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Student Success in Five Concepts: A Six-Year Study in an Introductory Chemistry Course for Non-Science Majors

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Abstract Introductory chemistry courses are normally designed for different students in colleges and universities. In many cases the *Introductory Chemistry* course is offered to students to satisfy a general science prerequisite and in other courses. At Stephen F. Austin State University, the *Introductory Chemistry* Course is taken by a majority of students who are declared nursing majors. This study examined the performance of student scores in five concepts in an Introductory Chemistry course. The data compares student performance for five randomly chosen concepts, namely; significant figures, reactivity of isotopes, half-lifes, electron configuration of ions, and equilibria. Standardized exams were used to assess and evaluate performance and trends of students (N = 841) in the five concepts for the academic years 2012 – 2018. Except for the "*Equilibria*" concept, many students showed performance that was greater than 55% or better. This study helps provide information that (i) can be used to improve areas where students may have poor understanding, (ii) is useful to instructors to decide on the time to spend in concepts in which students struggle. The reason(s) for the observed trends may stem from various factors, which include outside forces affecting students, or certain concepts may need more time for comprehension vis-à-vis others, and/or students not having strong previous foundations, especially in mathematical skills. The results of the study provide helpful information for instructors in science/education since these concepts may pose special challenges to different levels of difficulty. Overall, this study will help create a more successful classroom environment that is beneficial and enriches both the instructor and students.

Keywords: *undergraduate introductory chemistry course, five concepts, equilibria, radioactivity and isotopes*

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1. Introduction

The purpose of this project was to see where learning can be improved in an introductory chemistry course. Students learn through different styles which when used correctly can greatly benefit their overall success in the course. Studies from K-12 science show that, "when engaged, students can take initiative for their own learning" [1,2]. Thus, the use of different learning styles may lead to engaging students. This in turn creates a positive atmosphere where the student is excited to learn and takes control of their learning.

One way to engage students is to have them work in groups or pairs. This lets students exchange ideas while still expanding their knowledge with different chemistry concepts. Ivan and Dawn [3] noted that "students seemed to develop a more positive attitude about the laboratory and about chemistry in the collaborative learning sections". The idea of collaborative learning gives students a chance to get help from their peers when covering difficult topics.

Many times, students can sometimes better explain things to their peers rather than the teacher explaining the concept. The student-student explanations give another alternative view on the concept or topic, that may be more simplified. We examined five randomly selected concepts (*significant figures, radioactivity on isotopes, radioactivity half-lives, electron configuration of ions, and equilibria*) over a six-year period (2012 - 2018) in an Introductory Chemistry course. A total of 841 students were examined in the spring, summer and fall semesters of years 2012 – 2018. Except for the *Equilibria concepts*, many students showed performance that was greater than the national average. This study can provide meaningful insight to instructor(s) perception and prioritization in teaching these concepts. The questions addressed from the study include; (i) why do students in one year obtain a better success rate than another? (2) why do some concepts have lower scores than the benchmark? and

(3) what could be done to create a better more successful learning environment?

2. Methods and Materials

2.1. Participants and Data Collection

The data for this investigation was gathered by the author during a six-year period for the academic years 2012 - 2018, from an *Introductory Chemistry* course. The class is populated largely by students who declare themselves as pre-nursing students. The collected data (N = 841, Table 1) show performances from a standardized test scores the students received. Concepts tested are summarized in Table 2. The data was used in finding correlations via creating a bar graphs as shown in Figure 1. The independent and dependent variables are student success rate and five different concepts, respectively, for the 2012 - 2018 years in an Introductory Chemistry course taken by non-science majors. The student scores provide insights into students' understanding on each topic. This helps focus instructors on where more time is to be spent when teaching.

Table 1. Number of students assessed each year

Year	Number of students
2012	186
2013	29
2014	140
2015	154
2016	141
2017	69
2018	41
Total	841

2.2. Data Gathering Procedures

As noted, data was gathered from student performance test. A measure of "student performance" was defined as the scores received in the standardized test. The student's test score was converted to a 100-point scale to ensure the assigned score was independent of the number of questions.

2.3. Data Analysis

In this study, data were analyzed by using bar graphs for visualization of trends.

3. Results

Data for this study, consists of the final grades from 841 students. Table 1 tabulates the number of student enrolled in the course each year. The data represents students who took and completed the final comprehensive exam and received a grade at the end of the semesters/year.

Table 2 shows the percent performance of students in each of the five tested concepts. This was calculated by the course instructor, for each year. Although the number of students taught each semester varied, there is in general, balanced distribution throughout the years.

Figure 1 shows comparative data for the years 2012 - 2018. Five conceptual learning concepts; namely, significant figures, radioactivity on isotopes, radioactivity half-lives, electron configuration and ions, and equilibria were assessed. A benchmark of scoring 55% scores or better was set for a passing grade. This benchmark represents about 68 percentile or better for students in the USA. This represents getting 55 % of the answers correct.

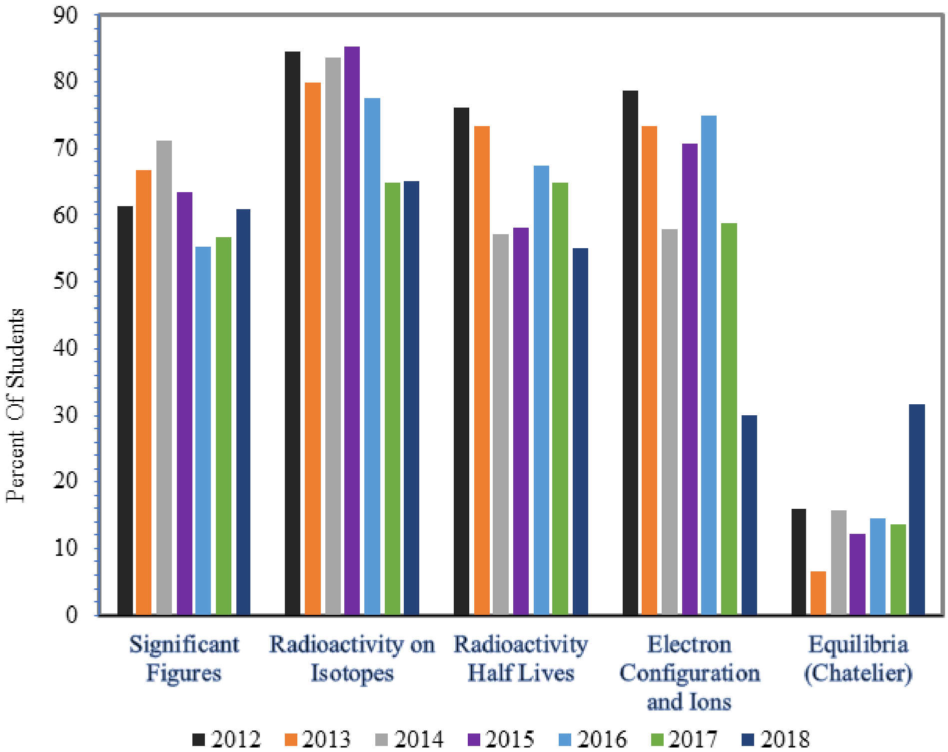

Figure 1. Student success rate in five different concepts in an introductory chemistry course assessed over six years in the period 2012 - 2018

Figure 1 shows the lowest scoring topic area throughout the six-year period is "*Equilibria*" with range of success 6.67 - 31.74 %. Whereas majority of equilibria scores were below 15%, notably the highest scoring area throughout the time period is "radioactivity on isotopes" concept in the range 64.86 - 85.37 %. Except for *equilibria* and *electron configuration of ions* the other three concepts scored above the benchmark (55%) throughout the six-year time period. Figure 1, shows that each area starts high and above the benchmark of 55 %. While a trend is visible in half of the areas (into in the middle of each area), there is a drop in success rate around the years 2015 – 2016. The drop in scores for the 2017-2018 years, seem to improve back to the earlier years in 2012 – 2013.

4. Discussion

The main purpose of this study was to investigate how students performed in the *Introductory Chemistry* course that is mainly taken by non-science majors. The different trends observed show differences in performances by students in the five concepts (Table 2). Figure 1, reveals many different trends observed with different performances. The possible reasons for these differences are herein explained.

Table 2. Data showing the concepts and their student success percentages (%) over a six-year period (N = 841)

Concept Tested/Year	2012	2013	2014	2015	2016	2017	2018
Significant Figures	61.39	66.67	71.21	63.41	55.26	56.76	60.87
Radioactivity on Isotopes	84.68	80	83.75	85.37	77.63	64.86	65.22
Radioactivity Half- Lives	76.23	73.33	57.14	58.02	67.39	64.86	55.00
Electron Configuration of Ions	78.72	73.33	57.94	70.73	75.00	58.83	30.00
Equilibria (Le Chatelier's principle)	15.84	6.67	15.79	12.20	14.47	13.51	31.74

The student's conceptual understanding of the five areas may be addressed with use of comparisons. The results for the *equilibria* concept was observed the lowest out of the five concepts tested. A reason for the low performance for the *equilibria* was sought. This is probably due to the topic being taught for the first time. It may also be that the students were not exposed to this concept in their prior high school, college or university studies. This may be the case as students lack a strong foundation to build upon in the understanding *equilibria*. This could explain why the scores for 2012 – 2017 year is lower than 16 percent, though it improved in 2018 and rose up to 31.74 percent. There are several uncertainties for the student performance in the examined years. Perhaps the students in 2018 had a firmer foundation prior to being taught the equilibria concept. It can also mean that the instructor spent more time on the concept than in previous times. These scenarios can be supported by the following observations below.

Tai et al. [4] show that students who have prior exposure to difficult concepts and more chemistry in high school do better in chemistry in college chemistry tests over the same concepts. In Tai's study [4] a survey was sent to college students in an introductory chemistry class. It was found that students with an earlier background in concepts taught did better in college than those without such background. The study notes that the background received in their high school chemistry was "strongly predictive of college chemistry success" [4]. While the score in 2018 is not great considering the 55 percent benchmark, scores in future would help for comparisons to assess students, post-, and pre-COVID-19. Thus, will seek any notable improvement in these concepts will be sought.

It is notable that the in radioactivity on isotopes students scored well above the benchmark of 55 percent. In the first few years, 2012 - 2016 the scores were above 75 percent, but then dropped in the years of 2017 - 2018. One possible reason for this is that the style, or way of teaching, may have been different than in past years [5]. It is also true that most people learn through visuals or kinesthetically [6]. The percent drop in scores could represent students who did not fully comprehend the concepts because of different learning styles. Another possibility is that since this concept was normally scored well previously, the instructor may have taught it quickly thinking students would still understand it. Since it could have been taught faster than normal, this may have led to students missing important information in their learning.

Lastly, it is noted that trends at the beginning and ending years for each concept were high, while the middle years tended to be lower. The lower percent performances in years around 2014 – 2016 show lower relative comprehension of questions. Among others, outside forces may have contributed to making it hard for students to focus in class and their learning. For example, in 2015 the federal government raised interest rates [7]. This meant more students had to obtain jobs in order to pay for college tuition and necessities. This possibility could explain why student scores from 2018 are lower than 2012. Students in the middle years had to shift their mindsets to adapt to a changing economy and lifestyle. These changes seem to have continued affecting students in the ending years of the data. It is however worth stating that efforts involving focusing students are needed when teaching students [8]. These efforts range from assigning actual lecture quizzes, homework/and or group assignments [8]. In general, teachers can be mindful of changes in the world that could affect student performance at each learning level. It is thus important for teachers to continually expend efforts to refocus students on each level in order to adapt to the changing times facing students.

5. Conclusions and Recommendations

The performance of student performance in five six concepts were compared in an *Introductory Chemistry course* over a six-year period. Understanding the performance of students in various concepts taught in an introductory class may depend on the student's prior exposure to the concepts. Although instructors play a profound role in conveying information, this study consistently show that the concept of "Equilibria" may need more concentrated and different approaches from instructors to effectively teach it. The different reasons for the observed trends are here posited, and possible remedies postulated. These potential different approaches can affect the classroom environment differently. Overall, this study shows that different concepts learnt by students and taught instructors may be adjusted in classroom environments. These findings point to seeking ways to make the environment more successful for both student and instructor. As is well known several different approaches can be sought in reaching out to students with different learning styles [8].

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