Examining the Use of the LOCUS Assessment with Undergraduate Students

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Statistics Education Instruments

- **Conceptual Understanding**: Levels of Conceptual Understanding in Statistics (LOCUS; Jacobbe et al., 2014; Whitaker et al., 2015)
  - 4 components: *Formulate Questions*, *Collect Data*, *Analyze Data*, and *Interpret Results*
  - Designed for grades 9-12, desire to use in undergraduate courses

- **Attitudes**: Survey of Attitudes Towards Statistics (SATS; Schau, 1992, 2003)
  - 4 components (SATS-28): *Affect*, *Value*, *Difficulty*, and *Cognitive Competence*
  - 6 components (SATS-36): *Interest* and *Effort* with the SATS-28 component
  - Widely used in undergraduate courses (Ramirez et al., 2012)

Goals & Data

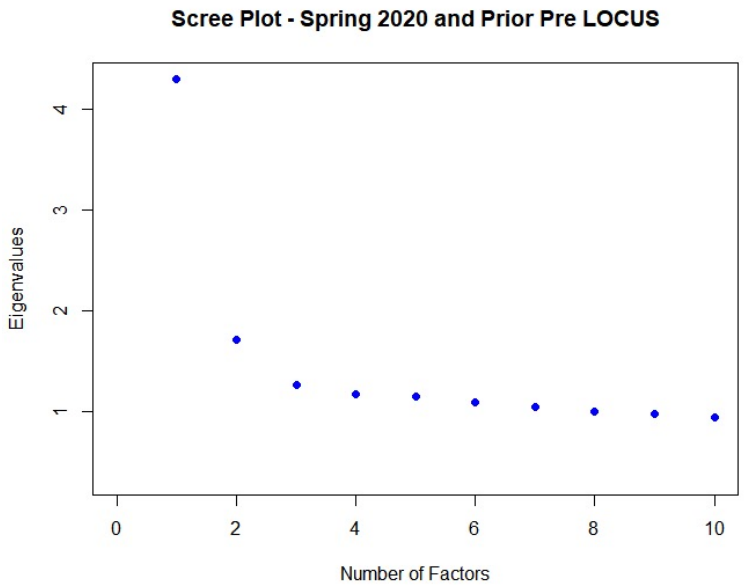
1. Examine the factor structure of the LOCUS when used with undergraduate students
   - Pairwise-complete observations (N = 963) were used

2. Model the relationship between attitudes (as measured by the SATS) and conceptual understanding in statistics (as measured by the LOCUS) using logistic regression
   - Pairwise-complete data: pre (N=328) and post (N=291)
     - LOCUS attempts that were less than 5 minutes removed

We thank Dr. Alana Unfried of California State University, Monterey Bay for providing the data used in the analysis.

Goal 1: Explore Factor Structure of LOCUS

- A four-factor solution was of interest to investigate the proposed four-construct structure
- The scree plots below suggested also trying a two-factor solution
- We decided to find two-factor and four-factor solutions, both pre and post



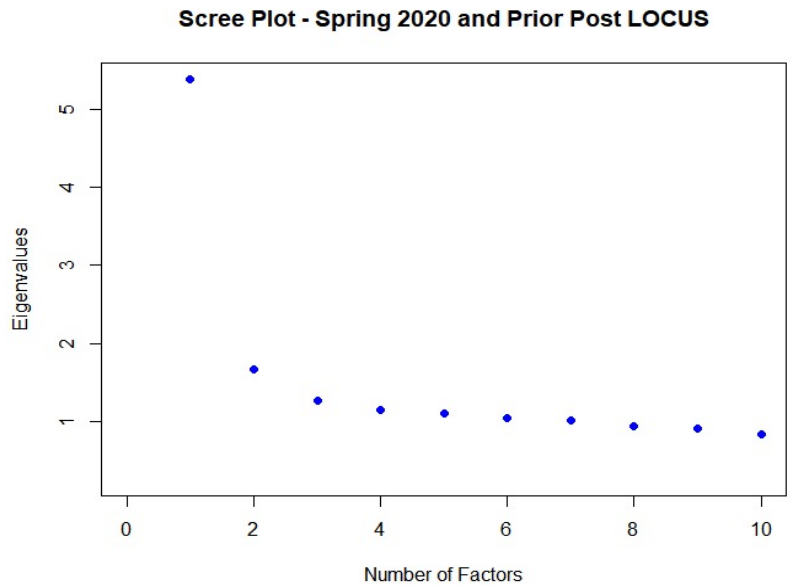


Table of loadings for four-factor solution of posttest with varimax rotation

	Factor 1	Factor 2	Factor 3	Factor 4	Communality	Nominal Construct
Item 2	0.7478	0.1660	0.0421	0.0450	0.5906	Formulate Questions
Item 5	0.3018	0.1629	0.0219	-0.2212	0.1670	Formulate Questions
Item 9	0.4820	0.4235	0.2006	0.0464	0.4541	Formulate Questions
Item 12	0.2293	0.3318	0.2781	0.2005	0.2802	Formulate Questions
Item 3	0.6124	0.1920	0.0083	0.0583	0.4154	Collect Data
Item 6	0.3202	0.1976	0.1113	-0.0773	0.1599	Collect Data
Item 10	0.3594	0.2014	0.1305	-0.0569	0.1900	Collect Data
Item 13	0.3175	0.4343	0.1444	-0.0644	0.3144	Collect Data
Item 21	0.0979	0.3778	-0.1314	0.2129	0.2149	Collect Data
Item 7	0.3518	0.2712	0.1155	0.0460	0.2128	Analyze Data
Item 11	0.2224	0.2762	0.3274	0.1720	0.2625	Analyze Data
Item 15	0.2796	0.0419	0.1687	0.0229	0.1089	Analyze Data
Item 16	0.1272	0.1090	0.3743	-0.0755	0.1738	Analyze Data
Item 18	0.0927	-0.0748	0.4415	0.0554	0.2122	Analyze Data
Item 20	0.1235	0.1924	0.3767	0.0916	0.2025	Analyze Data
Item 1	0.6085	0.1840	0.2388	0.0455	0.4633	Interpret Results
Item 4	0.5156	0.1695	0.2739	0.1815	0.4025	Interpret Results
Item 8	0.5318	0.1484	0.3680	-0.0573	0.4436	Interpret Results
Item 14	0.2383	-0.0655	0.2579	0.0575	0.1309	Interpret Results
Item 17	0.0097	-0.0289	0.3509	-0.1005	0.1342	Interpret Results
Item 19	0.0908	0.0687	0.3914	0.0038	0.1662	Interpret Results
Item 22	0.3702	0.8852	0.0103	-0.1199	0.9351	Interpret Results
Item 23	0.0138	0.0460	-0.0022	0.4671	0.2205	Interpret Results
Proportion of Variance Explained	0.1332	0.0816	0.0619	0.0213		
Cumulative Variance Explained	0.1332	0.2149	0.2768	0.2981		

We considered an item as loaded onto (or sufficiently associated with) a factor if the absolute value of its loading on that factor was greater than 0.4, as suggested by Swisher et al. (2004). If an item loads onto a factor, it is highlighted under that factor.

Table of loadings for two-factor solution of posttest with varimax rotation

	Factor 1	Factor 2	Communality	Nominal Construct
Item 2	0.6307	0.2197	0.4461	Formulate Questions
Item 5	0.3217	0.0505	0.1060	Formulate Questions
Item 9	0.6488	0.2061	0.4634	Formulate Questions
Item 12	0.3928	0.2397	0.2118	Formulate Questions
Item 3	0.5634	0.1470	0.3391	Collect Data
Item 6	0.3672	0.1321	0.1523	Collect Data
Item 10	0.3973	0.1628	0.1844	Collect Data
Item 13	0.5319	0.0985	0.2926	Collect Data
Item 21	0.3385	-0.1650	0.1418	Collect Data
Item 7	0.4466	0.1344	0.2175	Analyze Data
Item 11	0.3508	0.2904	0.2074	Analyze Data
Item 15	0.2241	0.2287	0.1025	Analyze Data
Item 16	0.1509	0.3483	0.1441	Analyze Data
Item 18	-0.0055	0.4676	0.2186	Analyze Data
Item 20	0.2172	0.3253	0.1530	Analyze Data
Item 1	0.5575	0.3492	0.4327	Interpret Results
Item 4	0.4824	0.3675	0.3678	Interpret Results
Item 8	0.4702	0.4515	0.4249	Interpret Results
Item 14	0.1131	0.3347	0.1248	Interpret Results
Item 17	-0.0263	0.3200	0.1031	Interpret Results
Item 19	0.0990	0.3684	0.1455	Interpret Results
Item 22	0.8137	-0.0563	0.6653	Interpret Results
Item 23	0.0512	0.0229	0.0031	Interpret Results
Proportion of Variance Explained	0.1730	0.0725		
Cumulative Variance Explained	0.1730	0.2456		

We considered an item as loaded onto (or sufficiently associated with) a factor if the absolute value of its loading on that factor was greater than 0.4, as suggested by Swisher et al. (2004). If an item loads onto a factor, it is highlighted under that factor.

Goal 1: Explore Factor Structure of LOCUS

- A clean factor solution aligned with the hypothesized model was not found when using the post-course data
- Two-factor and four-factor solutions were found, but neither result in item groupings that are meaningful

- *More work is needed!*

- For future analyses, a single LOCUS composite score will be used

Goal 2: Model Attitudes and Conceptual Understanding

- Ramirez et al. (2012) suggest that attitudes towards statistics play a critically important role in one's learning of the subject

- Long standing interest in the relationship between attitudes and achievement

- We will model the relationship between SATS scale scores (predictors) and LOCUS score (response)
  - Logistic regression models
  - Separate model building for pre and post variables

Final pretest and posttest models

All else held constant, the more somebody values statistics and its usefulness (i.e., the higher their pretest *Value* score) going into the pretest, the lower their expected pretest achievement.

	Dependent variable:	
	Correct LOCUS Pre Item	Correct LOCUS Post Item
	(1)	(2)
Constant	**0.084**	**-0.966**
	(0.011, 0.157)	(-1.225, -0.707)
	p = 0.025**	p = 0.000***
Centered *Cognitive Competence* (at the time)	**-0.123**	**-0.164**
	(-0.234, -0.012)	(-0.272, -0.057)
	p = 0.030**	p = 0.004***
Centered *Value* (at the time)	**-0.227**	**0.053**
	(-0.349, -0.105)	(-0.109, 0.215)
	p = 0.0004***	p = 0.523
Male indicator	**0.150**	**0.020**
	(0.010, 0.290)	(-0.129, 0.168)
	p = 0.037**	p = 0.796
Value/Male interaction term		**-0.309**
		(-0.592, -0.025)
		p = 0.034**
Cognitive Competence/Male interaction term	**-0.258**	
	(-0.471, -0.045)	
	p = 0.019**	
Total number of correct items in the pretest		**0.110**
		(0.090, 0.131)
		p = 0.000***
Residual Deviance	629.971 (df = 323)	492.227 (df = 285)
Null Deviance	711.011 (df = 327)	770.931 (df = 290)
Note:	*p <0.1 ; ** p<0.05 ; *** p<0.001	

All else held constant, the more a female student values statistics in the posttest, the **higher** their expected posttest achievement. For male students, it remains a **decrease** (in expected posttest achievement).

CIs have a confidence level of 95%.

Tables created with Hlavac's stargazer R package (2018)

Conclusion

- The LOCUS's proposed four-construct structure was not recovered in our EFA and that raises concerns (more work is needed)
- We were able to find empirical evidence of relationships between certain attitude scale scores (on the SATS) and achievement (on the LOCUS)
- How one administers the assessment may affect responses
  - Additional data is needed to address whether counting the LOCUS for participation or a grade matters (and, if so, which should be recommended)
  - Low-quality LOCUS attempts discovered while modelling are suggestive that test administration decisions may have an effect

Limitations and Future Directions

- We relied heavily on pairwise-complete or complete data throughout the project, and in doing so, may have dropped crucial data
  - A formal investigation into the types of missingness in this data would be appropriate

- More sophisticated models for the internal structure of the LOCUS should be used in future work
  - Confirmatory Factor Analysis
  - Item Response Theory

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Questions?

Live Q&A Thursday, July 1st
2:45pm-3:30pm ET

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Thank you!

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Supplementary Slides

Table of loadings for four-factor solution of pretest with varimax rotation

	Factor 1	Factor 2	Factor 3	Factor 4	Communality	Nominal Construct
Item 2	0.2879	0.5325	0.3783	-0.2345	0.5645	Formulate Questions
Item 5	0.2699	0.1139	0.2877	-0.0575	0.1719	Formulate Questions
Item 9	0.3603	0.2150	0.0939	0.0843	0.1920	Formulate Questions
Item 12	0.3281	0.2543	0.0552	0.0054	0.1754	Formulate Questions
Item 3	0.2632	0.2484	0.4215	0.0019	0.3086	Collect Data
Item 6	0.3548	0.1611	0.1450	0.1544	0.1967	Collect Data
Item 10	0.3289	0.1520	0.1284	0.0680	0.1524	Collect Data
Item 13	0.5523	0.1270	0.0688	-0.0888	0.3338	Collect Data
Item 21	0.2354	0.0290	-0.0392	0.0014	0.0578	Collect Data
Item 7	0.2775	0.2173	0.2261	0.0265	0.1760	Analyze Data
Item 11	0.2356	0.1707	0.1313	0.3647	0.2349	Analyze Data
Item 15	0.2478	0.0577	0.0725	0.0958	0.0792	Analyze Data
Item 16	0.0184	0.2069	0.3575	0.0550	0.1740	Analyze Data
Item 18	0.0863	-0.0095	0.0819	0.4863	0.2508	Analyze Data
Item 20	0.1363	0.0120	0.4448	0.3098	0.3125	Analyze Data
Item 1	0.3394	0.6365	0.1205	0.0424	0.5366	Interpret Results
Item 4	0.3569	0.3616	0.0231	0.2790	0.3365	Interpret Results
Item 8	0.2436	0.4343	0.2013	0.2332	0.3428	Interpret Results
Item 14	0.0439	-0.0121	0.0542	0.3267	0.1117	Interpret Results
Item 17	-0.0118	0.0804	-0.2742	0.3753	0.2227	Interpret Results
Item 19	-0.0448	0.1580	0.1176	0.2428	0.0998	Interpret Results
Item 22	0.7005	-0.0157	0.3412	-0.0764	0.6132	Interpret Results
Item 23	-0.0326	-0.0089	-0.0528	0.1036	0.0147	Interpret Results
Proportion of Variance Explained	0.0902	0.0615	0.0492	0.0451		
Cumulative Variance Explained	0.0902	0.1517	0.2009	0.2460		

We considered an item as loaded onto (or sufficiently associated with) a factor if the absolute value of its loading on that factor was greater than 0.4, as suggested by Swisher et al. (2004). If an item loads onto a factor, it is highlighted under that factor.

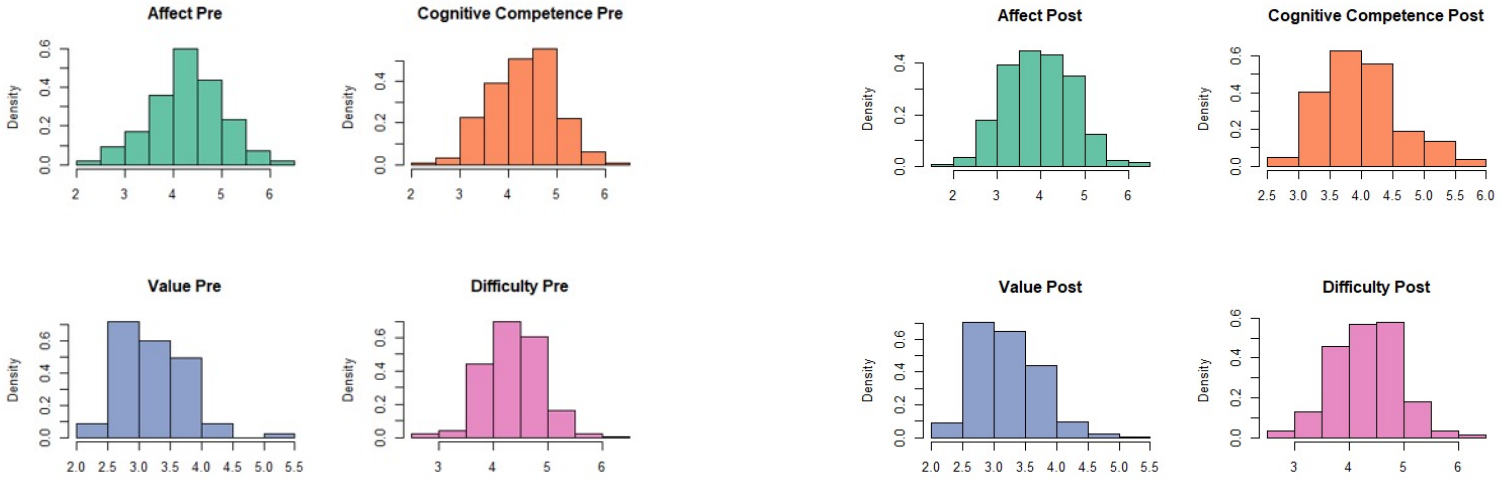
Table of loadings for two-factor solution of pretest with varimax rotation

	Factor 1	Factor 2	Communality	Nominal Construct
Item 2	0.6506	-0.1638	0.4502	Formulate Questions
Item 5	0.3947	-0.0692	0.1606	Formulate Questions
Item 9	0.4137	0.1026	0.1817	Formulate Questions
Item 12	0.3940	0.0359	0.1565	Formulate Questions
Item 3	0.5147	0.0028	0.2649	Collect Data
Item 6	0.4018	0.1675	0.1895	Collect Data
Item 10	0.3761	0.0757	0.1472	Collect Data
Item 13	0.4898	-0.0691	0.2447	Collect Data
Item 21	0.1634	0.0146	0.0269	Collect Data
Item 7	0.4211	0.0392	0.1789	Analyze Data
Item 11	0.3045	0.3860	0.2417	Analyze Data
Item 15	0.2388	0.0982	0.0667	Analyze Data
Item 16	0.2805	0.0571	0.0819	Analyze Data
Item 18	0.0750	0.4686	0.2252	Analyze Data
Item 20	0.2946	0.2422	0.1455	Analyze Data
Item 1	0.6052	0.1171	0.3800	Interpret Results
Item 4	0.4428	0.3134	0.2943	Interpret Results
Item 8	0.4830	0.2740	0.3083	Interpret Results
Item 14	0.0360	0.3245	0.1066	Interpret Results
Item 17	-0.1084	0.3847	0.1597	Interpret Results
Item 19	0.0945	0.2510	0.0719	Interpret Results
Item 22	0.6207	-0.0684	0.3900	Interpret Results
Item 23	-0.0591	0.1106	0.0157	Interpret Results
Proportion of Variance Explained	0.1498	0.0454		
Cumulative Variance Explained	0.1498	0.1952		

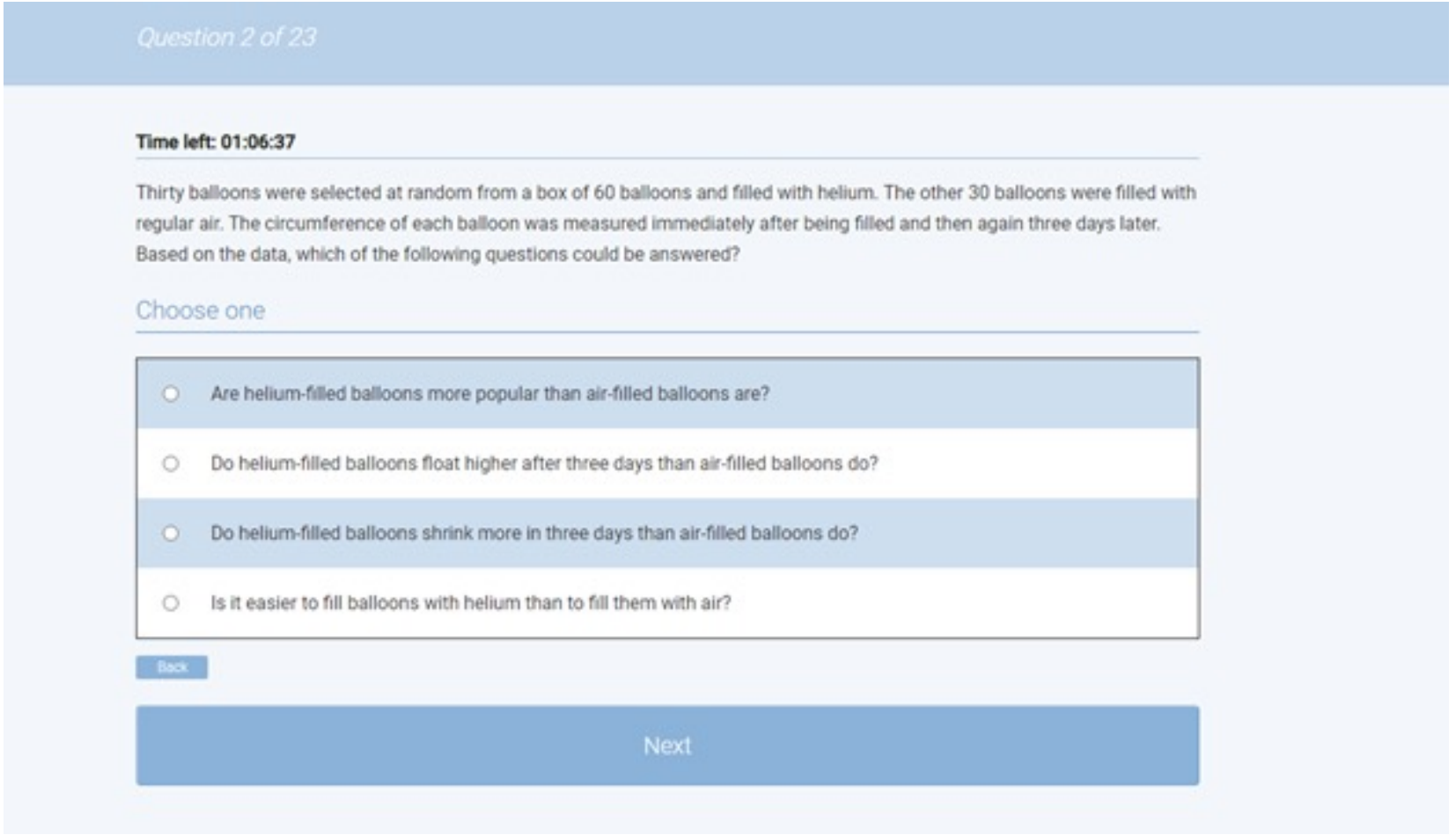
We considered an item as loaded onto (or sufficiently associated with) a factor if the absolute value of its loading on that factor was greater than 0.4, as suggested by Swisher et al. (2004). If an item loads onto a factor, it is highlighted under that factor.

Predictors we were interested in

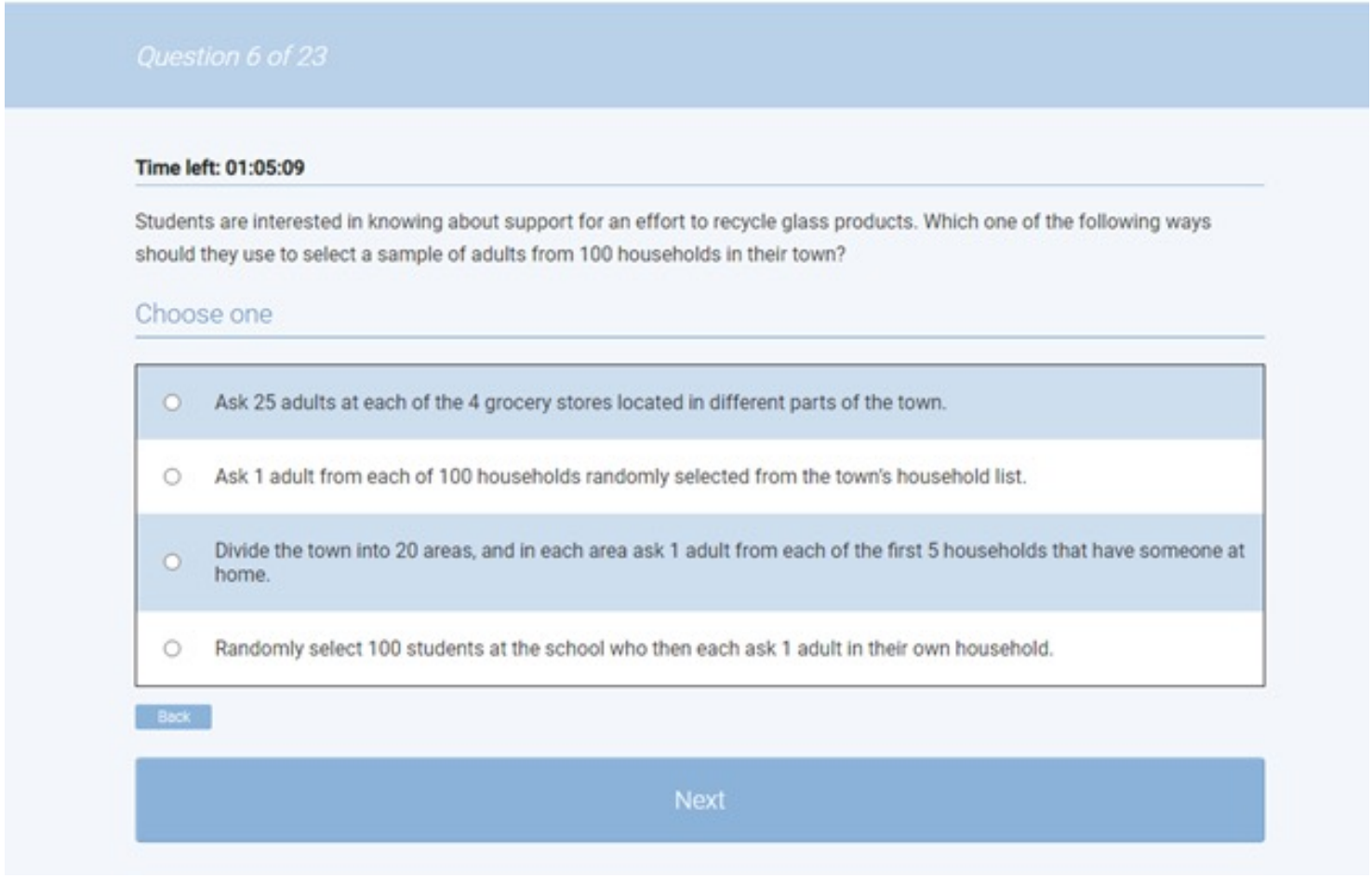
- For the pretest models: the (centered) pretest SATS-28 scale scores
- For the posttest models: the (centered) posttest SATS-28 scale scores *and* the number of correct items in the pretest
- We also included section and gender as covariates in the model-building process (via indicator variables)
  - Including section as a predictor allowed us try and account, at least a little, for section-to-section differences



Sample LOCUS *Formulate Questions* Item



Sample LOCUS *Collect Data* Item

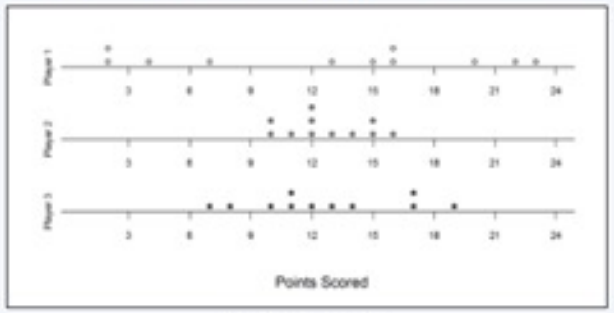


Sample LOCUS *Analyze Data* Item

Question 4 of 23

Time left: 01:05:54

Jason is the statistician for a summer basketball league. After eleven games he notes that the top three scorers in the league have about the same mean number of points per game (12.7, 12.7, and 12.6). He produces the dotplots of the points scored in eleven games for each player shown below.



Click image to enlarge.

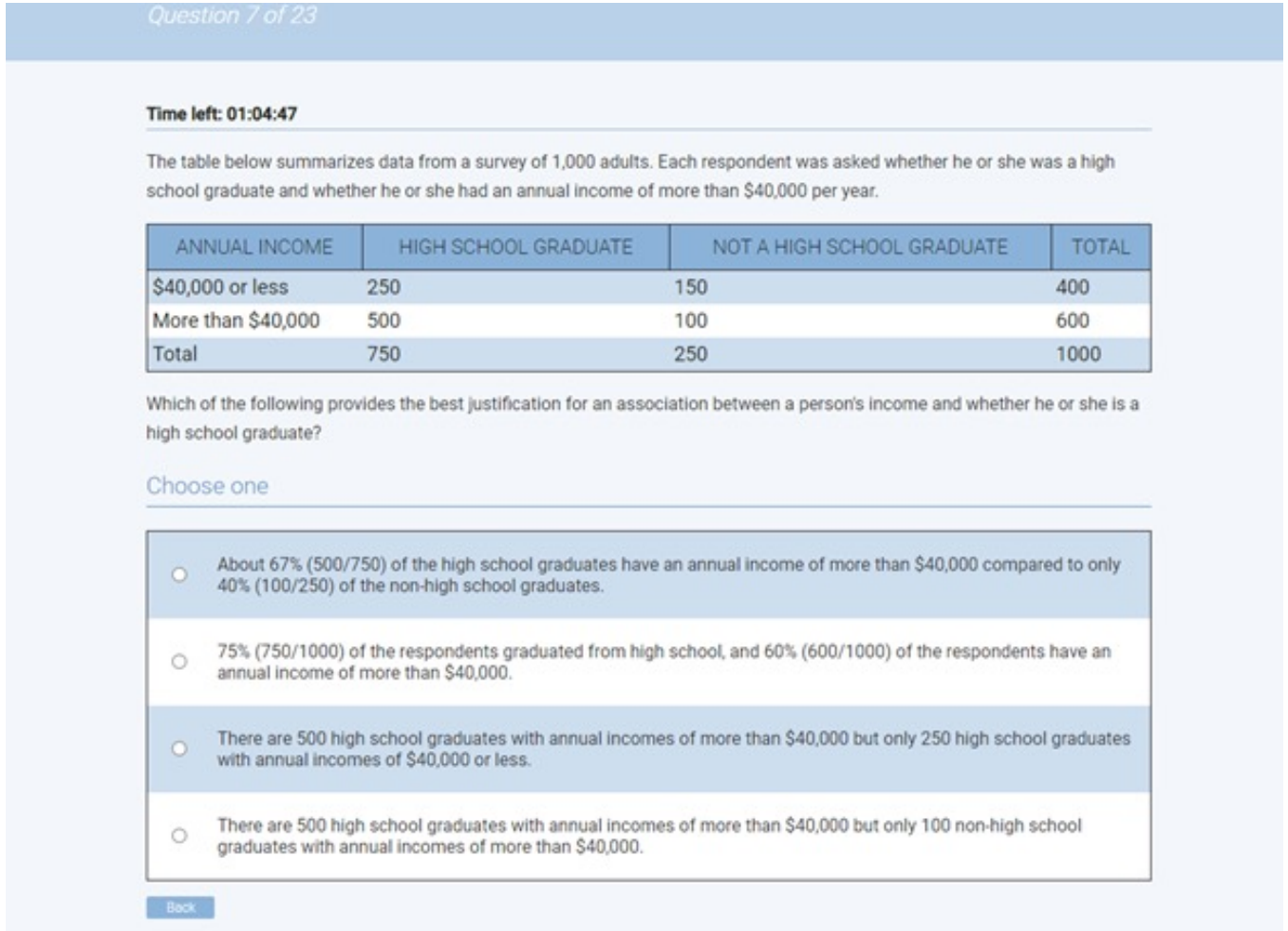
Which of the following best describes the additional information, if any, provided by the dotplots about the players' performances?

Choose one

- Player 1's scores have a smaller median and are more variable than the others.
- Player 1 always scores more points per game than either of the other two players.
- Player 2's scores are least variable, and Player 1's scores are most variable.
- The dotplots do not provide any additional information.

Back

Sample LOCUS *Interpret Results* Item



Question 7 of 23

Time left: 01:04:47

The table below summarizes data from a survey of 1,000 adults. Each respondent was asked whether he or she was a high school graduate and whether he or she had an annual income of more than $40,000 per year.

ANNUAL INCOME	HIGH SCHOOL GRADUATE	NOT A HIGH SCHOOL GRADUATE	TOTAL
$40,000 or less	250	150	400
More than $40,000	500	100	600
Total	750	250	1000

Which of the following provides the best justification for an association between a person's income and whether he or she is a high school graduate?

Choose one

- About 67% (500/750) of the high school graduates have an annual income of more than $40,000 compared to only 40% (100/250) of the non-high school graduates.
- 75% (750/1000) of the respondents graduated from high school, and 60% (600/1000) of the respondents have an annual income of more than $40,000.
- There are 500 high school graduates with annual incomes of more than $40,000 but only 250 high school graduates with annual incomes of $40,000 or less.
- There are 500 high school graduates with annual incomes of more than $40,000 but only 100 non-high school graduates with annual incomes of more than $40,000.

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