

2013-2014 ANNUAL ASSESSMENT REPORT TEMPLATE

This template intends to make our annual assessment and its reports simple, clear, and of high quality not only for this academic year but also for the years to come. Thus, it explicitly specifies some of the best assessment practices and/or expectations implied in the four WASC assessment rubrics we have used in the last few years (see the information below* that has appeared in Appendices 1, 2a, 2b, and 7 in the *Feedback for the 2011-2012 Assessment Report*; Appendix 2 in the *Feedback for the 2012-2013 Assessment Report*, and Appendices 5 to 8 in the *2013-2014 Annual Assessment Guideline*).

We understand some of our programs/departments have not used and/or adopted these best practices this year, and that is okay. You do not need to do anything extra this year, and ALL YOU NEED TO DO is to report what you have done this academic year. However, we hope our programs will use many of these best practices in the annual assessment in the future.

We also hope to use the information from this template to build a digital database that is simple, clear, and of high quality. If you find it necessary to modify or refine the wording or the content of some of the questions to address the specific needs of your program, please make the changes and highlight them in red. We will consider your suggestion(s). Thank you!

If you have any questions or need any help, please send an email to Dr. Amy Liu (liuqa@csus.edu), Director of University Assessment. We are looking forward to working with you.

*The four WASC rubrics refer to: 1) WASC “Rubric for Assessing the Quality of Academic Program Learning Outcomes”; 2) WASC “Rubric for Assessing the Use of Capstone Experience for Assessing Program Learning Outcomes”; 3) WASC “Rubric for Assessing the Use of Portfolio for Assessing Program Learning Outcomes”; and 4) WASC “Rubric for Assessing the Integration of Student Learning Assessment into Program Reviews”.

Part 1: Background Information

B1. Program name: [__B.A. Mathematics_____]

B2. Report author(s): [__Edward Bradley_____]

B3. Fall 2012 enrollment: [__227_____]

Use the *Department Fact Book 2013* by OIR (Office of Institutional Research) to get the fall 2012 enrollment: (<http://www.csus.edu/oir/Data%20Center/Department%20Fact%20Book/Departmental%20Fact%20Book.html>).

B4. Program type: [SELECT ONLY ONE]

x	1. Undergraduate baccalaureate major
	2. Credential
	3. Master’s degree
	4. Doctorate: Ph.D./E.D.D.
	5. Other, specify:

Part 2: Six Questions for the 2013-2014 Annual Assessment

Question 1 (Q1): Program Learning Outcomes (PLO) Assessed in 2013-2014.

Q1.1. Which of the following program learning outcomes (PLOs) or Sac State Baccalaureate Learning Goals did you assess **in 2013-2014**? (See 2013-2014 Annual Assessment Report Guidelines for more details). **[CHECK ALL THAT APPLY]**

x	1. Critical thinking (WASC 1) *
	2. Information literacy (WASC 2)
	3. Written communication (WASC 3)
	4. Oral communication (WASC 4)
	5. Quantitative literacy (WASC 5)
	6. Inquiry and analysis
	7. Creative thinking
	8. Reading
	9. Team work
	10. Problem solving
	11. Civic knowledge and engagement – local and global
	12. Intercultural knowledge and competency
	13. Ethical reasoning
	14. Foundations and skills for lifelong learning
	15. Global learning
	16. Integrative and applied learning
	17. Overall competencies for GE Knowledge
	18. Overall competencies in the major/discipline
	19. Others. Specify any PLOs that were assessed in 2013-2014 but not included above: a. b. c.

* One of the WASC's new requirements is that colleges and universities report on the level of student performance **at graduation** in five core areas: **critical thinking, information literacy, written communication, oral communication, and quantitative literacy.**

Q1.1.1. Please provide more detailed information about the PLO(s) you checked above:

The Department of Mathematics and Statistics has identified five learning outcomes for all programs in the department. During the past year the department has focused its attention on Program Learning Outcome 1 (PLO 1). This PLO states :

The mathematics major at CSUS is expected to develop a fundamental understanding of the process and role of mathematics reasoning.

In order to assess this PLO, the department developed a list of learning outcomes for Math 108 (Introduction to Formal Mathematics). The list of learning outcomes for this course is to be found in the appendix. Math 108 is part of the Core Curriculum for the Department of Mathematics and Statistics and it is a course that aims to develop student's ability to think analytically and logically, and to ultimately lead them to be able to present clear and logical proofs which are the essence of all upper division

mathematical thought. Since this course addresses questions of logic and analysis, it develops skills in both Critical Thinking (WASC 1) and Problem Solving (Tenth Value Rubric).

The Rubric for assessing student progress in terms of meeting PLO objectives are :

- (1) Student will be able to understand the nature of the problem posed.
- (2) Student will be able to identify a strategy that will lead to a logical solution.
- (3) Student will be able to construct a valid proof or is able to present a logical solution.
- (4) Student will be able to present his thoughts and reasoning in an effective manner.

Q1.2. Are your PLOs closely aligned with the mission of the university?

x	1. Yes
	2. No
	3. Don't know

Q1.3. Is your program externally accredited (except for WASC)?

	1. Yes
x	2. No (If no, go to Q1.4)
	3. Don't know (Go to Q1.4)

Q1.3.1. If yes, are your PLOs closely aligned with the mission/goals/outcomes of the accreditation agency?

	1. Yes
	2. No
	3. Don't know

Q1.4. Have you used the *Degree Qualification Profile (DQP)* * to develop your PLO(s)?

	1. Yes
	2. No, but I know what DQP is.
x	3. No. I don't know what DQP is.
	4. Don't know

* **Degree Qualifications Profile (DQP)** – a framework funded by the Lumina Foundation that describes the kinds of learning and levels of performance that may be expected of students who have earned an associate, baccalaureate, or master's degree. Please see the links for more details:

http://www.luminafoundation.org/publications/The_Degree_Qualifications_Profile.pdf and <http://www.learningoutcomeassessment.org/DQPNew.html>.

Question 2 (Q2): Standards of Performance/Expectations for EACH PLO.

Q2.1. Has the program developed/adopted **EXPLICIT** standards of performance/expectations for the PLO(s) you assessed in **2013-2014 Academic Year**? (For example: We expect 70% of our students to achieve at least a score of 3 on the Written Communication VALUE rubric.)

	1. Yes, we have developed standards/expectations for ALL PLOs assessed in 2013-14.
x	2. Yes, we have developed standards/expectations for SOME PLOs assessed in 2013-14.

	3. No (If no, go to Q2.2)
	4. Don't know (Go to Q2.2)
	5. Not Applicable (Go to Q2.2)

Q2.1.1. If yes, what are the desired levels of learning, including the criteria and standards of performance/expectations, especially at or near graduation, for EACH PLO assessed in 2013-2014 Academic Year? (For example: what will tell you if students have achieved your expected level of performance for the learning outcome.) Please provide the rubric and/or the expectations that you have developed for EACH PLO one at a time below. [WORD LIMIT: 300 WORDS FOR EACH PLO]

Q2.2. Have you published the PLO(s)/expectations/rubric(s) you assessed in 2013-2014?

	1. Yes
x	2. No (If no, go to Q3.1)

Q2.2.1. If yes, where were the PLOs/expectations/rubrics published? [**CHECK ALL THAT APPLY**]

	1. In SOME course syllabi/assignments in the program that claim to introduce/develop/master the PLO(s)
	2. In ALL course syllabi/assignments in the program that claim to introduce /develop/master the PLO(s)
	3. In the student handbook/advising handbook
	4. In the university catalogue
	5. On the academic unit website or in the newsletters
	6. In the assessment or program review reports/plans/resources/activities
	7. In the new course proposal forms in the department/college/university
	8. In the department/college/university's strategic plans and other planning documents
	9. In the department/college/university's budget plans and other resource allocation documents
	10. In other places, specify:

Question 3 (Q3): Data, Results, and Conclusions for EACH PLO

Q3.1. Was assessment data/evidence collected for 2013-2014?

x	1. Yes
	2. No (If no, go to Part 3: Additional Information)
	3. Don't know (Go to Part 3)
	4. Not Applicable (Go to Part 3)

Q3.2. If yes, was the data scored/evaluated for 2013-2014?

x	1. Yes
	2. No (If no, go to Part 3: Additional Information)
	3. Don't know (Go to Part 3)
	4. Not Applicable (Go to Part 3)

Q3.3. If yes, what **DATA** have you collected? What are the **results, findings, and CONCLUSION(s)** for EACH PLO assessed in 2013-2014? In what areas are students doing well and achieving the expectations? In what areas do students need improvement? Please provide a simple and clear summary of the key data and findings, including **tables and graphs** if applicable for EACH PLO one at a time. [WORD LIMIT: 600 WORDS FOR EACH PLO]

The Department of Mathematics and Statistics has developed the following Mathematics Reasoning Rubric for determining standards of performance for the mathematical reasoning program learning outcome. This Mathematics Reasoning Rubric is based on the Problem Solving Value Rubric of the Association of American Colleges and Universities which defines problem solving as the process of designing, evaluating and implementing a strategy to answer an open ended question. This definition aligns well with the department's understanding of the process and role of mathematics reasoning.

For the current assessment cycle, the department has assessed some of the Learning Outcomes for Math 108 which were developed this past year. Questions from final exams from Math 108 were used and evaluated in terms of the Mathematics Reasoning Rubric below.

Mathematics Reasoning Rubric

	Capstone	Milestones		Benchmark
	4	3	2	1
Understands the Nature of the Problem	31%	29%	29%	10%
Identifies a Strategy for Tackling the Problem	32%	32%	26%	10%
Constructs a Valid Solution / Proof for the Problem	21%	37%	34%	9%
Communicates Mathematical Thought and Reasoning	4%	38%	47%	10%

The immediate minimum goal of the Department of Mathematics and Statistics is for students to have an average score of 2.5 on each of the four criteria, and ultimately to attain an average score of 2.75 on each of the criteria.

For the first criteria, Understands the Nature of the Problem, the average score for the Math 108 exams surveyed was 2.79. This score clearly indicates that students have attained a level of competency that exceeds departmental expectation, however, one should be guarded against reading too much into this criteria. While it is the case that students demonstrated a grasp of the nature of the problem and had a clear sense of direction with regard to the problem, hence showing that they understood what was asked of them, the subsequent criteria give a better indication of how well students can then map out a method of solution to a given problem and thus arrive at a proof or solution to the problem at hand. Even so, the fact that 60% of the students managed a score in the top two levels of the criteria means that students are well grounded in the material and have a strong background to proceed with the mathematics.

For the second criteria the average score was 2.86. Again, this exceeds departmental expectation and indicates that students for the most part have a Strategy for Tackling Problems. The fact that this score more than meets expectations means that students are well prepared to formulate a method a solution to any given problem. Even though this score is reassuringly high, it is the case that a significant number of students cannot identify a strategy or have a poorly conceived notion of attack. The fact that 36% of the students in Math 108 struggled to see a method of solution to the problems suggests that instructors need to focus on helping students to transition from understanding the nature of the problem to where they can then set in place a logical format for addressing the needs of the question and identify a strategy of solution.

The third criteria addressed the question of Constructing Valid Proofs. The average score for this criteria was 2.72 which exceeded the department's minimum goal, however it did not meet the ultimate goal of 2.75. A number of the proofs lacked valid reasoning while others were clearly off track and showed that the student did not grasp the foundations of proofs. Given that 44% of the responses were in the lower two classifications, this suggests that more work is needed to lead students to an understanding of the expectations in presenting a clear and valid proof.

The last criteria concerned the Communication of Mathematical Thought and the average score was 2.34. The does not meet the department's minimum goal and shows that much attention needs to focus on raising student awareness of the need the express their work in a logical and cogent format. Too many students write fractured and sloppy proofs that ultimately raise questions about the student's true understanding of the logic that underpins the solution. Faculty need to identify ways in which students can come to an understanding of the importance of presenting their work in a format that can be easily comprehended. As a result of not meeting the minimum goal for this criteria, students do not meet the stated expectation.

Q3.4. Do students meet the expectations/standards of performance as determined by the program and achieved the learning outcomes? [PLEASE MAKE SURE THE PLO YOU SPECIFY HERE IS THE SAME ONE YOU CHECKED/SPECIFIED IN Q1.1].

Q3.4.1. First PLO: [Critical Thinking]

	1. Exceed expectation/standard
	2. Meet expectation/standard
x	3. Do not meet expectation/standard
	4. No expectation/standard set
	5. Don't know

[NOTE: IF YOU HAVE MORE THAN ONE PLO, YOU NEED TO REPEAT THE TABLE IN Q3.4.1 UNTIL YOU INCLUDE ALL THE PLO(S) YOU ASSESSED IN 2013-2014.]

Q3.4.2. Second PLO: [_____]

	1. Exceed expectation/standard
	2. Meet expectation/standard
	3. Do not meet expectation/standard
	4. No expectation/standard set
	5. Don't know

Question 4 (Q4): Evaluation of Data Quality: Reliability and Validity.

Q4.1. How many PLOs in total did your program assess in the 2013-2014 academic year? [1]

Q4.2. Please choose **ONE ASSESSED PLO** as an example to illustrate how you use direct, indirect, and/or other methods/measures to collect data. If you only assessed one PLO in 2013-14, YOU CAN SKIP this question. If you assessed MORE THAN ONE PLO, please check **ONLY ONE PLO BELOW EVEN IF YOU ASSESSED MORE THAN ONE PLO IN 2013-2014.**

x	1. Critical thinking (WASC 1) ¹
	2. Information literacy (WASC 2)
	3. Written communication (WASC 3)
	4. Oral communication (WASC 4)
	5. Quantitative literacy (WASC 5)
	6. Inquiry and analysis
	7. Creative thinking
	8. Reading
	9. Team work
	10. Problem solving
	11. Civic knowledge and engagement – local and global
	12. Intercultural knowledge and competency
	13. Ethical reasoning
	14. Foundations and skills for lifelong learning
	15. Global learning
	16. Integrative and applied learning
	17. Overall competencies for GE Knowledge
	18. Overall competencies in the major/discipline
	19. Other PLO. Specify:

Direct Measures

Q4.3. Were direct measures used to assess this PLO?

x	1. Yes
	2. No (If no, go to Q4.4)
	3. Don't know (Go to Q4.4)

Q4.3.1. Which of the following DIRECT measures were used? [Check all that apply]

	1. Capstone projects (including theses, senior theses), courses, or experiences
x	2. Key assignments from other CORE classes
	3. Key assignments from other classes
	4. Classroom based performance assessments such as simulations, comprehensive exams, critiques
	5. External performance assessments such as internships or other community based projects
	6. E-Portfolios
	7. Other portfolios
	8. Other measure. Specify:

Q4.3.2. Please provide the direct measure(s) [key assignment(s)/project(s)/portfolio(s)] that you used to collect the data. [WORD LIMIT: 300 WORDS]

Final exams from Math 108 were used to assess the Critical Thinking PLO. Three representative questions from a total of 28 students were analyzed in terms of the given criteria. The results were tabulated and presented in Table Q3.3. The questions chosen were on the topics of Number Theory, Set Theory and Relations, thus giving a wide spectrum of academic expectation,

Q4.3.2.1. Was the direct measure(s) [key assignment(s)/project(s)/portfolio(s)] aligned directly with the rubric/criterion?

x	1. Yes
	2. No
	3. Don't know

Q4.3.3. Was the direct measure (s) [key assignment(s)/project(s)/portfolio(s)] aligned directly with the PLO?

x	1. Yes
	2. No
	3. Don't know

Q4.3.4. How was the evidence scored/evaluated? [Select one only]

	1. No rubric is used to interpret the evidence (If checked, go to Q4.3.7)
	2. Use rubric developed/modified by the faculty who teaches the class
x	3. Use rubric developed/modified by a group of faculty
	4. Use rubric pilot-tested and refined by a group of faculty
	5. Use other means. Specify:

Q4.3.5. What rubric/criterion was adopted to score/evaluate the above key assignments/projects/portfolio? [Select one only]

	1. The VALUE rubric(s)
x	2. Modified VALUE rubric(s)
	3. A rubric that is totally developed by local faculty
	4. Use other means. Specify:

Q4.3.6. Was the rubric/criterion aligned directly with the PLO?

x	1. Yes
	2. No
	3. Don't know

Q4.3.7. Were the evaluators (e.g., faculty or advising board members) who reviewed student work calibrated to apply assessment criteria in the same way?

x	1. Yes
	2. No
	3. Don't know

Q4.3.8. Were there checks for inter-rater reliability?

x	1. Yes
	2. No
	3. Don't know

Q4.3.9. Were the sample sizes for the direct measure adequate?

x	1. Yes
	2. No
	3. Don't know

Q4.3.10. How did you select the sample of student work (papers, projects, portfolios, etc)? Please briefly specify here:

The exams from all the students in one section of Math 108 were studied and analyzed.

Indirect Measures

Q4.4. Were indirect measures used to assess the PLO?

	1. Yes
x	2. No (If no, go to Q4.5)

Q4.4.1. Which of the following indirect measures were used?

	1. National student surveys (e.g., NSSE, etc.)
	2. University conducted student surveys (OIR surveys)
	3. College/Department/program conducted student surveys
	4. Alumni surveys, focus groups, or interviews
	5. Employer surveys, focus groups, or interviews
	6. Advisory board surveys, focus groups, or interviews
	7. Others, specify:

Q4.4.2. If surveys were used, were the sample sizes adequate?

	1. Yes
	2. No
	3. Don't know

Q4.4.3. If surveys were used, please briefly specify how you select your sample? What is the response rate?

Other Measures

Q4.5. Were external benchmarking data used to assess the PLO?

	1. Yes
x	2. No (If no, go to Q4.6)

Q4.5.1. Which of the following measures was used?

	1. National disciplinary exams or state/professional licensure exams
	2. General knowledge and skills measures (e.g., CLA, CAAP, ETS PP, etc)
	3. Other standardized knowledge and skill exams (e.g., ETS, GRE, etc)
	4. Others, specify:

Q4.6. Were other measures used to assess the PLO?

	1. Yes
x	2. No (Go to Q4.7)
	3. Don't know (Go to Q4.7)

Q4.6.1. If yes, please specify: [_____]

Alignment and Quality

Q4.7. Please describe how you collected the data? For example, in what course(s) (or by what means) were data collected? How reliable and valid is the data? [WORD LIMIT: 300 WORDS]

The Assessment Committee read the Math 108 exams and came to an agreement as to how to score these exams. The results were then tabulated.

Q4.8. How many assessment tools/methods/measures **in total** did you use to assess this PLO? [__1__]

NOTE: IF IT IS ONLY ONE, GO TO Q5.1.

Q4.8.1. Did the data (including all the assignments/projects/portfolios) from all the different assessment tools/measures/methods directly align with the PLO?

	1. Yes
	2. No
	3. Don't know

Q4.8.2. Were **ALL** the assessment tools/measures/methods that were used good measures for the PLO?

	1. Yes
	2. No
	3. Don't know

Question 5 (Q5): Use of Assessment Data.

Q5.1. To what extent have the assessment results from 2012-2013 been used for? [CHECK ALL THAT APPLY]

	Very Much (1)	Quite a Bit (2)	Some (3)	Not at all (4)	Not Applicable (9)
1. Improving specific courses				x	
2. Modifying curriculum				x	
3. Improving advising and mentoring			x		
4. Revising learning outcomes/goals		x			
5. Revising rubrics and/or expectations			x		
6. Developing/updating assessment plan				x	
7. Annual assessment reports			x		
8. Program review				x	
9. Prospective student and family information				x	
10. Alumni communication				x	
11. WASC accreditation (regional accreditation)			x		
12. Program accreditation					x
13. External accountability reporting requirement					x
14. Trustee/Governing Board deliberations					x
15. Strategic planning					x
16. Institutional benchmarking					x
17. Academic policy development or modification					x
18. Institutional Improvement					x
19. Resource allocation and budgeting				x	
20. New faculty hiring			x		
21. Professional development for faculty and staff				xx	
22. Other Specify:					

Q5.1.1. Please provide one or two best examples to show how you have used the assessment data above.

Q5.2. As a result of the **assessment effort in 2013-2014** and based on the prior feedbacks from OAPA, do you anticipate making any changes for your program (e.g., course structure, course content, or modification of program learning outcomes)?

	1. Yes
x	2. No (If no, go to Q5.3)
	3. Don't know (Go to Q5.3)

Q5.2.1. What changes are anticipated? By what mechanism will the changes be implemented? How and when will you assess the impact of proposed modifications? [WORD LIMIT: 300 WORDS]

Q5.2.2. Is there a follow-up assessment on these areas that need improvement?

	1. Yes
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	2. No
	3. Don't know

Q5.3. Many academic units have collected assessment data on aspects of a program that are not related to program learning outcomes (i.e., impacts of an advising center, etc.). If your program/academic unit has collected assessment data in this way, please briefly report your results here. [WORD LIMIT: 300 WORDS]

Question 6 (Q6). Which program learning outcome(s) do you plan to assess next year?

	1. Critical thinking (WASC 1) ¹
	2. Information literacy (WASC 2)
	3. Written communication (WASC 3)
x	4. Oral communication (WASC 4)
	5. Quantitative literacy (WASC 5)
	6. Inquiry and analysis
	7. Creative thinking
	8. Reading
	9. Team work
	10. Problem solving
	11. Civic knowledge and engagement – local and global
	12. Intercultural knowledge and competency
	13. Ethical reasoning
	14. Foundations and skills for lifelong learning
	15. Global learning
	16. Integrative and applied learning
	17. Overall competencies for GE Knowledge
	18. Overall competencies in the major/discipline
	19. Others. Specify any PLOs that the program is going to assess but not included above: a. b. c.

Part 3: Additional Information

A1. In which academic year did you **develop** the current assessment plan?

x	1. Before 2007-2008
	2. 2007-2008
	3. 2008-2009
	4. 2009-2010
	5. 2010-2011
	6. 2011-2012
	7. 2012-2013
	8. 2013-2014
	9. Have not yet developed a formal assessment plan

A2. In which academic year did you last **update** your assessment plan?

x	1. Before 2007-2008
	2. 2007-2008
	3. 2008-2009
	4. 2009-2010
	5. 2010-2011
	6. 2011-2012
	7. 2012-2013
	8. 2013-2014
	9. Have not yet updated the assessment plan

A3. Have you developed a curriculum map for this program?

	1. Yes
x	2. No
	3. Don't know

A4. Has the program indicated explicitly where the assessment of **student learning** occurs in the curriculum?

	1. Yes
x	2. No
	3. Don't know

A5. Does the program have any capstone class?

x	1. Yes
	2. No
	3. Don't know

A5.1. If yes, please list the course number for each capstone class: [_Math 193_____]

A6. Does the program have **ANY** capstone project?

	1. Yes
x	2. No
	3. Don't know

A7. Name of the academic unit: [Mathematics and Statistics ____]

A8. Department in which the academic unit is located: [Mathematics and Statistics_ ____]

A9. Department Chair's Name: [Edward Bradley_____]

A10. Total number of annual assessment reports submitted by your academic unit for 2013-2014: [1____]

A11. College in which the academic unit is located:

	1. Arts and Letters
	2. Business Administration
	3. Education
	4. Engineering and Computer Science
	5. Health and Human Services
x	6. Natural Science and Mathematics
	7. Social Sciences and Interdisciplinary Studies
	8. Continuing Education (CCE)
	9. Other, specify:

Undergraduate Degree Program(s):

A12. Number of undergraduate degree programs the academic unit has: [1 ____]

A12.1. List all the name(s): [BA in Mathematics and Statistics_____]

A12.2. How many concentrations appear on the diploma for this undergraduate program? [0 ____]

Master Degree Program(s):

A13. Number of Master's degree programs the academic unit has: [1 ____]

A13.1. List all the name(s): [MA in Mathematics_____]

A13.2. How many concentrations appear on the diploma for this master program? [0_____]

Credential Program(s):

A14. Number of credential degree programs the academic unit has: [0_____]

A14.1. List all the names: [_____]

Doctorate Program(s)

A15. Number of doctorate degree programs the academic unit has: [0_____]

A15.1. List the name(s): [_____]

A16. Would this assessment report apply to other program(s) and/or diploma concentration(s) in your academic unit*?

	1. Yes
x	2. No

*If the assessment conducted for this program (including the PLO(s), the criteria and standards of performance/expectations you established, the data you collected and analyzed, the conclusions of the assessment) is the same as the assessment conducted for other programs within the academic unit, you only need to submit one assessment report.

16.1. If yes, please specify the name of each program: _____

16.2. If yes, please specify the name of each diploma concentration: _____

Appendix 1 Critical Thinking/ Mathematics Reasoning Rubric

The Department of Mathematics and Statistics has developed the following Mathematics Reasoning Rubric for determining standards of performance for the mathematical reasoning program learning outcome. This Mathematics Reasoning Rubric is based on the Problem Solving Value Rubric of the Association of American Colleges and Universities which defines problem solving as the process of designing, evaluating and implementing a strategy to answer an open ended question. This definition aligns well with the department's understanding of the process and role of mathematics reasoning.

Mathematics Reasoning Rubric

	Capstone 4	Milestones		Benchmark 1
		3	2	
Understands the Nature of the Problem	Demonstrates a full understanding of all aspects of the problem	Demonstrates an understanding of the problem but may not grasp all aspects involved	Demonstrates an understanding of parts of the problem, but work lacks depth	Demonstrates a limited understanding of any aspect of the problem
Identifies a Strategy for Tackling the Problem	Identifies a clear strategy for solving all aspects of the problem	Identifies a strategy for solving that applies to most, but not all, aspects of the problem	Identifies a strategy that may have limited application	Identifies a strategy that may not apply to any aspect of the problem
Constructs a Valid Solution / Proof for the Problem	Constructs a thorough and logically structured proof that demonstrates full comprehension of the mathematics. Examines the feasibility of the solution	Constructs a logically structured proof, albeit brief or minimal, that demonstrates adequate comprehension of the mathematics	Constructs a limited proof that may contain faulty reasoning and shows minimal understanding of the mathematics	Constructs an incomplete or disorganized proof that may contain faulty reasoning and shows little understanding of the mathematics
Communicates Mathematical Thought and Reasoning	Communicates mathematical ideas effectively with ease and clarity	Communicates mathematical ideas adequately, but not always clearly	Communicates mathematical ideas in a vague or imprecise manner	Communicates mathematical ideas in a vague and imprecise manner that may include inaccuracies

Appendix 2 : Math 108 Learning Goals

The Department of Mathematics and Statistics has as a goal in all of its Core Curriculum classes (Math 108, Math 110A/B, and Math 130 A/B) that students be able to understand the vital role that definitions play in the development of formal mathematics. Students must also effectively communicate mathematical ideas in written form. This could include clear written explanations of mathematical ideas as well as constructed formal proofs. The writing allows students to reflect on their learning and deepen their understanding of the concepts in the courses. It is a useful aspect for understanding the language of mathematics and allows students to express themselves clearly in this language.

Math 108 (Introduction to Formal Mathematics) Learning Goals

Math 108 Students will be able to:

- a. Demonstrate an understanding of propositions, including the negation ($\sim P$), conjunction ($P \wedge Q$), disjunction ($P \vee Q$), conditional ($P \Rightarrow Q$), and biconditional ($P \Leftrightarrow Q$) statements, and know vocabulary phrases that are commonly used to translate these connectors.
- b. Demonstrate an understanding of the converse and contrapositive of the conditional statement, and prove conditional statements using the contrapositive.
- c. Correctly use the universal and existential quantifiers "for every" (\forall), "there exists" (\exists), and "there exists unique" ($\exists!$), and be able to translate from quantifiers to words and vice versa.
- d. Negate conjunctions, disjunctions, conditional statements, universal and existential quantified statements, and disprove universally quantified statements with counterexamples.
- e. Write direct and indirect proofs.
- f. Demonstrate an understanding of set theory, including set builder notation, the empty set (\emptyset), complement (\bar{A}), subset ($A \subseteq B$), union ($A \cup B$), intersection ($A \cap B$), set difference ($A - B$), and power set ($\mathcal{P}(A)$). Prove sets are equal. Use indexed family of sets, taking unions, intersections, and their complements, over indexed families of sets.
- g. Know the equivalence of the Principle of Mathematical Induction, the Principle of Complete Induction, and the Well Ordering Principle, and write proofs using these Principles.
- h. Demonstrate an understanding of the Cartesian product of sets ($A \times B$), relations between sets, the domain, range, inverse, and composition of relations.
- i. Demonstrate an understanding of the reflexive, symmetric, and transitive properties of a relation defined on a set. Understand equivalence relations, and be able to prove that a given relation on a set is, or is not, an equivalence relation. Demonstrate a knowledge of equivalence classes, and a partition of a set, and know the connection between equivalence relations and partitions. Understand the equivalence relation of congruence, $\text{mod } n$, on \mathbb{Z} , in particular.
- j. Demonstrate an understanding of functions, function notation, domain, codomain, range, composition, one-to-one, onto, and inverse functions. Prove functions are, or are not, one-to-one and onto.
- k. Demonstrate an understanding of, and prove results concerning, the image and inverse image of

sets under functions.