Converting A 16-Week Exam-Laden Curriculum in CHEM 121 into An Evidence-Based 8-Week Learning Curriculum:

Application of Statistical Difficulty and Discrimination Indices Embedded in Canvas

By

Franklin S. Carman III, Ph.D.,

Professor of Biophysical Sciences

WNC-Carson City Campus

In Partial Fulfillment of

Accreditation-Mandated Assessment

Institutionally-Mandated Assessment

Annual Plan 2019-2020

Self-Evaluation 2019-2020

26 August 2019

Tables

Appendices

Abstract/Executive Summary

The initially proposed goal of this report was to take students in CHEM 121 towards mastery and away from performance, as defined previously, by examining the current NSBE/Q's over the previous five semesters to look for average patterns of learning and non-learning (guessing) and utilize that information to generate a statistically viable assessment/examination approach to be implemented in a reduced time (8-week) course with minimal impact on course content and rigor. The Difficulty and Discrimination Indices' values for 2,060 questions were individually keyed into an Excel spreadsheet and averaged by individual question as well as by individual exam. Inclusion/exclusion criteria are described in the report. 148 questions were itemized by common topic into a single Canvas Exam file for further utilization. The remaining 362 questions were likewise compiled, without itemization, into a single Canvas Exam file for further utilization. Data indicates that, on average, the difficulty of all exams across the previous five semesters are slightly ahead (57.2 vs 50%) of the "statistical ideal" and the discrimination is in the "fair" range (between 10% and 30%), statistically. The data suggests that the direction to take during course acceleration would be more appropriately in the direction of mastery coupled with achievement. In addition, the review indicates that another SLO needs to be added to the CHEM 121 WNC course outline.

Flesch-Kincaid 18.1; 223 words

Introduction

At present, BIOL 190, 251, 223 and 224 are offered to students at WNC as both traditional 16-week courses and accelerated, 8-week, courses. In the accelerated versions of these courses, there are a series of five (5) semester assessments and exams: pre- and post-course assessments and NSBE/Q 1, NSBE/Q 2 and NSBE/Q 3 (NOTE: acronyms, unless otherwise specified, are as reported upon in previous reports, e.g., [1]), as well as lab final exams.

Beginning Fall 2019, CHEM 121 is being accelerated to an 8-week course comparable to the BIOL courses previously mentioned. Under the current 16 week organization, there are a series of nine (9) semester assessments and exams: pre- and post-course assessments, and NSBE/Q 1, NSBE/Q 2, NSBE/Q 3, NSBE/Q 4, NSBE/Q 5, NSBE/Q 6 and NSBE/Q 7, as well as two lab exams (one part practical and one part theoretical).

In a previous report, it was noted [2] that in CHEM 121 for the previous five semesters (Spring 2017 - Spring 2019), the average scores of the first four NSBE/Q's were statistically higher than the average scores of the last three NSBE/Q's in each of the five semesters reviewed [2].

Clearly, CHEM 121 is heavily exam-invested across the 16-week semester format with some issues. In order to accommodate course compression, as well as to bring some "old school" methods back into the classroom, many changes need to be implemented, including reducing the number of exams without taking away adequate and proper rigor in the learning/assessment process.

The initially proposed goal of this report, then, is to continue taking students in CHEM 121 towards mastery and away from performance, as defined previously …

> *Mastery: Demonstrating continuous improvement towards learning about a fixed body of knowledge; determined, overall, statistically using Difficulty and Discriminatory Indices embedded in Canvas.* [3]
>
> *Performance: Demonstrating on examination at some degree ranging between the "best" and the "worst" scores.* [3]

… by examining the current NSBE/Q's over the previous five semesters to look for average patterns of learning and non-learning (guessing) and utilize that information to generate a statistically viable assessment/examination approach to be implemented in a reduced time (8-week) course with minimal impact on course content and rigor.

Methods

A very nice booklet developed at Arizona State University and utilized by Marshall University [4] provided the statistical background/framework to examine NSBE/Q's 1-7, as well as the Post-Course Assessment Exam across the five semesters.

The Difficulty and Discrimination Indices' values for 2,060 post-course assessment questions and NSBE/Q 1, NSBE/Q 2, NSBE/Q 3, NSBE/Q 4, NSBE/Q 5, NSBE/Q 6 and NSBE/Q 7 questions were individually keyed into an Excel spreadsheet and averaged by individual question as well as by individual exam.

Primary Inclusion Criteria is defined as averaging the Difficulty Indices and Discrimination Indices by individual question and include (retain) for assessment purposes questions that were $\geq$ 30% in both cases (NOTE: Canvas uses per cent values for Difficulty and decimal values for Discrimination. For the purposes of this report, Difficulty is recorded per Canvas, while Discrimination is reported as a per cent, as well.).

Secondary Inclusion Criteria was to retain only questions with Difficulty/Discrimination between 30% and 70%.

All other questions, i.e., with Difficulty/Discrimination values < 30% and > 70% were "excluded" from the "inclusion" question bank.

Exam-level averages in both Difficulty and Discrimination were completed using Excel.

Results

As can be seen in **Appendix 1**, both Difficulty and Discrimination Indices qualitatively parallel the exam scores in Appendix 8 [5], i.e., the first four NSBE/Q's appear to be "easier" than the last three NSBE/Q's.

Across all exams, however, on average, the Difficulty of each exam across the student groups is just higher than a "statistical ideal" of 50% (**dark purple horizontal** line in **Appendix 1**).

On average, the exam Discrimination by student group is below 30% (multiple **light purple horizontal** lines in **Appendix 1**) for the Spring '17 – Fall '18 students, whereas it's above 30% for the Spring '19 students.

Table 1, below, summarizes the number of questions included and excluded from the five semesters' worth of eight exams for the purposes of this study.

Exam	NSBE/Q 1	NSBE/Q 2	NSBE/Q 3	NSBE/Q 4	NSBE/Q 5	NSBE/Q 6	NSBE/Q 7	Post-Course Assessment
# Inclusion Questions	17	19	25	21	18	14	15	22
# Exclusion Questions	23	32	45	36	42	21	20	43
% Excluded Questions	57.5	62.7	64.3	63.2	70	60	57.1	66.2

Table 1. Summary of inclusion/exclusion questions for CHEM 121 acceleration adaptation.

Upon removal of duplicate questions, a total of 148 questions were itemized by common topic into a single Canvas Exam file for further utilization. The remaining 362 questions were likewise compiled, without itemization at this time, into a single Canvas Exam file for further utilization.

Discussion and/or Conclusions

Taken as a whole, the first four NSBE/Q's are clearly less difficult than the last three NSBE/Q's. A number of hypotheses have been forwarded regarding this phenomenon, e.g., the students are tired in the second half of the course, the students are more distracted by extraneous going's-on's than in the first half. Regardless, this difficulty divide is the prime reason that CHEM 121 is being accelerated Fall 2019, i.e., to increase student focus and see if CHEM students benefit academically from acceleration as much as the BIOL students.

Likewise, taken as a whole, the discrimination is all over the place. That said, there are about as many ways in which to interpret the meaning of the Discrimination Index as there are Carter's Little Pills. Likely the most "flexible" explanation regarding the Discrimination Index is *"… item discrimination* [is classified] *as "good" if the index is above 0.30; "fair" if it is between 0.10 and 0.30; and "poor" if it is below 0.10.* [8] In spite of this "flexibility", it's clear from the data that reaching a Discrimination level above 0.30 is realistically attainable, is academically preferable, is less reliant upon guessing and more reliant on subject knowledge. Without a doubt, the Spring 2019 group of students put in their time studying to learn the material: seven (7) of eight (8) of their exams were at or above a discrimination of 0.30; their average Discrimination for the semester was above 0.30 (0.34). Equally, as regards difficulty, on average the Spring 2019 class literally raised the bar relative to the previous four classes' results.

One, I suppose, could argue that the Spring '17 – Fall '18 Discriminations actually "fit" the final course grade outcomes if one equates "fair" with "average".

The number of questions included and excluded for the development of a statistical approach for accelerating CHEM 121 are intriguing: a review of "road map questions" (a series of questions that rely upon the previous questions' responses for completion/calculation/determination) is dumbfounding. In one instance, students responded statistically correctly to 2 of 3 roadmap questions; in another, 1 of 4. In either case the questions missed were variations of the questions that students calculated correctly.

This assessment started off with the concept that the course needs to move away from "performance" to one of "mastery".

> ***Mastery orientation*** *is described as a focus on learning and improvement – that ideal student.* ***Performance orientation*** *refers to a focus on demonstrating competence relative to others – trying to appear smart or avoid looking stupid, for example.*[7]

> *If the purpose of a test is to determine if the students have **mastered** a topic area, high difficulty values should be expected. If the purpose of a test is to discriminate between different levels of **achievement**, items with difficulty values between 0.3 and 0.7 are most effective. The optimal level should be 0.5.* [4]

NOTE: For this study, the optimal difficulty value is 50% -- the optimal level multiplied by 100.

Perhaps the direction to take would be more appropriately in the direction of mastery coupled with achievement.

> ***Achievement orientation** is a drive to accomplish one's goals and to meet or exceed a high **standard** of **success**. Achievement-oriented people often want to do things better or more efficiently than they have been done in the past.* [6]

Perhaps one might summarize this coupled approach as a person's (student's; faculty's???) drive to develop one's personal and academic ability, adjustment and well-being which focuses upon improvement and growth while ignoring a "grade" (evaluation???) … while doable, it is very difficult for pre-NURS and pre-MED students to embrace given the emphasis placed upon grades (performance) for admissions/acceptance into NURS and MED Programs.

Recommendations and Implementations

Item 1: Questions for inclusion will be a new pre- and post-course assessment for CHEM 121 (accelerated) in Fall 2019. The categories were established in a borderline arbitrary, albeit "best fit", manner. There may be some overlap between categories, however, that is not viewed as a "downside", rather as a continuity feature at this time given the inter-relationships between all of the category topics.

The current Student Learning Outcomes (SLO's; per the revised WNC website [9], accessed 24 August 2019, 0832 hours PDT) are as follow:

- Describe, identify and balance the six (6) general types of chemical, as well as college freshman level reduction-oxidation, reactions (GE #1);
- Illustrate and explain the chemistry and function of aqueous solutions of acids and bases (GE #1);
- Illustrate and explain the role thermochemistry plays in forming molecules in the solid, liquid and gaseous states (GE #1);
- Illustrate and explain the role the periodic table plays in chemistry (GE #1);
- Draw conclusions with basic calculations of and from general chemistry laboratory experiences (GESLO #1, #4).

The categories (and numbers) of the inclusion questions with their "best fit" alignment to the current SLO's are tabulated below:

Category (Number of Category Questions)	Current SLO "Best Fit" Alignment	Category (Number of Category Questions)	Current SLO "Best Fit" Alignment
Periodic Table (7)	1,4	Redox Reactions (15)	1,4
VSEPR Theory (21)	**(4)[1]**	Reaction Calculations (9)	1,4
Aqueous Chemistry (5)	1	Bond Type (4)	1,4
Ions (7)	1,4	Gas Laws (5)	1
Reaction Types (8)	1	Quantum Mechanics (4)	1
Chemical Calculations (9)	1,4	Concentration Questions (1)	1,4
Thermochemistry (7)	1,4	Acid-Base Calculations (1)	1,4
Chemical Nomenclature (8)	1,4	Electronic Configuration (3)	1
States of Matter (1)	1	Lewis Structures (1)	1,4
Solid State Chemistry (2)	1	Potentiometric Titration (2)	1,4
Stoichiometry (12)	1,4	MATH (16)	1,4

[1]A previous assessment outcome [10] has recently been included in both BIOL 190 and CHEM 121 for this topic.

Of interest is that VSEPR Theory doesn't seem to fit clearly in any of the current SLO's, yet the number of included questions is, by far, the greatest, with MATH and Redox Reactions (which are clearly noted in the SLO's) coming in at close second and third, respectively. Given the importance of VSEPR Theory in determining three-dimensional shapes of molecules, particularly in organic chemistry for which CHEM 121 is an early academic-stage pre-requisite, it seems that this topic needs its own SLO. It is therefore recommended that an additional SLO be added to the current CHEM 121 SLO's. Perhaps a starting place for inter-CHEM faculty discussion, i.e., an example for modification to initiate discussion, a framework of sorts, for adding that SLO is as follows:

> "**Using their own words, students will describe, identify, illustrate and explain how molecular geometry and orbital hybridization vis-à-vis VSEPR Theory determine the overall shape of ions and compounds.**"

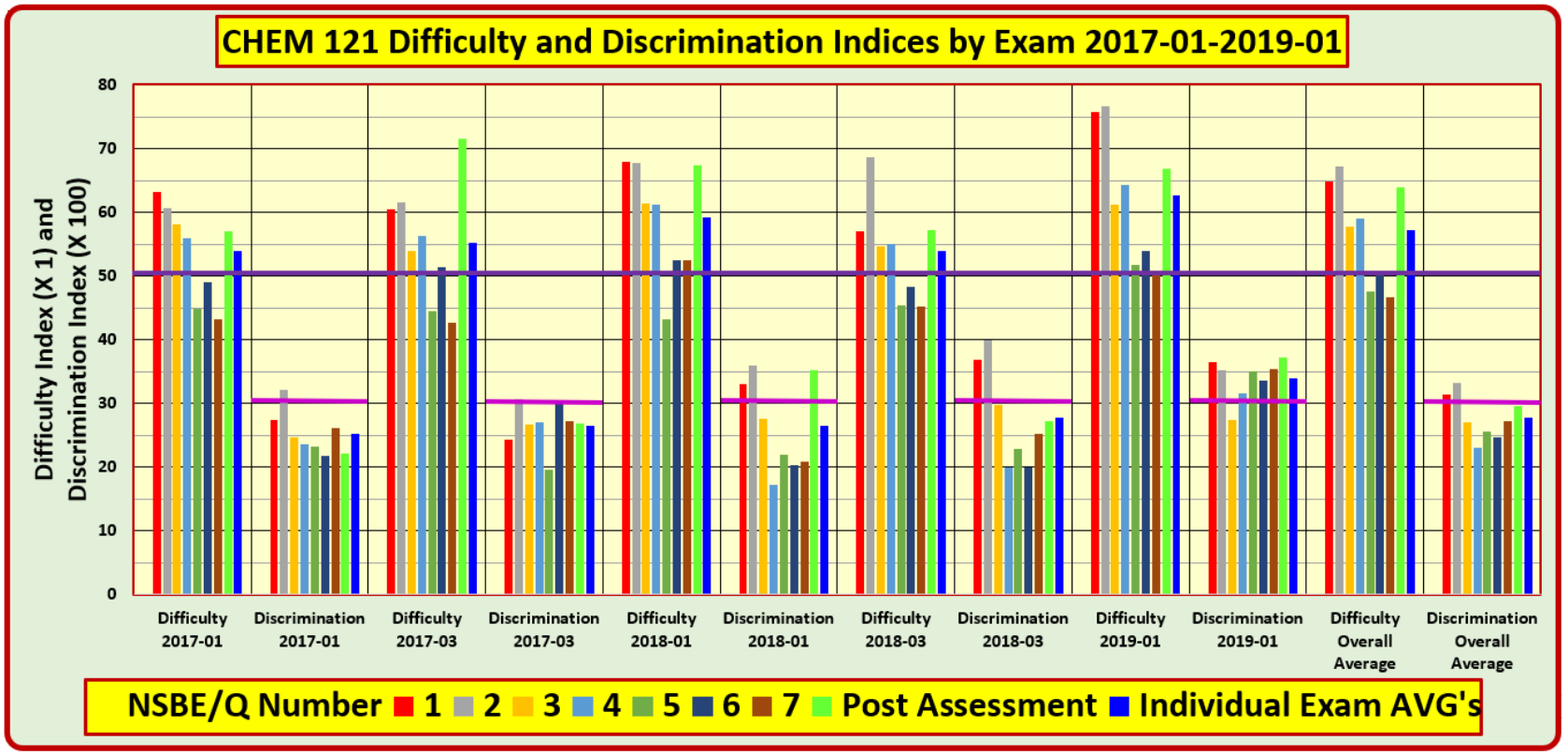
Perhaps a goal for adding the new SLO to the CHEM 121 SLO's beginning Fall 2020 is attainable and within reason. Until then, it will continue to be assessed in the accelerated CHEM 121 beginning Fall 2019 as it was in the traditional 16-week course in Spring 2019.

Item 2: Questions for exclusion will be used to develop new lectures (in addition to text/content currently encompassed in Dr. Carman's website) which will not be made available on Dr. Carman's website; students will have to take hand-written notes on the content just like Dr. Carman did some 40 or so years ago. The questions will be "culled" to develop a new lab final (replacing the old one) using the general questions' content that students have taken notes on, i.e., no test will be "taught to".

Item 3: Difficulty and Discrimination on the new pre- and post-course assessment will be watched/recorded for a future assessment report for CHEM 121 across the academic year (2019-2020). Anticipation is that the students in the two courses will achieve comparably, if not 5% better, than their predecessors.

Appendix 1: Figure 1

CHEM 121 Difficulty and Discrimination Indices by Exam 2017-01-2019-01


CHEM 121 Difficulty and Discrimination Indices by Exam 2017-01-2019-01
Difficulty Index (X 1) and Discrimination Index (X 100)
80
70
60
50
40
30
20
10
0
Difficulty 2017-01
Discrimination 2017-01
Difficulty 2017-03
Discrimination 2017-03
Difficulty 2018-01
Discrimination 2018-01
Difficulty 2018-03
Discrimination 2018-03
Difficulty 2019-01
Discrimination 2019-01
Difficulty Overall Average
Discrimination Overall Average
NSBE/Q Number 1 2 3 4 5 6 7 Post Assessment Individual Exam AVG's