

Essay exam on experimental design

Our department administered an essay exam on experimental design in our advanced analytical chemistry course, which is populated by our juniors and seniors. The exam was based on a rubric published in the *Journal of Chemical Education*¹. The entire rubric is posted in our departmental assessment folder. Briefly, the exam has three questions and each question is assessed on three criterion:

- 1) The student identifies the important or relevant features of the problem.
- 2) In formulating a strategy for the solution of the problem, the student presents a complete justification or explanation of the strategy.
- 3) The student provides an effective strategy that is likely to work to solve the chemical problem.

Each criterion is given a numerical score from 1-4 with 1 indicating that the student's response indicates an emerging understanding and a 4 indicating that the student's response indicates mastery. The maximum score on the essay exam is therefore 36, which would indicate mastery of all three criterion for all three questions. The exams were graded by two department members and average results are tabulated below.

2011 Results

Student	Question 1			Question 2			Question 3			Total	Jr/Sr?
	C1	C2	C3	C1	C2	C3	C1	C2	C3		
GJ	3	2.5	3.5	3.5	3	3	4	3	3	28.5	S
A	3	2	2.5	3	2	2.5	3	2.5	4	24.5	?
B	Did not answer			1.5	1	2	Did not answer			4.5	?
JM	3	2.5	3	3	2.5	3	3	2.5	4	26.5	S
DL	3	2.5	3	3.5	3	2.5	2.5	3	1.5	24.5	J
CO	3.5	3.5	3	2.5	2	3	3	3	2.5	26	S
AB	3	3	3	3	2.5	3	3	2.5	4	27	S
C	3.5	3	3.5	3	2.5	2.5	3	3.5	2.5	27	?
D	3.5	3	3.5	2.5	2	3	3.5	2.5	4	27.5	?
E	1.5	1	1.5	1	1	1.5	Did not answer			7.5	?
DC	2	2.5	2.5	2.5	2	2	2	2	2	19.5	?
SG	3.5	3	3	3	3.5	3	4	3.5	4	30.5	J
Averages:	2.95	2.59	2.91	2.67	2.25	2.58	3.10	2.80	3.15	22.79	
Stdev	0.65	0.66	0.58	0.75	0.75	0.51	0.61	0.48	0.97	8.31	
90% confid	0.32	0.33	0.29	0.37	0.37	0.25	0.30	0.24	0.48	4.11	

2012 Results

Student	Question 1			Question 2			Question 3			Total	Jr/Sr?
	C1	C2	C3	C1	C2	C3	C1	C2	C3		
HR	3	2.5	2	2.5	2.5	1.5	3	2.5	3	22.5	S
AC	2	2.5	2.5	3	2	3	2	2.5	1	20.5	S
TS	3.5	3.5	3.5	3.5	3	2.5	3	2.5	3.5	28.5	S
SL	3	3	2.5	2.5	2.5	1.5	2.5	2.5	2	22	S
EP	3	2.5	3.5	3	2	3	3	3	4	27	S
BD	2.5	3	2.5	3	2.5	3	3.5	3	4	27	J
HT	2.5	2	2.5	3.5	2.5	2.5	2.5	2.5	1.5	22	J
CB	2.5	2.5	2	2.5	2	2.5	2.5	2.5	1.5	20.5	S
A2012	2.5	2	2	3	3	3	3	2.5	4	25	?
SZ	3	3	3.5	3	2.5	3	3.5	3	3.5	28	S
Averages:	2.75	2.65	2.65	2.95	2.45	2.55	2.85	2.65	2.8	24.3	
Stdev	0.42	0.47	0.63	0.37	0.37	0.60	0.47	0.24	1.18	3.15	
90% confid	0.25	0.27	0.36	0.21	0.21	0.35	0.27	0.14	0.69	1.82	

¹ S.E Shadle, E.C. Brown, M.H. Towns, and D.L Warner, *A Rubric for Assessing Students' Experimental Problem-Solving Ability*, *J. Chem. Educ.* 2012, 89, 319-325

2013 Results											
Student	Question 1			Question 2			C1 (avg)	C2 (Avg)	C3 (Avg)	Total (Avg)	Jr/Sr?
	C1	C2	C3	C1	C2	C3					
AB	4	3	3	3.5	3	1.5	3.25	3	3.25	27.5	S
JD	3.5	3	2	3.5	2.75	3	2.75	2.5	1.5	24.5	S
NG	3.5	2.5	2.5	3.5	2.5	3	3	2.75	1.75	25	S
EG	3	2.5	2	3	2.5	1.25	3	3	3.5	23.75	S
CH	3.5	2.75	2.25	2.5	1.75	1	2.75	2.5	2.5	21.5	S
JK	4	3	3	3.5	2.75	3	3	3	3	28.25	S
KM	4	3	3	3	2.5	2.5	2.5	2	1.5	24	S
RS	3.25	2	2	3.5	2.5	3	2.5	2.5	1.5	22.75	S
TV	4	3	3	3.75	3	3.5	2.5	2	1	25.75	S
BW	3.5	3	2.5	3.75	3	3	3.25	3	3	28	J
Averages:	3.63	2.78	2.53	3.35	2.63	2.48	2.85	2.63	2.25	25.10	
Stdev	0.36	0.34	0.45	0.39	0.38	0.89	0.29	0.40	0.90	2.27	
90% confidence +/-	0.18	0.17	0.22	0.19	0.19	0.44	0.15	0.20	0.44	1.12	

For comparison, the authors of the paper in which this rubric was published reported that their students achieved an average score of 20 as juniors and 28 as seniors.

Department discussion of essay exam on experimental design

The department is generally satisfied with the results of the essay exam on experimental design. Students met the benchmark (24) in 2012 and 2013. Nonetheless, we developed additional steps to further improve student performance.

Action	Implementation Date
Add an NMR analysis component to the deconvolution of IR spectra lab to illustrate the use of NMR to quantify relative amounts in a mixture.	Fall 2013
Add an NMR analysis component to the diethyl malonate methanolysis kinetics lab to demonstrate how NMR can be used to follow the kinetics of the reaction.	Fall 2015
Add more discussion of gas and liquid chromatography to the course to demonstrate a broader applicability of these techniques to chemical problems.	Fall 2015