incorrect	What pattern can you identify from the graph above? S6: As the fertilizer amount increases, ____________________ As the pruning length increases, ____________________________	What pattern can you identify from the graph above? P6: As the pendulum length increases, _______________ (0) incorrect	What pattern can you identify from the graph above? M6: As the starting position of the mass increases, ________________ (0) incorrect

	(1) time increases (linear) (constant rate) (2) time increases at an increasing rate D7: Explain your answer. (0) offtask (1) wrong interpretations or explanations (2) correctly describes one variable only or mentions correlation between the two variables without mentioning the nature of the relationship. (3) mention the type of correlation between speed (slope, time difference) and distance (4) scientifically explain why slowing down	(0) incorrect (1) one correct (2) both correct S7: Explain your answers. (0) offtask (1) wrong interpretations or explanations (2) correctly describes one variable only or mentions correlation between the two variables without mentioning the nature of the relationship. (3) mention the type of correlation between speed (slope, time difference) and distance (4) scientifically explain why slowing down	(1) correct: a period increasing (2) period increasing at a slower rate P7: Explain your answer. (0) offtask (1) wrong interpretations or explanations (2) correctly describes one variable only or mentions correlation between the two variables without mentioning the nature of the relationship. (3) mention the type of correlation between speed (slope, time difference) and distance (4) scientifically explain why slowing down	(1) correct: period stays constant M7: Explain your answer. (0) offtask (1) wrong interpretations or explanations (2) correctly describes one variable only or mentions correlation between the two variables without mentioning the nature of the relationship. (3) mention the type of correlation between speed (slope, time difference) and distance (4) scientifically explain why slowing down
PSR5 Identifying and explaining outliers or errors in a primary or a parameter space graph	D2: Tom became curious about his 200-meter dash record related to Trial 3. Which of the following should Tom do? (a) Discard the record (b) Keep (0) incorrect (1) correct choosing (a) D3: Explain. (0) offtask, I don't know... (1) incorrect: because all data should be included in the analysis regardless: the data is his fastest record (2) Recognizing as a	S2: Before her experiment, Sarah realized that the amount of water could also affect the growth of rose bushes. To conduct an accurate experiment to find out the best combination of fertilizer and pruning, what should Sarah do about watering and why? (0) off task (1) incorrect judgment antd rationale (2) would like to measure water amount as well (3) correct judgement (water amount should be kept constant) without rationale (4) correct judgment (water amount should be kept constant) with rationale • if not, the outcome is also dependent on water amount		

	measurement err OR suggest remedies: do more trials (3) outlier relative to other points based on data (bring average down, for example) (4) explain why: outlier because this is too low (humans cannot do this)	• if not, then the water amount would be another variable to consider		

Appendix D: Rasch Analysis Results: Conquest Software Output

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Partial Credit Model: IS Construct                          Sat Jul 05 16:49 2014
SUMMARY OF THE ESTIMATION
===========================================================Build: Dec 21 2012===

Estimation method was: Gauss-Hermite Quadrature with 15 nodes
Assumed population distribution was: Gaussian
Constraint was: DEFAULT
The Data File: psrall2.dat
The format:  name 1-6 responses 7-34
No case weights
The regression model: Not applicable
Grouping Variables:
The item model: item+item*step
Slopes are fixed
Sample size: 631
Final Deviance:    28226.90591
Total number of estimated parameters: 70
The number of iterations: 458
Termination criteria:  Max iterations=1000, Parameter Change= 0.00010
                       Deviance Change= 0.00010
Iterations terminated because the deviance convergence criteria was reached
Random number generation seed:    1.00000
Number of nodes used when drawing PVs: 2000
Number of nodes used when computing fit: 200
Number of plausible values to draw: 5
Maximum number of iterations without a deviance improvement: 100
Maximum number of Newton steps in M-step: 10
Value for obtaining finite MLEs for zero/perfects:    0.30000

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Partial Credit Model: IS Construct                          Sat Jul 05 16:49 2014
TABLES OF RESPONSE MODEL PARAMETER ESTIMATES
===========================================================Build: Dec 21 2012===
TERM 1: item
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VARIABLES				UNWEIGHTED FIT			WEIGHTED FIT		
	item	ESTIMATE	ERROR^	MNSQ	CI	T	MNSQ	CI	T
1	D1	-0.677	0.075	1.28	(0.89, 1.11)	4.6	1.16	(0.83, 1.17)	1.8
2	D2	0.505	0.085	1.04	(0.89, 1.11)	0.7	1.04	(0.95, 1.05)	1.5
3	D3	0.383	0.084	1.32	(0.89, 1.11)	5.2	1.23	(0.90, 1.10)	4.3
4	D4	-0.554	0.109	1.04	(0.89, 1.11)	0.7	1.04	(0.87, 1.13)	0.6
5	D5	-0.786	0.102	1.01	(0.89, 1.11)	0.2	0.97	(0.88, 1.12)	-0.5
6	D6	0.102	0.082	1.07	(0.89, 1.11)	1.3	1.08	(0.90, 1.10)	1.4
7	D7	0.392	0.070	1.38	(0.89, 1.11)	6.1	1.39	(0.87, 1.13)	5.5
8	S1	-1.065	0.110	0.94	(0.89, 1.11)	-1.1	0.97	(0.86, 1.14)	-0.4
9	S2	-0.653	0.084	1.27	(0.89, 1.11)	4.5	1.14	(0.88, 1.12)	2.1
10	S3	-0.565	0.128	1.22	(0.89, 1.11)	3.7	1.20	(0.91, 1.09)	4.0
11	S4	-1.021	0.089	1.50	(0.89, 1.11)	7.7	1.05	(0.79, 1.21)	0.5
12	S5	0.174	0.058	1.00	(0.89, 1.11)	0.1	1.00	(0.91, 1.09)	-0.0
13	S6	0.426	0.071	0.90	(0.89, 1.11)	-1.8	0.90	(0.90, 1.10)	-2.0
14	S7	1.339	0.101	1.09	(0.89, 1.11)	1.5	1.06	(0.90, 1.10)	1.2
15	P1	-2.981	0.223	1.28	(0.89, 1.11)	4.6	1.00	(0.60, 1.40)	0.1
16	P2	1.002	0.191	1.01	(0.89, 1.11)	0.1	1.01	(0.87, 1.13)	0.1
17	P3	-1.397	0.121	0.65	(0.89, 1.11)	-7.0	0.84	(0.83, 1.17)	-2.0
18	P4	-0.401	0.073	0.93	(0.89, 1.11)	-1.3	0.93	(0.89, 1.11)	-1.2
19	P5	-0.103	0.062	0.82	(0.89, 1.11)	-3.3	0.84	(0.89, 1.11)	-3.1
20	P6	1.559	0.145	0.73	(0.89, 1.11)	-5.2	0.86	(0.82, 1.18)	-1.6
21	P7	0.663	0.063	0.90	(0.89, 1.11)	-1.8	0.96	(0.88, 1.12)	-0.7
22	M1	-0.268	0.092	0.91	(0.89, 1.11)	-1.7	0.94	(0.92, 1.08)	-1.4
23	M2	1.619	0.145	0.93	(0.89, 1.11)	-1.2	0.94	(0.88, 1.12)	-1.1
24	M3	-0.051	0.089	0.84	(0.89, 1.11)	-3.0	0.87	(0.93, 1.07)	-3.7
25	M4	0.216	0.053	0.92	(0.89, 1.11)	-1.5	0.94	(0.90, 1.10)	-1.2
26	M5	0.578	0.052	0.85	(0.89, 1.11)	-2.7	0.87	(0.92, 1.08)	-3.2
27	M6	0.432	0.085	0.76	(0.89, 1.11)	-4.7	0.79	(0.94, 1.06)	-7.9
28	M7	1.130*	0.059	0.85	(0.89, 1.11)	-2.8	0.85	(0.90, 1.10)	-3.1

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An asterisk next to a parameter estimate indicates that it is constrained
Separation Reliability =  0.988
Chi-square test of parameter equality =    1679.40,  df = 27,  Sig Level = 0.000
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^ Empirical standard errors have been used

TERM 2: item*step

	item	category	ESTIMATE	ERROR^	UNWEIGHTED FIT MNSQ	UNWEIGHTED FIT CI	UNWEIGHTED FIT T	WEIGHTED FIT MNSQ	WEIGHTED FIT CI	WEIGHTED FIT T
1	D1	0			1.32	(0.89, 1.11)	5.2	1.18	(0.81, 1.19)	1.8
1	D1	1	1.411	0.182	1.05	(0.89, 1.11)	0.9	1.00	(0.70, 1.30)	0.0
1	D1	2	-1.411*		1.20	(0.89, 1.11)	3.3	1.11	(0.85, 1.15)	1.4
3	D3	0			0.85	(0.89, 1.11)	-2.7	1.01	(0.48, 1.52)	0.1
3	D3	1	-3.308	0.233	1.16	(0.89, 1.11)	2.7	1.13	(0.93, 1.07)	3.6
3	D3	2	0.352	0.127	1.04	(0.89, 1.11)	0.7	1.02	(0.94, 1.06)	0.6
3	D3	3	0.966	0.138	1.21	(0.89, 1.11)	3.4	1.03	(0.90, 1.10)	0.5
3	D3	4	1.989*		13.38	(0.89, 1.11)	73.2	1.17	(0.77, 1.23)	1.5
4	D4	0			18.78	(0.89, 1.11)	88.4	1.04	(0.49, 1.51)	0.2
4	D4	1	-0.821	0.268	0.72	(0.89, 1.11)	-5.5	0.97	(0.71, 1.29)	-0.2
4	D4	2	-1.542	0.205	1.01	(0.89, 1.11)	0.3	1.01	(0.94, 1.06)	0.4
4	D4	3	2.363*		1.10	(0.89, 1.11)	1.8	1.03	(0.91, 1.09)	0.8
6	D6	0			1.37	(0.89, 1.11)	5.9	1.11	(0.79, 1.21)	1.0
6	D6	1	-1.692	0.093	1.01	(0.89, 1.11)	0.1	1.01	(0.95, 1.05)	0.3
6	D6	2	1.692*		1.07	(0.89, 1.11)	1.2	1.02	(0.91, 1.09)	0.4
7	D7	0			1.20	(0.89, 1.11)	3.3	1.11	(0.69, 1.31)	0.7
7	D7	1	-1.580	0.199	1.62	(0.89, 1.11)	9.3	1.17	(0.82, 1.18)	1.8
7	D7	2	-0.722	0.163	1.05	(0.89, 1.11)	1.0	1.03	(0.89, 1.11)	0.5
7	D7	3	-0.715	0.122	1.35	(0.89, 1.11)	5.7	1.16	(0.94, 1.06)	4.8
7	D7	4	3.017*		1.76	(0.89, 1.11)	11.1	1.07	(0.73, 1.27)	0.5
9	S2	0			2.08	(0.89, 1.11)	14.7	1.02	(0.51, 1.49)	0.1
9	S2	1	-1.047	0.283	2.38	(0.89, 1.11)	17.9	1.02	(0.75, 1.25)	0.2
9	S2	2	-0.328	0.206	1.36	(0.89, 1.11)	5.8	1.05	(0.87, 1.13)	0.7
9	S2	3	0.797	0.154	1.00	(0.89, 1.11)	-0.0	1.00	(0.89, 1.11)	-0.0
9	S2	4	0.578*		1.10	(0.89, 1.11)	1.7	1.08	(0.93, 1.07)	2.1
10	S3	0			3.92	(0.89, 1.11)	30.8	0.95	(0.09, 1.91)	0.1
10	S3	1	-2.046	0.413	1.33	(0.89, 1.11)	5.3	1.03	(0.74, 1.26)	0.2
10	S3	2	-1.181	0.216	1.11	(0.89, 1.11)	2.0	1.09	(0.95, 1.05)	3.3
10	S3	3	1.803	0.165	1.21	(0.89, 1.11)	3.4	1.04	(0.90, 1.10)	0.9
10	S3	4	1.424*		1.43	(0.89, 1.11)	6.7	1.12	(0.92, 1.08)	2.8
11	S4	0			1.90	(0.89, 1.11)	12.7	1.08	(0.75, 1.25)	0.7
11	S4	1	1.488	0.213	0.95	(0.89, 1.11)	-0.9	0.99	(0.65, 1.35)	-0.0
11	S4	2	-1.488*		1.19	(0.89, 1.11)	3.2	1.01	(0.81, 1.19)	0.2
12	S5	0			1.00	(0.89, 1.11)	-0.0	0.97	(0.89, 1.11)	-0.6
12	S5	1	0.319	0.101	1.00	(0.89, 1.11)	0.0	1.00	(0.89, 1.11)	0.0
12	S5	2	-0.319*		1.01	(0.89, 1.11)	0.1	1.02	(0.93, 1.07)	0.6
13	S6	0			0.88	(0.89, 1.11)	-2.3	0.95	(0.86, 1.14)	-0.7
13	S6	1	-1.319	0.084	0.98	(0.89, 1.11)	-0.3	0.98	(0.96, 1.04)	-1.0
13	S6	2	1.319*		0.81	(0.89, 1.11)	-3.5	0.93	(0.91, 1.09)	-1.7
14	S7	0			0.93	(0.89, 1.11)	-1.2	0.99	(0.83, 1.17)	-0.1
14	S7	1	-1.985	0.157	1.12	(0.89, 1.11)	2.0	1.02	(0.91, 1.09)	0.3
14	S7	2	-0.791	0.151	0.95	(0.89, 1.11)	-0.8	0.98	(0.91, 1.09)	-0.4
14	S7	3	-0.768	0.143	1.09	(0.89, 1.11)	1.6	1.07	(0.93, 1.07)	2.1
14	S7	4	3.544*		35.33	(0.89, 1.11)	121.6	1.02	(0.29, 1.71)	0.2
16	P2	0			1.01	(0.89, 1.11)	0.2	0.91	(0.42, 1.58)	-0.2
16	P2	1	-2.869	0.342	0.99	(0.89, 1.11)	-0.1	1.02	(0.77, 1.23)	0.2
16	P2	2	-2.784	0.248	1.02	(0.89, 1.11)	0.3	1.02	(0.93, 1.07)	0.5
16	P2	3	1.030	0.218	1.02	(0.89, 1.11)	0.4	1.03	(0.90, 1.10)	0.6
16	P2	4	4.624*		0.37	(0.89, 1.11)	-15.0	0.97	(0.00, 2.35)	0.2
18	P4	0			0.52	(0.89, 1.11)	-10.5	0.94	(0.70, 1.30)	-0.4
18	P4	1	-0.821	0.168	0.87	(0.89, 1.11)	-2.5	0.98	(0.85, 1.15)	-0.3
18	P4	2	-0.059	0.143	1.03	(0.89, 1.11)	0.5	1.01	(0.94, 1.06)	0.4
18	P4	3	0.879*		0.96	(0.89, 1.11)	-0.7	0.98	(0.94, 1.06)	-0.5
19	P5	0			0.67	(0.89, 1.11)	-6.7	0.80	(0.87, 1.13)	-3.2
19	P5	1	0.462	0.111	1.05	(0.89, 1.11)	0.9	1.01	(0.87, 1.13)	0.2
19	P5	2	-0.462*		0.94	(0.89, 1.11)	-1.0	0.93	(0.92, 1.08)	-1.7
20	P6	0			0.64	(0.89, 1.11)	-7.3	0.82	(0.81, 1.19)	-1.9
20	P6	1	-3.154	0.154	0.74	(0.89, 1.11)	-5.1	0.87	(0.83, 1.17)	-1.6
20	P6	2	3.154*		1.07	(0.89, 1.11)	1.3	1.02	(0.50, 1.50)	0.1
21	P7	0			0.51	(0.89, 1.11)	-10.7	0.89	(0.78, 1.22)	-1.0
21	P7	1	-1.150	0.167	0.88	(0.89, 1.11)	-2.1	0.99	(0.83, 1.17)	-0.1
21	P7	2	-0.785	0.158	1.00	(0.89, 1.11)	0.1	0.99	(0.88, 1.12)	-0.1
21	P7	3	-0.929	0.120	0.99	(0.89, 1.11)	-0.1	0.95	(0.94, 1.06)	-1.7
21	P7	4	2.865*		1.71	(0.89, 1.11)	10.4	1.06	(0.71, 1.29)	0.4
23	M2	0			1.02	(0.89, 1.11)	0.4	0.99	(0.82, 1.18)	-0.1

```
 23  M2             1             -1.837   0.200    0.91 ( 0.89, 1.11) -1.7   0.96 ( 0.86, 1.14) -0.5
 23  M2             2             -2.299   0.185    0.95 ( 0.89, 1.11) -1.0   0.96 ( 0.95, 1.05) -1.6
 23  M2             3              1.055   0.193    0.99 ( 0.89, 1.11) -0.1   1.01 ( 0.83, 1.17)  0.2
 23  M2             4              3.081*           0.62 ( 0.89, 1.11) -7.9   0.97 ( 0.00, 2.08)  0.1
 25  M4             0                               0.68 ( 0.89, 1.11) -6.5   0.91 ( 0.84, 1.16) -1.1
 25  M4             1             -0.370   0.124    0.98 ( 0.89, 1.11) -0.4   1.00 ( 0.88, 1.12) -0.0
 25  M4             2             -0.177   0.126    0.98 ( 0.89, 1.11) -0.3   0.99 ( 0.94, 1.06) -0.2
 25  M4             3              0.547*           0.95 ( 0.89, 1.11) -0.9   1.01 ( 0.93, 1.07)  0.2
 26  M5             0                               0.87 ( 0.89, 1.11) -2.3   0.88 ( 0.92, 1.08) -2.8
 26  M5             1              1.831   0.168    1.04 ( 0.89, 1.11)  0.8   1.00 ( 0.71, 1.29)  0.0
 26  M5             2             -1.831*           0.85 ( 0.89, 1.11) -2.7   0.87 ( 0.92, 1.08) -3.3
 28  M7             0                               1.05 ( 0.89, 1.11)  0.8   0.95 ( 0.86, 1.14) -0.7
 28  M7             1             -1.525   0.118    0.86 ( 0.89, 1.11) -2.6   0.93 ( 0.93, 1.07) -2.1
 28  M7             2             -0.201   0.122    0.94 ( 0.89, 1.11) -1.1   0.98 ( 0.91, 1.09) -0.4
 28  M7             3             -0.194   0.125    0.75 ( 0.89, 1.11) -4.8   0.92 ( 0.92, 1.08) -1.9
 28  M7             4              1.919*           7.14 ( 0.89, 1.11) 49.3   1.00 ( 0.70, 1.30)  0.0
--------------------------------------------------------------------------------
An asterisk next to a parameter estimate indicates that it is constrained
================================================================================
================================================================================
Partial Credit Model: IS Construct                         Sat Jul 05 16:49 2014
TABLES OF POPULATION MODEL PARAMETER ESTIMATES
===========================================================Build: Dec 21 2012===
REGRESSION COEFFICIENTS



Regression Variable

CONSTANT                   0.738 ( 0.038)
-----------------------------------------------
An asterisk next to a parameter estimate indicates that it is constrained
===============================================
CONDITIONAL COVARIANCE/CORRELATION MATRIX



Dimension

Dimension_1
-------------------------------------------
Variance                   0.607  ( 0.043)
-------------------------------------------
An asterisk next to a parameter estimate indicates that it is constrained

===========================================

RELIABILITY COEFFICIENTS
------------------------

Dimension: (Dimension_1)
-----------------------
 MLE Person separation RELIABILITY:  Unavailable
 WLE Person separation RELIABILITY:  Unavailable
 EAP/PV RELIABILITY:                   0.867
------------------------
================================================================================
Partial Credit Model: IS Construct                         Sat Jul 05 16:49 2014
MAP OF LATENT DISTRIBUTIONS AND RESPONSE MODEL PARAMETER ESTIMATES
===========================================================Build: Dec 21 2012===
             Terms in the Model (excl Step terms)

                               +item
----------------------------------------------------
                |                                  |
                |                                  |
                |                                  |
                |                                  |
                |                                  |
                |                                  |
                |                                  |
                |                                  |
   3            |                                  |
                |                                  |
                |                                  |
```

```
                |                                  |
                |                                  |
               X|                                  |
                |                                  |
               X|                                  |
               X|                                  |
   2           X|                                  |
             XXX|                                  |
             XXX|                                  |
            XXXX|                                  |
          XXXXXX|23                                |
         XXXXXXX|20                                |
          XXXXXX|                                  |
         XXXXXXX|14                                |
      XXXXXXXXXX|                                  |
       XXXXXXXXX|28                                |
   1  XXXXXXXXXX|16                                |
       XXXXXXXXX|                                  |
       XXXXXXXXX|                                  |
        XXXXXXXX|21                                |
       XXXXXXXXX|26                                |
         XXXXXXX|2 27                              |
       XXXXXXXXX|3 7 13                            |
          XXXXXX|                                  |
             XXX|12 25                             |
           XXXXX|6                                 |
   0         XXX|24                                |
           XXXXX|19                                |
             XXX|22                                |
             XXX|18                                |
            XXXX|                                  |
              XX|4 10                              |
               X|1 9                               |
              XX|5                                 |
              XX|                                  |
  -1            |11                                |
               X|8                                 |
               X|                                  |
               X|                                  |
                |17                                |
                |                                  |
                |                                  |
                |                                  |
                |                                  |
  -2            |                                  |
                |                                  |
                |                                  |
                |15                                |
====================================================
Each 'X' represents 3.8 cases

====================================================
================================================================================
Partial Credit Model: IS Construct                        Sat Jul 05 16:49 2014
MAP OF LATENT DISTRIBUTIONS AND THRESHOLDS
===========================================================Build: Dec 21 2012===
                                              Generalised-Item Thresholds


--------------------------------------------------------------------------------------
                                              |14.4 16.4 20.2 23.4                   |
                                              |                                      |
                                              |21.4                                  |
                                              |                                      |
                                              |7.4                                   |
                                              |                                      |
                                              |28.4                                  |
                                              |                                      |
   3                                          |                                      |
                                              |                                      |
                                              |                                      |
                                             X|3.4                                   |
                                             X|23.3                                  |
                                           XXX|                                      |
```

```
                                            XX|                                      |
                                          XXXX|                                      |
                                          XXXX|                                      |
   2                                    XXXXXX|16.3                                  |
                                 XXXXXXXXXXXXX|                                      |
                                  XXXXXXXXXXXX|4.3 6.2 13.2                          |
                              XXXXXXXXXXXXXXXX|                                      |
                        XXXXXXXXXXXXXXXXXXXXXX|                                      |
                 XXXXXXXXXXXXXXXXXXXXXXXXXXXXX|                                      |
                     XXXXXXXXXXXXXXXXXXXXXXXXX|3.3 10.4                              |
                'XXXXXXXXXXXXXXXXXXXXXXXXXXXXX|28.3                                  |
      XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|                                      |
           XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|14.3 25.3                             |
   1    XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|                                      |
         XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|                                      |
           XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|18.3                                  |
              XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|10.3 26.2 28.2                        |
            XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|9.4                                   |
                XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|2 12.2 26.1 27                        |
            XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|3.2 21.3                              |
                      XXXXXXXXXXXXXXXXXXXXXXXX|14.2                                  |
                                 XXXXXXXXXXXXX|7.3 19.2 25.2                         |
                         XXXXXXXXXXXXXXXXXXXXX|                                      |
   0                             XXXXXXXXXXXXX|24                                    |
                           XXXXXXXXXXXXXXXXXXX|9.3 12.1 23.2                         |
                                 XXXXXXXXXXXXX|21.2 22                               |
                                 XXXXXXXXXXXXX|                                      |
                              XXXXXXXXXXXXXXXX|18.2 19.1                             |
                                     XXXXXXXXX|1.2 7.2                               |
                                         XXXXX|25.1 28.1                             |
                                        XXXXXX|1.1 5                                 |
                                        XXXXXX|11.2 14.1 23.1                        |
  -1                                         X|9.2 13.1 21.1                         |
                                         XXXXX|8                                     |
                                           XXX|11.1                                  |
                                          XXXX|                                      |
                                             X|4.2 16.2 17                           |
                                              |7.1 10.2 18.1                         |
                                              |6.1 20.1                              |
                                              |                                      |
                                            XX|                                      |
                                              |                                      |
  -2                                          |9.1                                   |
                                              |4.1                                   |
                                              |                                      |
                                              |3.1 10.1 15 16.1                      |
=====================================================================================
Each 'X' represents 1.0 cases
The labels for thresholds show the levels of
    item, and category, respectively

=====================================================================================

================================================================================
Partial Credit Model: IS Construct                       Sat Jul 05 16:49 2014
GENERALISED ITEM ANALYSIS
Group: All Students
================================================================================
Item 1
------
item:1 (D1)
Cases for this item     631   Item-Rest Cor.  0.33   Item-Total Cor.  0.39
Item Threshold(s):    -0.80 -0.56   Weighted MNSQ   1.16
Item Delta(s):         0.73 -2.09
-----------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)   PV1Avg:1 PV1 SD:1
-----------------------------------------------------------------------------
   0       0.00       67      10.62   -0.30    -7.94(.000)  0.02     0.71
   1       1.00       35       5.55   -0.12    -3.08(.002)  0.32     0.81
   2       2.00      529      83.84    0.33     8.72(.000)  0.85     0.71
=============================================================================

Item 2
------
item:2 (D2)
```

```
Cases for this item     631   Item-Rest Cor.  0.26   Item-Total Cor.  0.31
Item Threshold(s):     0.51   Weighted MNSQ   1.04
Item Delta(s):         0.51
-------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
-------------------------------------------------------------------------------
   0       0.00      282      44.69   -0.26    -6.78(.000)  0.44     0.72
   1       1.00      349      55.31    0.26     6.78(.000)  0.97     0.72
===============================================================================

Item 3
------
item:3 (D3)
Cases for this item     631   Item-Rest Cor.  0.30   Item-Total Cor.  0.39
Item Threshold(s):    -2.95  0.40  1.43  2.65   Weighted MNSQ   1.23
Item Delta(s):        -2.92  0.74  1.35  2.37
-------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
-------------------------------------------------------------------------------
   0       0.00       12       1.90   -0.15    -3.73(.000) -0.28     0.81
   1       1.00      234      37.08   -0.23    -5.91(.000)  0.43     0.73
   2       2.00      198      31.38    0.02     0.61(.540)  0.75     0.67
   3       3.00      138      21.87    0.23     5.95(.000)  1.17     0.66
   4       4.00       49       7.77    0.09     2.26(.024)  1.17     0.69
===============================================================================

Item 4
------
item:4 (D4)
Cases for this item     631   Item-Rest Cor.  0.33   Item-Total Cor.  0.38
Item Threshold(s):    -2.08 -1.42  1.83   Weighted MNSQ   1.04
Item Delta(s):        -1.38 -2.10  1.81
-------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
-------------------------------------------------------------------------------
   0       0.00       11       1.74   -0.13    -3.34(.001)  0.01     1.15
   1       1.00       35       5.55   -0.26    -6.79(.000) -0.09     0.68
   2       2.00      416      65.93   -0.06    -1.40(.161)  0.69     0.72
   3       3.00      169      26.78    0.23     6.03(.000)  1.07     0.68
===============================================================================

Item 5
------
item:5 (D5)
Cases for this item     631   Item-Rest Cor.  0.32   Item-Total Cor.  0.36
Item Threshold(s):    -0.79   Weighted MNSQ   0.97
Item Delta(s):        -0.79
-------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
-------------------------------------------------------------------------------
   0       0.00      129      20.44   -0.32    -8.60(.000)  0.24     0.84
   1       1.00      502      79.56    0.32     8.60(.000)  0.86     0.69
===============================================================================

Item 6
------
item:6 (D6)
Cases for this item     631   Item-Rest Cor.  0.25   Item-Total Cor.  0.30
Item Threshold(s):    -1.62  1.83   Weighted MNSQ   1.08
Item Delta(s):        -1.59  1.79
-------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
-------------------------------------------------------------------------------
   0       0.00       57       9.03   -0.11    -2.78(.006)  0.44     0.80
   1       1.00      406      64.34   -0.17    -4.25(.000)  0.62     0.76
   2       2.00      168      26.62    0.25     6.55(.000)  1.11     0.64
===============================================================================

Item 7
------
item:7 (D7)
Cases for this item     631   Item-Rest Cor.  0.25   Item-Total Cor.  0.33
Item Threshold(s):    -1.52 -0.52  0.19  3.43   Weighted MNSQ   1.39
Item Delta(s):        -1.19 -0.33 -0.32  3.41
-------------------------------------------------------------------------------
```

Label	Score	Count	% of tot	Pt Bis	t (p)	PV1Avg:1	PV1 SD:1
0	0.00	26	4.12	-0.26	-6.66(.000)	-0.33	0.64
1	1.00	69	10.94	-0.07	-1.73(.084)	0.43	0.66
2	2.00	127	20.13	-0.04	-1.05(.296)	0.64	0.66
3	3.00	370	58.64	0.15	3.81(.000)	0.87	0.75
4	4.00	39	6.18	0.06	1.59(.112)	1.05	0.71

Item 8

item:8 (S1)
Cases for this item 631 Item-Rest Cor. 0.31 Item-Total Cor. 0.35
Item Threshold(s): -1.07 Weighted MNSQ 0.97
Item Delta(s): -1.07

Label	Score	Count	% of tot	Pt Bis	t (p)	PV1Avg:1	PV1 SD:1
0	0.00	105	16.64	-0.31	-8.32(.000)	0.17	0.77
1	1.00	526	83.36	0.31	8.32(.000)	0.85	0.71

Item 9

item:9 (S2)
Cases for this item 631 Item-Rest Cor. 0.45 Item-Total Cor. 0.53
Item Threshold(s): -2.03 -0.97 -0.12 0.54 Weighted MNSQ 1.14
Item Delta(s): -1.70 -0.98 0.14 -0.07

Label	Score	Count	% of tot	Pt Bis	t (p)	PV1Avg:1	PV1 SD:1
0	0.00	11	1.74	-0.22	-5.62(.000)	-0.50	0.65
1	1.00	38	6.02	-0.27	-7.10(.000)	-0.08	0.82
2	2.00	100	15.85	-0.19	-4.77(.000)	0.34	0.72
3	3.00	135	21.39	-0.05	-1.31(.192)	0.60	0.61
4	4.00	347	54.99	0.37	9.92(.000)	1.03	0.65

Item 10

item:10 (S3)
Cases for this item 631 Item-Rest Cor. 0.33 Item-Total Cor. 0.41
Item Threshold(s): -2.89 -1.52 0.70 1.46 Weighted MNSQ 1.20
Item Delta(s): -2.61 -1.75 1.24 0.86

Label	Score	Count	% of tot	Pt Bis	t (p)	PV1Avg:1	PV1 SD:1
0	0.00	4	0.63	-0.14	-3.45(.001)	-0.51	1.02
1	1.00	38	6.02	-0.22	-5.69(.000)	0.03	0.78
2	2.00	260	41.20	-0.12	-3.04(.002)	0.56	0.69
3	3.00	147	23.30	0.01	0.23(.814)	0.78	0.79
4	4.00	182	28.84	0.26	6.81(.000)	1.12	0.62

Item 11

item:11 (S4)
Cases for this item 630 Item-Rest Cor. 0.32 Item-Total Cor. 0.36
Item Threshold(s): -1.13 -0.91 Weighted MNSQ 1.05
Item Delta(s): 0.47 -2.51

Label	Score	Count	% of tot	Pt Bis	t (p)	PV1Avg:1	PV1 SD:1
0	0.00	42	6.67	-0.26	-6.87(.000)	-0.06	0.89
1	1.00	26	4.13	-0.17	-4.40(.000)	0.15	0.86
2	2.00	562	89.21	0.32	8.56(.000)	0.82	0.71

Item 12

item:12 (S5)
Cases for this item 631 Item-Rest Cor. 0.47 Item-Total Cor. 0.54
Item Threshold(s): -0.18 0.53 Weighted MNSQ 1.00
Item Delta(s): 0.49 -0.15

```
 Label    Score     Count   % of tot  Pt Bis     t  (p)   PV1Avg:1 PV1 SD:1
-------------------------------------------------------------------------------
   0       0.00      149      23.61   -0.46   -12.99(.000)  0.11     0.76
   1       1.00      131      20.76   -0.01    -0.24(.811)  0.65     0.66
   2       2.00      351      55.63    0.40    10.97(.000)  1.03     0.63
===============================================================================

Item 13
-------
item:13 (S6)
Cases for this item     631   Item-Rest Cor.  0.50   Item-Total Cor.  0.55
Item Threshold(s):    -0.96  1.81   Weighted MNSQ   0.90
Item Delta(s):        -0.89  1.74
-------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)   PV1Avg:1 PV1 SD:1
-------------------------------------------------------------------------------
   0       0.00       98      15.53   -0.39   -10.71(.000)  0.02     0.76
   1       1.00      368      58.32   -0.07    -1.79(.074)  0.68     0.67
   2       2.00      165      26.15    0.40    11.06(.000)  1.29     0.55
===============================================================================

Item 14
-------
item:14 (S7)
Cases for this item     631   Item-Rest Cor.  0.49   Item-Total Cor.  0.57
Item Threshold(s):    -0.90  0.30  1.08  4.90   Weighted MNSQ   1.06
Item Delta(s):        -0.65  0.55  0.57  4.88
-------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)   PV1Avg:1 PV1 SD:1
-------------------------------------------------------------------------------
   0       0.00       71      11.25   -0.40   -11.06(.000) -0.13     0.68
   1       1.00      153      24.25   -0.21    -5.52(.000)  0.40     0.74
   2       2.00      159      25.20    0.13     3.24(.001)  0.84     0.56
   3       3.00      241      38.19    0.33     8.70(.000)  1.12     0.61
   4       4.00        7       1.11    0.04     1.13(.261)  1.28     0.99
===============================================================================

Item 15
-------
item:15 (P1)
Cases for this item     631   Item-Rest Cor.  0.11   Item-Total Cor.  0.13
Item Threshold(s):    -2.98   Weighted MNSQ   1.00
Item Delta(s):        -2.98
-------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)   PV1Avg:1 PV1 SD:1
-------------------------------------------------------------------------------
   0       0.00       20       3.17   -0.11    -2.90(.004)  0.40     1.01
   1       1.00      611      96.83    0.11     2.90(.004)  0.75     0.76
===============================================================================

Item 16
-------
item:16 (P2)
Cases for this item     631   Item-Rest Cor.  0.35   Item-Total Cor.  0.41
Item Threshold(s):    -2.33 -1.35  2.03  5.65   Weighted MNSQ   1.01
Item Delta(s):        -1.87 -1.78  2.03  5.63
-------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)   PV1Avg:1 PV1 SD:1
-------------------------------------------------------------------------------
   0       0.00        9       1.43   -0.23    -5.87(.000) -0.53     0.84
   1       1.00       48       7.61   -0.19    -4.94(.000)  0.20     0.73
   2       2.00      429      67.99   -0.05    -1.23(.218)  0.69     0.73
   3       3.00      143      22.66    0.23     5.96(.000)  1.12     0.62
   4       4.00        2       0.32    0.08     1.93(.054)  2.19     1.66
===============================================================================

Item 17
-------
item:17 (P3)
Cases for this item     631   Item-Rest Cor.  0.52   Item-Total Cor.  0.54
Item Threshold(s):    -1.40   Weighted MNSQ   0.84
Item Delta(s):        -1.40
-------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)   PV1Avg:1 PV1 SD:1
-------------------------------------------------------------------------------
```

```
   0       0.00       81      12.84   -0.52   -15.27(.000) -0.20     0.72
   1       1.00      550      87.16    0.52    15.27(.000)  0.87     0.67
==============================================================================

Item 18
-------
item:18 (P4)
Cases for this item     631   Item-Rest Cor.  0.55   Item-Total Cor.  0.61
Item Threshold(s):    -1.54 -0.43  0.77   Weighted MNSQ   0.93
Item Delta(s):        -1.22 -0.46  0.48
------------------------------------------------------------------------------
 Label    Score     Count    % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
------------------------------------------------------------------------------
   0       0.00       29       4.60   -0.36    -9.80(.000) -0.45     0.61
   1       1.00       88      13.95   -0.32    -8.61(.000)  0.10     0.62
   2       2.00      208      32.96   -0.04    -0.97(.334)  0.68     0.71
   3       3.00      306      48.49    0.41    11.40(.000)  1.07     0.60
==============================================================================

Item 19
-------
item:19 (P5)
Cases for this item     631   Item-Rest Cor.  0.59   Item-Total Cor.  0.64
Item Threshold(s):    -0.41  0.21   Weighted MNSQ   0.84
Item Delta(s):         0.36 -0.57
------------------------------------------------------------------------------
 Label    Score     Count    % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
------------------------------------------------------------------------------
   0       0.00      116      18.38   -0.60   -18.77(.000) -0.20     0.67
   1       1.00      107      16.96   -0.00    -0.03(.972)  0.66     0.65
   2       2.00      408      64.66    0.49    13.97(.000)  1.02     0.58
==============================================================================

Item 20
-------
item:20 (P6)
Cases for this item     631   Item-Rest Cor.  0.50   Item-Total Cor.  0.53
Item Threshold(s):    -1.60  4.71   Weighted MNSQ   0.86
Item Delta(s):        -1.60  4.71
------------------------------------------------------------------------------
 Label    Score     Count    % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
------------------------------------------------------------------------------
   0       0.00       68      10.78   -0.54   -15.90(.000) -0.32     0.70
   1       1.00      549      87.00    0.46    13.14(.000)  0.86     0.67
   2       2.00       14       2.22    0.07     1.70(.090)  0.99     0.47
==============================================================================

Item 21
-------
item:21 (P7)
Cases for this item     631   Item-Rest Cor.  0.57   Item-Total Cor.  0.64
Item Threshold(s):    -0.98 -0.25  0.34  3.55   Weighted MNSQ   0.96
Item Delta(s):        -0.49 -0.12 -0.27  3.53
------------------------------------------------------------------------------
 Label    Score     Count    % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
------------------------------------------------------------------------------
   0       0.00       50       7.92   -0.48   -13.65(.000) -0.44     0.58
   1       1.00       74      11.73   -0.28    -7.20(.000)  0.15     0.63
   2       2.00      121      19.18   -0.03    -0.66(.512)  0.66     0.61
   3       3.00      352      55.78    0.43    12.03(.000)  1.01     0.62
   4       4.00       34       5.39    0.06     1.50(.135)  1.14     0.77
==============================================================================

Item 22
-------
item:22 (M1)
Cases for this item     631   Item-Rest Cor.  0.39   Item-Total Cor.  0.43
Item Threshold(s):    -0.27   Weighted MNSQ   0.94
Item Delta(s):        -0.27
------------------------------------------------------------------------------
 Label    Score     Count    % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
------------------------------------------------------------------------------
   0       0.00      183      29.00   -0.39   -10.71(.000)  0.27     0.73
   1       1.00      448      71.00    0.39    10.71(.000)  0.93     0.69
==============================================================================
```

```
Item 23
-------
item:23 (M2)
Cases for this item     631   Item-Rest Cor.  0.54   Item-Total Cor.  0.59
Item Threshold(s):    -0.84 -0.10  2.60  4.81   Weighted MNSQ   0.94
Item Delta(s):        -0.22 -0.68  2.67  4.70
------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
------------------------------------------------------------------------------
   0       0.00       71      11.25   -0.41   -11.22(.000) -0.09     0.72
   1       1.00      101      16.01   -0.27    -7.13(.000)  0.25     0.74
   2       2.00      379      60.06    0.30     8.03(.000)  0.91     0.62
   3       3.00       77      12.20    0.23     5.88(.000)  1.24     0.57
   4       4.00        3       0.48    0.08     1.90(.058)  1.93     1.27
==============================================================================

Item 24
-------
item:24 (M3)
Cases for this item     631   Item-Rest Cor.  0.51   Item-Total Cor.  0.54
Item Threshold(s):    -0.05   Weighted MNSQ   0.87
Item Delta(s):        -0.05
------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
------------------------------------------------------------------------------
   0       0.00      209      33.12   -0.51   -14.73(.000)  0.20     0.74
   1       1.00      422      66.88    0.51    14.73(.000)  1.00     0.63
==============================================================================

Item 25
-------
item:25 (M4)
Cases for this item     631   Item-Rest Cor.  0.58   Item-Total Cor.  0.65
Item Threshold(s):    -0.64  0.15  1.12   Weighted MNSQ   0.94
Item Delta(s):        -0.15  0.04  0.76
------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
------------------------------------------------------------------------------
   0       0.00       85      13.47   -0.50   -14.62(.000) -0.21     0.62
   1       1.00      112      17.75   -0.18    -4.70(.000)  0.37     0.65
   2       2.00      193      30.59    0.10     2.59(.010)  0.83     0.65
   3       3.00      241      38.19    0.40    10.99(.000)  1.16     0.56
==============================================================================

Item 26
-------
item:26 (M5)
Cases for this item     631   Item-Rest Cor.  0.58   Item-Total Cor.  0.65
Item Threshold(s):     0.50  0.66   Weighted MNSQ   0.87
Item Delta(s):         2.41 -1.25
------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
------------------------------------------------------------------------------
   0       0.00      258      40.89   -0.56   -17.16(.000)  0.21     0.69
   1       1.00       38       6.02   -0.02    -0.58(.559)  0.57     0.67
   2       2.00      335      53.09    0.57    17.29(.000)  1.16     0.54
==============================================================================

Item 27
-------
item:27 (M6)
Cases for this item     631   Item-Rest Cor.  0.61   Item-Total Cor.  0.64
Item Threshold(s):     0.43   Weighted MNSQ   0.79
Item Delta(s):         0.43
------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)    PV1Avg:1 PV1 SD:1
------------------------------------------------------------------------------
   0       0.00      272      43.11   -0.61   -19.25(.000)  0.21     0.67
   1       1.00      359      56.89    0.61    19.25(.000)  1.13     0.57
==============================================================================

Item 28
-------
item:28 (M7)
```

```
Cases for this item     631   Item-Rest Cor.  0.62   Item-Total Cor.  0.69
Item Threshold(s):    -0.62  0.64  1.34  3.16   Weighted MNSQ   0.85
Item Delta(s):        -0.40  0.93  0.94  3.05
------------------------------------------------------------------------------
 Label    Score     Count   % of tot  Pt Bis     t  (p)   PV1Avg:1 PV1 SD:1
------------------------------------------------------------------------------
   0       0.00      100      15.85   -0.45   -12.59(.000) -0.05     0.71
   1       1.00      188      29.79   -0.28    -7.25(.000)  0.39     0.60
   2       2.00      147      23.30    0.16     3.98(.000)  0.90     0.56
   3       3.00      165      26.15    0.42    11.73(.000)  1.30     0.43
   4       4.00       31       4.91    0.18     4.53(.000)  1.57     0.75
==============================================================================

------------------------------------------------------------------------------
The following traditional statistics are only meaningful for complete
designs and when the amount of missing data is minimal.
In this analysis  0.01%  of the data are missing.

The following results are scaled to assume that a single response
was provided for each item.

N                                 631
Mean                            43.38
Standard Deviation               9.98
Variance                        99.59
Skewness                        -0.86
Kurtosis                         0.25
Standard error of mean           0.40
Standard error of measurement    3.55
Coefficient Alpha                0.87
==============================================================================
```