STANDARDS FOR PEDAGOGY

When planning a lesson, an instructor should start with the question "what should students do?", rather than "what should I do?" AMATYC supports the idea that learning is a social endeavor; therefore, it is important that we humanize the culture of learning mathematics, statistics, and data science (Yeh & Otis, 2019). The most impactful classrooms use learner-centered pedagogies, such as active learning, in a classroom environment that fosters a sense of community (CBMS, 2016; NCTM, 2014). Faculty must create frequent opportunities for students to develop and demonstrate conceptual, contextual, and procedural understanding of topics. This requires pedagogical practices that may include students using concrete tools to model abstract ideas, engaging in mathematical and statistical discourse, connecting different representations of the same idea, using prior knowledge to construct new knowledge, and understanding connections between the mathematics and statistics they are learning and what they already know.

Progress has been made toward the goal of more effectively teaching students to deeply understand mathematics and statistics; however, there is a need for more faculty to consistently identify and use pedagogical strategies that promote equitable student learning. AMATYC’s Standards for Pedagogy that follow recommend the use of instructional strategies that provide for student activity and student-constructed knowledge. Evidence-based strategies which can be incorporated by most teachers without requiring substantial faculty development are highlighted in these standards. Furthermore, the standards are in agreement with the instructional recommendations contained in Common Vision (Saxe et al., 2015). The standards include active learning, making mathematical connections, multiple representations and approaches, teaching with technology, experiencing mathematics and statistics, and assessment of student learning.

Standard P-1: Active Learning

Faculty will facilitate active learning that promotes increased and deeper mathematical and statistical reasoning abilities in students. Widespread implementation of high-quality active learning can help reduce or eliminate achievement gaps in STEM courses and promote equity in higher education.

The Conference Board of Mathematical Sciences (CBMS, 2016) uses the phrase “active learning to refer to classroom practices that engage students in activities, such as reading, writing, discussion, or problem solving, that promote higher-order thinking" and calls on institutions to incorporate active learning into post-secondary instruction.

Active learning (AL) can be further defined by developing PROWESS and the following guiding principles: (1) students’ deep engagement in mathematical thinking (PRoficiency), (2) instructors’ interest in and use of student thinking (OWNership), (3) student-to-student interaction (Engagement), and (4) instructors’ attention to
equitable and inclusive practices (Student Success). Active learning benefits all students and offers disproportionately greater benefits for individuals from underrepresented groups by reducing achievement gaps in exam scores and passing rates (Laursen & Rasmussen, 2019).

Learning occurs when students construct their own knowledge through collaboration and when students are cognitively engaged with mathematics (Smith, et al, 2021). Participation in mathematical and statistical discourse, as well as writing and reading about mathematical and statistical ideas teaches students how to communicate about mathematics both orally and in writing. This creates a sense of community in the classroom and allows students to learn to work effectively to solve challenging problems. “For students from different socioeconomic, cultural, and educational backgrounds, and for students with different approaches to learning and social interaction, a supportive community of learners can be cultivated using AL techniques.” (CBMS, 2016, para. 13) “Working in groups also provided less confident or less able students with opportunities to explain, question, agree and disagree and test their thinking in a less threatening context” (Sharma, 2015).

**Standard P-2: Making Mathematical Connections**

*Faculty will actively involve students in meaningful mathematics work that connects to students’ experiences and focuses on broad mathematical and statistical themes that build connections within branches of mathematics, and with other disciplines. Students will view mathematics and statistics as relevant to their lives. Making mathematics and statistics relevant and meaningful is the collective responsibility of faculty, administrators, and producers of instructional materials.*

Traditionally, there has been a disconnect between classroom mathematics and real-world mathematics. Mathematics and statistics must not be presented as isolated sets of rules and procedures, but rather as disciplines that arose out of, and are connected to the needs of other fields. Further, students should be encouraged to make explicit connections between mathematical concepts, including those that may have been traditionally compartmentalized. Topics learned in one branch of mathematics should be explicitly aligned with topics from another, for example how principles learned in arithmetic can be generalized to principles in algebra, which can then be connected to topics in geometry.

Students must have the opportunity to observe the interrelatedness between scientific and statistical, and mathematical investigation, and see first-hand how mathematics and statistics connect to their lives. Curriculum should include meaningful mathematics work that allows students to bring their experiences into the classroom. Authentic applications help students see how mathematics and statistics are relevant in their lives and in the world around them (Benson-O’Connor, 2019; GAISE, 2016).

Understanding that mathematics and statistics have relevance to their life and to the
world in general improves student motivation to learn and ability to connect ideas. Students who understand the role that mathematics and statistics have played in their cultures and the contributions of their cultures to mathematics and statistics are more likely to persevere in their study of the discipline. Faculty should include aspects of mathematics history and contemporary mathematics that provide counterexamples to the pervasive Eurocentric bias found in modern mathematics. Instructional activities should provide examples of how mathematics and statistics are used in a variety of cultures, and by people of every race, ethnicity, gender identity, class, and other social groups. Additionally, instruction should be culturally relevant, culturally responsive, and culturally sustaining (Paris & Alim, 2017).

Standard P-3 Multiple Problem-Solving Strategies

Faculty should help students become flexible problem solvers by allowing students to discover multiple problem-solving strategies and to identify efficient strategies.

Flexibility in problem solving is an essential element of mathematical proficiency (CCSS, 2012). Faculty should provide opportunities for students to discover their own problem-solving strategies and reflect on them (Star & Rittle-Johnson, 2008). Flexibility develops from exposure to multiple methods, comparison of worked examples, prompting and direct instruction, invention of a second method for a previously solved problem, and the opportunity to collaborate with peers (Newton et al., 2020). Experience with multiple problem-solving strategies helps students adaptively choose more efficient strategies based on the content or context of the problem (Rittle-Johnson & Star, 2007).

Standard P-4 Multiple Representations of Mathematical Concepts

Faculty will provide opportunities for students to use, share, and make sense of multiple representations of mathematical and statistical ideas. These multiple representations may include words, equations, different algebraic notations, graphs, diagrams, models, manipulatives, and computer code.

Mathematics and statistics are connected webs of knowledge where conceptual knowledge links individual pieces of information. “The development of this conceptual knowledge can only be done so by the construction of relationships between pieces of information” (Hiebert, 1986). “The skills that are at the focal point of conceptual learning in mathematics are the ability to identify and express the same concept in different forms of representation, to choose the most appropriate representation from among the various representations, and to be aware of the advantages and disadvantages of the representations” (Incikabi, 2017). Using multiple representations broadens and deepens the connections students make between concepts (Abell et al., 2018; Knill, 2009). This will motivate students to go beyond the mastery of basic operations to a deeper understanding of how to use mathematics and statistics, the meaning of the answers, and how to interpret them (NRC., 1989).
Standard P-5: Teaching with Technology

Faculty will use appropriate technology\(^1\) to promote deeper student learning and will model the use of technology.

Technology is an integral part of modern mathematics and statistics instruction. Faculty should be purposeful in their selection of technology, considering how it aids learning mathematical, statistical, and data science ideas. Pedagogy will include the use of technology to solve, model, and investigate mathematical and statistical problems and will provide students with opportunities to develop conceptual understanding. Emphasis should be placed on the use of high-quality, flexible, accessible technologies that enhance learning. The use of tools that students are likely to encounter in future work and careers, such as statistical software and web-based apps, is essential.

Standard P-6: Experiencing Mathematics and Statistics

Faculty will provide learning activities beyond the scope of the classroom that promote independent thinking and challenge students to persistently pursue efforts over an extended time period.

Faculty should seek opportunities to expand student knowledge of how mathematics and statistics are used beyond the scope of the classroom by providing learning activities, including open-ended projects and research opportunities. In addition, they should help their institutions form partnerships with area businesses and industries to develop opportunities for students to have realistic career experiences (Reich, 1993). Such activities will enable students to acquire the confidence to access and use needed technical information, and to independently form conjectures from an array of specific examples, and to draw conclusions from general principles.

Standard P-7: Assessment of Student Learning

Faculty will incorporate multiple strategies for formative and summative assessments to inform future pedagogical practices and to help students recognize their current understanding.

Formative and summative assessments are complementary tools for assessing the progression of student learning and informing instruction. Formative assessment benefits students and faculty by helping them recognize students’ current knowledge and setting goals for future understanding. Formative assessment takes place regularly during a term and is designed to be low-stakes and informative. Any activity that gives students an opportunity to engage with feedback to improve their understanding is an opportunity for formative assessment. Another goal of formative assessment is to inform teaching practices and strategies to best meet the needs of learners. Good formative assessment produces significant, and often substantial, learning gains (Black & William, 2005).
Formative assessment is most effective when the following principles are applied (Gehrtz, Brantner, & Andrews, 2022; Purcell, 2014; Yale University, n.d.).

- Regularly refer to the learning objectives and explicitly connect them to the learning activities.
- Watch and listen to students as they work to understand student thinking before intervening. Ask open-ended questions that provide opportunities for students to further describe and explain their thinking and reasoning.
- Use qualitative oral and written comments that help students recognize what they understand and what they need to do to increase understanding.
- Adapt teaching plans as a result of the formative assessment outcomes.
- Useful and timely feedback is essential for assessments to lead to learning (GAISE, 2016)

Summative assessments are for the purpose of evaluating student learning and assigning grades. It is especially important to ensure that the assessment aligns with the goals and expected outcomes of the instruction. Instructors should use multiple forms of summative assessment such as projects, portfolios, and demonstration of understanding in authentic situations. Instructors should consider the following principles when designing summative assessments (Blonder, et al.; Yale University, n.d.).

- Design clearly understood questions that align with learning objectives.
- Provide an opportunity for students to demonstrate their understanding of how the foundational concepts of the course are interrelated and can be applied beyond the course contexts.
- Provide opportunities to close the gap between current and desired performance, such as opportunities for resubmission.
- Consider matters of equity to ensure all students have opportunities to succeed. This may require flexible structure in conducting assessments. Flexible assessments, such as team quizzes, take home assignments, and projects provide more equity and inclusion in math courses.

---

1AMATYC Position Statement on Technology Usage:
https://amatyc.org/general/custom.asp?page=PositionTechnology
References


https://people.math.harvard.edu/~knill/pedagogy/harvardcalculus/


