# APPLIED ABSTRACT AND QUANTITATIVE REASONING (AAQR)
**September 1, 2015**

## I. Short Description

Students will confront an increasing amount of information that makes claims on their lives. It is critical, therefore, that they develop the mental acuity and Christian discernment to both understand the force and assess the weight of such claims. The Abstract and Quantitative Reasoning requirement will develop skills for describing and analyzing the quantitative and functional properties of real-world and abstract phenomena. This requirement will equip students to make wise decisions and to effectively communicate arguments using data about a given phenomenon.

## II. Thematic Core Learning Outcomes and Interpretation

### A. Students will be able to….

1. describe phenomena using mathematical, computational, or symbolic tools (such as graphs, formulas, tables, diagrams, and algorithms)
2. solve problems or draw evidence-based inferences about phenomena using a variety of mathematical techniques
3. communicate logical arguments using structured reasoning and quantitative information

### B. Expansion and interpretation of the outcome statements

The AAQR title includes the notion of "applied," which deliberately emphasizes the use of abstract and quantitative reasoning to derive knowledge about a pattern in nature, society, or thought. It is expected that the substantive focus of an AAQR course will be dedicated to learning and using mathematical strategies. Each of the three learning outcomes should be significantly present throughout the course but all are important together in the process of describing, solving problems or drawing inferences, and communicating claims regarding phenomena.

The learning outcomes emphasize "drawing evidence-based inferences about problems" in order to: 1) broaden the limited scope that is usually ascribed to "problem solving;" and 2) to allow for more exploratory inquiry such that every element of the course does not have to be problem-oriented. Part of drawing inferences involves the ability to describe an observed phenomenon with mathematical structures. Another aspect of drawing inferences involves weighing the relative advantages and limitations of tools used to study the same problem. Students will be expected to develop experience with the tools as well as wisdom in selecting the most appropriate ones for the task.

1. Learning Outcome #1: Students will be able to describe phenomena using mathematical, computational, or symbolic tools (such as graphs, formulas, tables, diagrams, and algorithms).

   *"Phenomena"* refers to well-defined observed patterns in nature, society, or thought.

   *"Problem solving"* usually means answering a specific, limited question, often numerical in value, concerning a phenomenon once it is described by a certain set of functional relationships.

2. Learning Outcome #2: Students will be able to solve problems or draw evidence-based inferences about phenomena using a variety of mathematical techniques.

   *"Mathematical techniques"*: The nature and scope of mathematical techniques constitute what is generally understood as a mathematical way of thinking. At its core, abstract and quantitative reasoning constitutes an analysis of patterns. This includes: patterns of thought (logic, algorithms); patterns of number, counting, and measure (basic algebra, combinatorics); patterns of chance and likelihood (probability, statistics); patterns of shape (geometry); patterns of change (calculus); patterns of symmetry and function (abstract algebra). AAQR courses must develop the mathematical way of thinking from one or more of the above branches with a view towards obtaining wisdom concerning an applied problem.

   *"Solving Problems" and "Drawing inferences"*: Including "solving problems" and "drawing inferences" covers a broad range of abstract and quantitative approaches to phenomena. Drawing inferences means deducing that a set of data with a given property must also have another property, proving that one symbolic relationship implies another, that a certain numerical relationship leads to some specific value of one or more of the quantities involved, or that a desired algorithm is properly implemented with certain specific steps. Another sizeable and possibly overlapping portion of the coursework in an AAQR course must address the applied nature.

   Courses should help students develop a process for dealing with observed phenomena: linking theory, information from observations, strategies for analyzing the data, and developing and communicating reasonable arguments based on conclusions inferred from the data. Consequently, though the use of computer systems to implement a computation is a valuable skill to learn, it must not be done at the exclusion of analytical reasoning that provides the logical connection between the original set of data and the numerical or functional result of a computation.

   The ability to draw inferences and to reason analytically can be done abstractly, without reference to a phenomenon. For pedagogical reasons, it is sometimes natural or necessary to decouple the work of drawing inferences from applications to real-world phenomenon. However, both must be assessed in an AAQR course.

3. Learning Outcome #3: Students will be able to communicate logical arguments using structured reasoning and quantitative information.

   *"Communicate logical arguments"*: Effective communication involves providing logical arguments, explaining the reasons for selecting that method of argument, and effectively using accepted terminology, diagrams, and notation. Furthermore, proper communication may also require demonstrating the reasonableness of the claims (i.e., the "number sense") when a claim involves a numerical value. Effective communication also involves the ability to critique claims that use quantitative evidence.

4. Pursuing the integration of faith and learning in AAQR courses

   These outcomes will be pursued as Christian instructors and students. In AAQR courses, this might include: discussing integral relationships between quantitative reasoning and the Christian faith and scriptures, discussing and practicing Christian humility and integrity in working with data (acknowledging both its possibilities and its limitations); utilizing these tools to examine problems pertinent to Christians in today's world (from matters of faith to pressing social and natural concerns); practicing interpreting and communicating findings for both Christian and non-Christian audiences; developing the Christian skills of wisdom and discernment for evaluating evidence and communicating findings.

## III. Guidelines

### A. Expanded Description

None given.

### B. Connection between area outcomes (Part II above) and the 12 overall program goals of Christ at the Core (see p. 8-9 of the Proposal).

Courses with the AAQR tag fit naturally under the Christ at the Core education goal of Holistic Learning, items (1) and (2), but also contribute to students' Growth in Wisdom, items (3) and (4):

1. AAQR courses ask students to analyze, evaluate, and communicate quantitative and abstract claims. This relates to "Christ at the Core," Holistic Learning Goal #1: "developing strong abilities to discover and evaluate information they need to draw conclusions, practicing analytical and scientific reasoning, presenting their thoughts clearly in oral and written forms, and developing skills in aesthetic engagement." This is only the first level at which AAQR courses contribute to the Christ at the Core goals.

2. AAQR courses should also sketch both the contributions but also the limitations of abstract and quantitative reasoning. Consequently, a student should learn how abstract and quantitative reasoning may inform another discipline and when certain dimensions of the human experience are better served by another discipline and when certain dimensions of the human experience are better served by another discipline. This relates to "Christ at the Core," Holistic Learning Goal #2: "pursuing varied approaches to knowledge with discernment and humility as they map both the rich connections and the conflicts among the disciplines."

3. A central goal of abstract and quantitative reasoning is Growth in Wisdom, and in particular the content expressed in "Christ at the Core," Wisdom Learning Goals #3 and #4. The objective of drawing inferences about problems has a technological value (to devise a machine, a policy, a treatment or an algorithm that performs a certain function). However, the ultimate purpose is to make wise decisions based on certain standards. More specifically, wisdom draws its source from God but abstract and quantitative reasoning may allow for an effective implementation of that wisdom in personal, technological and social decisions. AAQR will equip students to participate in independent and collaborative decision-making to creatively address complex questions utilizing quantitative and abstract reasoning.

### C. Examples of Assessment

A range of rigorous assignments could provide evidence that students have successfully achieved the three Student Outcomes given in section II.A. Depending on the structure of the course, one significant assignment might be relevant for assessing more than one outcome; in other cases a series of assignments will be more appropriate. Faculty are encouraged to go beyond these or substitute other creative assignments as they develop individual courses.

We could also envision rubrics used within or across disciplines that can help effectively assess the three learning outcomes. Such rubrics could be applied to a variety of student work and could give individual or groups of faculty a common starting point. Here is an example of a rubric that could be adapted:

| | Not acceptable | Deficient | Acceptable | Exceptional |
|---|---|---|---|---|
| **1. Students will be able to describe phenomena using mathematical, computational, or symbolic tools (graphs, formulas, tables, diagrams, algorithms).** | Students are unable to use and apply formulas correctly. Inability to represent data visually using graphs or tables. | Attempts to describe an observed phenomenon are insufficient or incorrect. | Students are able to recognize and visualize patterns, and describe them using mathematical, symbolic or computational tools. | Exceptional ability to detect, describe and model complex patterns using mathematical tools. |
| **2. Students will be able to solve problems or draw evidence-based inferences about phenomena using a variety of mathematical strategies.** | Inability to solve problems or draw reasonable inferences. Conclusions are vague or incorrect. Students do not use any quantitative or mathematical strategy. | Attempts to solve problems or draw reasonable inferences are incorrect, leading to erroneous conclusions. Incorrect application of mathematical or computational techniques. | Students are able to solve problems or draw correct inferences from data using mathematical strategies. Ability to discern and choose an appropriate strategy. | Students show exceptional ability to draw complex arguments from a data set using a variety of advanced mathematical techniques. Students show experience and knowledge of available methods and wisdom in selecting the appropriate one. |
| **3. Students will be able to construct and communicate logical arguments using structured reasoning and quantitative information.** | No attempt is made to communicate arguments or steps leading to results. Explanations are incorrect. Lack of number sense. | Communication is unclear and muddled. Specialized terminology is not used or used incorrectly. Calculations are difficult to follow. | Students are able to communicate effectively, and clearly. Correct terminology and notation are used. Calculations are presented in an organized fashion. | Students display exceptional ability to communicate logical arguments, using correct terminology, notation and diagrams. Calculations are presented clearly, concisely and elegantly. |

*This rubric is adapted from the Quantitative Literacy VALUE Rubric from the Association of American Colleges & Universities. (http://www.aacu.org/value/rubrics/quantitative-literacy

**D. General Advice**

None given.