**2015-2016 Annual Program Assessment Report**

Please submit report to your department chair or program coordinator, the Associate Dean of your College, and to james.solomon@csun.edu, director of assessment and program review, by September 30, 2015. You may, but are not required to, submit a separate report for each program, including graduate degree programs, which conducted assessment activities, or you may combine programs in a single report. Please identify your department/program in the file name for your report.

**College: Science and Mathematics**

**Department: Chemistry and Biochemistry**

**Program: BA/BS/MS**

**Assessment liaison: Thomas Minehan**

1. **Please check off whichever is applicable:**

**A. \_\_\_√\_\_\_\_\_ Measured student work.**

**B. \_\_\_\_√\_\_\_\_ Analyzed results of measurement.**

**C. \_\_\_\_√\_\_\_\_ Applied results of analysis to program review/curriculum/review/revision.**

1. **Overview of Annual Assessment Project(s).** On a separate sheet,provide a brief overview of this year’s assessment activities, including:
* an explanation for why your department chose the assessment activities (measurement, analysis, and/or application) that it enacted
* if your department implemented assessment **option A**, identify which program SLOs were assessed (please identify the SLOs in full), in which classes and/or contexts, what assessment instruments were used and the methodology employed, the resulting scores, and the relation between this year’s measure of student work and that of past years: (include as an appendix any and all relevant materials that you wish to include)
* if your department implemented assessment **option B**, identify what conclusions were drawn from the analysis of measured results, what changes to the program were planned in response, and the relation between this year’s analyses and past and future assessment activities
* if your department implemented **option C**, identify the program modifications that were adopted, and the relation between program modifications and past and future assessment activities
* in what way(s) your assessment activities may reflect the university’s commitment to diversity in all its dimensions but especially with respect to underrepresented groups
* any other assessment-related information you wish to include, including SLO revision (especially to ensure continuing alignment between program course offerings and both program and university student learning outcomes), and/or the creation and modification of new assessment instruments

**3. Preview of planned assessment activities for next year.** Include a brief description and explanation of how next year’s assessment will contribute to a

continuous program of ongoing assessment.

**2. Overview of Annual Assessment Project(s).** Provide a brief overview of this year’s assessment activities.

**The following assessment activities took place this year:**

**•A. Measure Student Work**

1. **Assess basic knowledge in organic and biochemistry (SLO1) using standardized exam questions in course finals.**
2. **Implemented a signature assignment for longitudinal assessment of knowledge (SLO1) in the gateway (Chem 321) and capstone (Chem 401) courses**
3. **Assess graduate students’ scientific oral communication abilities in literature and thesis seminars (SLO2m) utilizing our department oral presentation rubric**

**•B. Analyze Results of Measurement**

1. **An analysis of student performance trends in organic chemistry and biochemistry was undertaken.**
2. **The results of the signature assignment were again reviewed and suggestions for changing the “gateway” course and assignment questions have been made.**
3. **Review evidence pertaining to graduate students’ scientific oral communication abilites (SLO2m) collected over the last three years.**

**•C. Applied results of analysis to curriculum revision**

1. **Additional resources created and made available to Organic Chemistry I and II students via moodle: a series of 3-5 minute problem-solving videos addressing the most difficult course concepts tested on quizzes and exams.**
2. **Alternative questions created by department faculty for inclusion in this year’s longitudinal assessment assignment.**
3. **Creation of a “Group Entrepreneurship Project” as a culminating assignment in Biochemistry.**

**The department chose these activities so as to 1.) move forward with year 2 of our longitudinal assessment program, collecting additional data in the hopes of observing “value added” learning between the gateway and capstone courses, 2.) encourage faculty to continue doing assessment in their courses each year so as to identify trends over multiple semesters and weaknesses in student comprehension that need to be addressed at the individual course level and in the program as a whole, and 3.) initiate “closing the loop” activities aimed at addressing problems evident in previous years’ assessments.**

**A. Measure Student Work**

**SLO’s addressed: SLO 1: Assess basic knowledge in the following area of chemistry: organic chemistry.**

1. **1. Assess basic knowledge in organic chemistry (SLO1) using standardized exam questions in course finals. Alignment with core competencies: critical thinking, quantitative literacy.**

**Organic Chemistry Assessment: Students taking Chem 334 (Organic Chemistry II) in fall 2015 and Chem 333 (Organic Chemistry I) in spring 2016 were administered a 70 question ACS standardized exam (the ACS First Term Organic Chemistry exam for Chem 333 and the ACS Organic Chemistry exam for Chem 334) on the last day of class. 65 Chem 334 students took the exam in fall 2015 and 59 Chem 333 students took the exam in spring 2016. Our benchmark level of performance for these exams is 50th percentile (the national average), which is either 40 correct out of 70 (for the ACS First Term Organic Chemistry exam) or 41 correct out of 70 (for the ACS Organic Chemistry exam). For Chem 334, 12 out of 65 students (19 %) achieved the benchmark score or higher; the average score for the class was 31/70 or 20th percentile. For Chem 333, 12 out of 59 students (20%) achieved the benchmark score or higher; the average score for the class was 31/70 or 26th percentile.**

**If the instructor selects the ACS standardized exam questions more reflective of material emphasized in the course, the students do better. In one section of Chem 333 in the Fall 2015, 10 ACS Organic Chemistry exam questions were included in the final examination. Out of 62 students, 18 (29%) achieved a benchmark level of 7/10 correct or better; 28 students (45%) achieved the benchmark level of 6/10 correct or better. In a section of Chem 334 in Spring 2016, 10 ACS Organic Chemistry exam questions were also included in the final examination. Out of 61 students, 21 (34%) achieved a benchmark level of 7/10 correct or better; 31 students (51%) achieved the benchmark level of 6/10 correct or better.**

**B.d. Analysis of the Results of Measurement**

**The organic chemistry I and II courses are taken by chemistry and biochemistry majors, and in addition many non-majors (especially biology majors) are also required to take this sequence. Since many students struggle with organic chemistry and perform poorly in these courses, they are bottleneck classes for majors and non-majors alike. Previous assessments in chem 333 have led us to implement a mandatory recitation session, chem 333R (starting in the 2013-2014 academic year), for this course to provide more opportunities for our students to work on problem-solving skills. Indeed, we have seen an improvement in student performance in this course as gauged by results from the ACS standardized exams: in fall 2013, only 8 out of 66 students (12%) achieved the benchmark level of performance on the ACS exam; in fall 2014, 9 out of 63 students (14%) achieved the benchmark level; in the spring of 2015, 11 out of 64 students (17%) achieved the benchmark level. Currently in chem 333, approximately 20% of the class has achieved the benchmark, which is a significant improvement over three years ago. However, there is clearly much room for further improvement. In chemistry 334, there is no mandatory recitation session available, and only a single optional recitation per class. In Fall 2013, 24 students out of 120 (20%) achieved the benchmark level of performance. These results are essentially the same as the 2012 Chem 334 assessment (20% of students at or above benchmark). Thus, the current performance in chem 334 (19% at or above benchmark) indicates that the average student performance on the ACS exams in this course has essentially not changed in four years. Since the implementation of Chem 333R led to improved student performance in Chem 333, it is likely that a similar focus on engaging students in problem solving activities both inside and outside of class is key to improving outcomes in Chem 334 as well. The creation of a mandatory 334R course is not an option currently; however, new additional resources available via the internet may begin to address the problems of student performance in both chem 333 and chem 334 (see following section).**

**C.g. Applied results of analysis to curriculum/course revision**

**In an attempt to foster more problem-solving activities in the Chem 333 and Chem 334 lecture classes, some of the lecture content has been crafted into a series of audio notes uploaded to Moodle that students can view outside of class. The intent is to free up lecture time to demonstrate the application of course concepts to solving typical quiz and exam questions. In addition, a series of 3-5 minute Youtube videos illustrating the step-by-step approach to handling mechanism, synthesis, and acid-base type problems has been created and uploaded to moodle for student viewing outside of class. These resources are being made available starting in the 2016-2017 academic year, and future assessments will evaluate their impact on student learning in the chem 333 and chem 334 courses. In addition, our department curriculum committee is currently considering the establishment of a minimum grade requirement for student movement between Chem 333 and Chem 334. The current minimum grade is D-, and most instructors agree that grades in the D range for these courses really should be F’s given the leniency of grading on the low end. A minimum grade of C- would be in line with current minimum grade for proceeding from general chemistry I (Chem 101) to general chemistry II (Chem 102). It is anticipated that this policy would mitigate some of the poor performances evident in Chem 334 by forcing students to achieve a minimum proficiency in Chem 333 before moving on.**

**A. Measure Student Work**

**SLO’s addressed: SLO 1: Assess basic knowledge in the following areas of chemistry: biochemistry.**

1. **2. Assess basic knowledge in biochemistry (SLO1) using standardized exam questions. Alignment with core competencies: critical thinking, quantitative literacy.**

**Chem 464 is a one-semester course in biochemistry taken primarily by non-majors; Chem 461 and Chem 462 are the two-semester biochemistry courses taken by biochemistry majors. In Fall 2015, 35 students were administered 8 ACS Standardized Exam in Biochemistry questions on the course final exam. The established benchmark level for this class was 5 out of 8 questions answered correctly; 22 students (63%) achieved the benchmark score or higher. In Spring 2016, 31 students in Chem 464 were administered 5 ACS Standardized Exam in Biochemistry questions on the first day of class and on their course final. The results were compared to see if students are improving in their understanding of the course material. 23 out of 31 students (74%) improved their performance on the questions given on the final relative to the same questions given on the first day of class. The average on the pre-test was 1.38/5; the average on the final was 2.94/5.**

**In Fall 2015, 28 chem 461 students were administered 8 ACS Standardized Exam in Biochemistry questions on the course final. The established benchmark level for this course was 5 out 8 questions answered correctly. 19 out of 28 (68%) students achieved the benchmark level of performance or higher. In spring 2016, 23 students were administered 10 ACS Standardized Exam in Biochemistry questions on the course final. The established benchmark level for this course was 7 out 10 questions answered correctly. 18 out of 23 students (78%) achieved the benchmark level of performance or higher.**

**B.d. Analysis of the Results of Measurement**

**In chem 464, student performance on the same ACS standardized questions more than doubled on going from the pre-test to the final exam questions. This is indeed indicative of value-added learning in the Chem 464 course. For Chem 461, 68% of students achieved the benchmark level of performance or higher, which is lower than in fall 2013 and fall 2014 (~70%) and approximately the same as Fall 2011. These results appear to reflect the year-over-year fluctuations in the strengths of each cohort of students. In Chem 462, 78% of the students achieved the benchmark level of performance or higher, which is quite impressive. The result is identical to last year’s performance. At this point it might be helpful, time permitting, to administer the entire ACS Exam in Biochemistry to see how our students compare to the national average.**

**A. Measure Student Work**

**b. Signature Assignment Administration, year 2: previously, twenty multiple-choice questions from all subdisciplines of chemistry (general, organic, inorganic, analytical, physical, and biochemistry) were assembled to create an assignment with the input of the department faculty. Although this assessment has now been implemented into Moodle, for the 2015-2016 academic year an in-class paper exam/scantron was given in Chem 401 (Inorganic Chemistry, sp 2016). The assignment was administered to 46 students in Chem 321 (gateway) and 42 students in Chem 401 (capstone; majors and “unclassified” graduate students who would like to demonstrate proficiency in inorganic chemistry).**

**•Results of assessment: In Chem 321, the average score for the majors and non-majors who completed the assignment was 10.3 correct out of 20. For Chem 401, the average score for all of the students taking the exam was 9.4 correct out of 20. While there is a slightly better average performance of the students in Chem 321 than in Chem 401, the difference is quite small (0.9 points); nonetheless this was an unexpected result.**

**B.e. Analysis of the Results of Measurement**

 **The small difference in the average performance of Chem majors in Chem 321 (gateway course) and students in Chem 401 (capstone course) is alarming. This is the second year such an assignment has been given, and the results last year were essentially identical. In discussion of the results with department faculty members, it was suggested that some of the questions be revised to include some “higher level” questions from each subdivision so that students in Chem 401 would have an advantage, having more recently taken those upper division courses (see section C.h below). However, it was also mentioned that students do not necessarily take the courses in the major in sequence, such that it is possible for a student to take Chem 321 in the fall and Chem 401 in the spring of the same year. As a result, it has been suggested to change the gateway course to Chem 333 (Organic Chemistry I), which is usually the first course majors take after general chemistry. This change will be implemented next semester. Additional assignment questions are being crafted in all divisions and will be incorporated in future iterations of the signature assignment. Finally, faculty have suggested that students may not be motivated to take the assessment as seriously as course exams, since it is not directly impacting their course grade. A solution to this “motivation” problem that has been put forward is to provide “bonus” points to all students who take the exam, and extra bonus points for those performing above a certain benchmark level. If the students see the assessment as positively impacting their grade, they are more likely to put in the effort to do as well as they can.**

**These results are very useful for instructors in our lower division classes (especially Chem 101/Chem 102) and upper division classes in terms of identifying the challenging topics that our students struggle with throughout the program. It is anticipated that, after reflection on these results, our department faculty will direct more attention to these problem areas in their respective courses.**

**C.h. Applied results of analysis to curriculum/course revision**

**Alternative questions for the signature assignment have been crafted by several department faculty members (see appendix) and will be included in this year’s longitudinal assessment.**

**A. Measure Student Work**

**c. Assess students’ scientific oral communication abilities in literature and thesis seminars, relevant to SLO2: Organize and communicate scientific information clearly and concisely, both verbally and in writing. Alignment with core competencies: oral communication, information literacy.**

**The oral presentation rubric developed in the department of chemistry and biochemistry (see appendix) was used to assess the literature and thesis seminars given by 16 MS chemistry students in the 2015-2016 academic year. The scoring rubric has five categories: organization, understanding of scientific content, style/delivery, use of visual aids, and ability to answer questions. Performance in each category could be rated with a score of 0-20. The rubric provided descriptions for excellent (16-20 points), good (11-15 points), marginal (6-10 points), and inadequate (0-5 points) performance. Faculty attending the seminar filled out the rubrics and forwarded them to the seminar coordinator. The seminar coordinator then tabulated the results for each category and an average score for literature and thesis seminars was obtained**

**Results for 2015-2016: For the nine literature seminars, the average score for the category of organization was 18.6/20; the average score for the category of understanding of scientific content was 17.7/20; the average score for the category of style and delivery was 16.7/20; the average score for the category of use of visual aids was 17.8/20; and the average score for the category of ability to answer questions was 16.8/20. The average total score for the literature seminars was 87.6/100. For the seven thesis seminars, the average score for the category of organization was 18.4/20; the average score for the category of understanding of scientific content was 17.4/20; the average score for the category of style and delivery was 17.1/20; the average score for the category of use of visual aids was 17.7/20; and the average score for the category of ability to answer questions was 17.0/20. The average total score for the thesis seminars was 87.7/100.**

**Results from the 2014-2015 academic year are also provided: For the five literature seminars, the average score for the category of organization was 17.2/20; the average score for the category of understanding of scientific content was 16.6/20; the average score for the category of style and delivery was 16.3/20; the average score for the category of use of visual aids was 16.6/20; and the average score for the category of ability to answer questions was 16.2/20. The total score for the literature seminars was 82.9/100. For the seven thesis seminars, the average score for the category of organization was 19.0/20; the average score for the category of understanding of scientific content was 17.0/20; the average score for the category of style and delivery was 16.3/20; the average score for the category of use of visual aids was 17.3/20; and the average score for the category of ability to answer questions was 15.7/20. The total score for the thesis seminars was 85.3/100.**

 **Results from the 2013-2014 academic year are also provided: for the nine literature seminars, the average score for the category of organization was 16.8/20; the average score for the category of understanding of scientific content was 15.6/20; the average score for the category of style and delivery was 16.6/20; the average score for the category of use of visual aids was 16.9/20; and the average score for the category of ability to answer questions was 14.4/20. The total score for the literature seminars was 80.3/100. For the seven thesis seminars, the average score for the category of organization was 17.6/20; the average score for the category of understanding of scientific content was 17.1/20; the average score for the category of style and delivery was 16.7/20; the average score for the category of use of visual aids was 17.2/20; and the average score for the category of ability to answer questions was 16.0/20. The total score for the thesis seminars was 84.6/100.**

**B.f. Analysis of the Results of Measurement**

**As can be seen, the overall scores for both literature and thesis seminars increased during the 2015-2016 academic year as compared to both the 2014-2015 and 2013-2014 academic years. Over the three years, the thesis seminar grades are higher than the literature seminar grades, although only slightly so in the most recent year. The results indicate that, on the whole, graduate students are doing well in their oral seminars, since the average scores in most categories are in the 17-18 range. The weakest category tends to be the ability to answer questions. Perhaps a useful suggestion to improve performance in this category is to have the student give their practice presentations before an audience consisting not just of the individual’s research group students and professor, but rather including students and/or professors from other research groups and subdisciplines, so that a broad variety of questions about their literature and thesis topic may be encountered prior to the actual seminar. About two years ago we raised our minimum GPA for admission to our Chemistry and Biochemistry programs.  It will be interesting to see how this may have an impact on the quality of the literature and thesis presentations in the future.**

**C.i. Applied results of analysis to curriculum/course revision**

 **Previous assessment of our graduate student literature and thesis seminars has revealed that many of our entering MS students lack good scientific oral and written communication skills, as well as information literacy. This was most pronounced for the literature seminars, which are usually the students’ first experience in scientific oral presentation. To avoid this potential deficiency in our undergraduate majors, a curricular adjustment in our Chem 462 course (one of the last courses our biochemistry majors take) has been made with the recent implementation of a culminating assignment, the “Group Entrepreneurship Project”. The intent is for students to integrate knowledge gained over the two-semester biochemistry sequence, apply critical thinking skills, and demonstrate creativity in addressing real world biomedical problems. It is also designed to develop professionalism and communication skills**. **Students working in groups develop an idea for a drug, device or process that will remedy a problem. At the end of the semester, the groups submit a one-page written abstract and give a group presentation. Each group then gives a 10-minute presentation followed by a 5-10 minute “Question and Answer” session. The goal is to explain clearly and concisely what the problem is (in specific biochemical detail), why the problem is important, what the remedy is, why the remedy will work and why it will be better than other remedies already in existence. The main focus of the talk and abstract is on communicating clearly the biochemical underpinnings of the problem and feasibility of the idea for the remedy so as to convince the audience that the idea is the best solution to an important problem.**

 **Assessment of this project utilizing the department’s oral and written presentation rubrics will be taking place going forward and it is anticipated that improvements students’ critical thinking skills, creative thinking, and ability to work as part of a team will all be demonstrated.**

**3. Preview of planned assessment activities for next year.** Include a brief description and explanation of how next year’s assessment will contribute to a

continuous program of ongoing assessment.

**In the next year we plan to continue our assessment of student subject knowledge (SLO1) in individual courses as well as throughout the program through our revised signature assignment administered in the new gateway (Chem 333) and capstone courses. For 2016-2017, we will also focus our efforts on assessment of our laboratory courses to evaluate SLO’s 4-6 (4: work effectively and safely in a laboratory environment, including the ability to follow experimental chemical procedures and maintain a proper lab notebook; 5: effectively utilize modern chemical instrumentation to obtain data and perform research; 6:** **perform qualitative and quantitative chemical analysis). We will be encouraging our lab instructors to utilize our customizable lab notebook rubric for notebook evaluations. We will also be obtaining useful data on student learning from our upper division labs that involve quite a bit of chemical analysis (Chem 321, Chem 422, Chem 411) and the use of chemical instrumentation (Chem 321, Chem 422, Chem 411 and Chem 433).**

**Appendix A: Longitudinal Assessment Assignment, Revised 2016 (new questions: \*)**

1. Which best represents a step in the mechanism for the saponification of methyl acetate?

2. A mixture of the following four compounds is dissolved in diethyl ether and shaken with a 2M NaOH solution. Which compound(s) remain in the organic (ether) phase?



1. A, B and D
2. B and C
3. B, C, and D
4. B and D
	1. The correct chair conformation of the following structure is:



* 1. Which of the following molecules are expected to have a net dipole moment?
		+ 1. BF3
			2. CCl4
			3. CH2O
			4. CH4

5. What are the chief products of aerobic metabolism?\*

(A) Sugars, fats and amino acids.

1. Water and oxygen
2. Carbon dioxide, oxygen and adenosine triphosphate (ATP)
3. Carbon dioxide, water and adenosine triphosphate (ATP)
4. Oxygen, nicotinamide adenine dinucleotide in its oxidized form (NAD+) and adenosine triphosphate (ATP).
5. Which level of protein structure is described by the amino acid sequence of a protein?\*
	1. Primary
	2. Secondary
	3. Tertiary
	4. Quaternary
	5. Primary and secondary are both described by the amino acid sequence.
6. What is the chief thermodynamic driving force causing the formation of lipid bilayers by polar lipids such as phosphatidylcholine? \*
	1. The polar head groups are attracted to each other forming hydrogen bonds and ionic interactions with neighboring polar head groups.
	2. The fatty alkyl chains become dispersed in the water solvent which is entropically favorable.
	3. The polar head groups assemble in a head-to-tail fashion with the fatty alkyl chains which forms lots of strong hydrogen bonds.
	4. When the fatty alkyl chains interact and orient themselves toward the center of the bilayer, waters-of-solvation are released to the bulk solvent which is entropically favorable.
	5. None of these are correct.
7. Which of the enzymes below produces adenosine triphosphate (ATP) during glycolysis? \*
	1. 3-Phosphoglyerate Kinase
	2. Triosephosphate Isomerase
	3. Pyruvate Kinase
	4. Hexokinase
	5. Both a and c are correct
8. Which of the following is true about how enzymes catalyze reactions: \*

(A) They accelerate reaction rates by stabilizing the reaction product(s).

(B) They accelerate reaction rates by stabilizing the transition state of the reaction.

(C) They shift the reaction equilibrium to the right, favoring product(s).

(D) They stabilize the reactant, thereby lowering the ΔG of the overall reaction.

(E) Both A and C are correct.

 10. Which solution should be mixed with 50.0 mL of 0.050 M HF to make an effective buffer?

1. 50.0 mL of 0.10 M NaOH
2. 25.0 mL of 0.10 M NaOH
3. 50.0 mL of 0.050 M NaOH
4. 25.0 mL of 0.050 M NaOH

11. In the dissociation of a monoprotic weak acid in aqueous solutions, HA, which leads to the assumption that [H+] ≈ [A-]?

1. The autoprotolysis of water is the dominant source of H+
2. The concentration of the acid is sufficiently high such that the dissociation of the acid is the dominant source of [H+]
3. The concentration of the acid has no effect on the approximation; [H+] is always approximately equal to [A-]

12. The confidence interval for a set of measurements represents for a defined confidence level that

1. The true value lies within a certain range about the mean value
2. The results from two different methods will agree with each other
3. The variances of two different methods will agree with each other
4. An experimental value lies within a certain range about the mean value

13. Which choice is not a requirement of a primary standard solid?

1. Its reactions must be known and stoichiometric
2. It can be dried to remove surface moisture
3. Its purity must be accurately known
4. It must have a low formula weight

14. Glass pH electrodes must be soaked in water prior to conducting measurements in order to

1. Clean the glass surface
2. Allow the internal reference electrode to reach its equilibrium potential
3. Hydrate the glass to allow ion-exchange between the sample solution and the glass surface
4. Adjust the concentration of the internal filling solution with respect to the external sample solution

15. The addition of traces of antimony to crystalline silicon produces a material having

 (A) a lower conductivity than silicon.

 (B) a higher conductivity than silicon.

 (C) no conductivity

 (D) superconductivity

 (E) metallic conductivity

16. The bonding interactions in SmF3 are stronger than the bonding interactions in SmI3. Therefore, one can conclude that

 **I.** Sm3+ is a soft acid.

 **II.** Sm2O3 will be more stable than Sm2S3.

 **III.** Sm3+ is a hard acid.

 (A) only I

 (B) only III

 (C) I and II

 (D) II and III

17. What substitution mechanism is most common for square planar complexes?

 (A) associative

 (B) dissociative

 (C) migratory insertion

 (D) reductive elimination

18. In a dissociative reaction, how does an increase in the nucleophilicity of the incoming ligand affect the rate of the reaction?

 (A) The rate of the reaction increases

 (B) The rate of the reaction decreases

 (C) The rate of the reaction is unchanged

 (D) The change in the rate of the reaction depends on the oxidation state of the metal.

19. Square planar complexes containing metal atoms in a low oxidation state typically undergo

 (A) ligand dissociation

 (B) migratory insertion

 (C) oxidative addition

 (D) reductive elimination

20. How does “negative overlap” in Molecular Orbital Theory lead to “antibonding” between atoms?

 (A) The opposing charges of two orbitals cancel each other out.

 (B) The opposing phases of two orbitals cancel each other out.

 (C) The like charges of two orbitals repel each other.

 (D) The concentration of electron density between nuclei pushes them apart.

 (E) The negative phases of two orbitals repel each other.

**Appendix B: Chemistry and Biochemistry Oral Presentation Rubric**

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