Statistics Resources Toolkit

For Departments Implementing a Statistics Pathway

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Section 1: Overview

A study by Douglas et al. (2023) reported that students are more likely to complete college-level statistics courses and have more earning potential when offered multiple entry-level mathematics pathways. The need to reconsider how mathematics is aligned with a student's career aspirations is pertinent. With the support of mathematics and statistics professional societies, many institutions are exploring the benefits of providing multiple entry-level mathematics pathways that can better accommodate diverse student interests and career goals. Because introductory statistics is the appropriate gateway mathematics course for a large and growing number of students (Mathematical Association of America, 2004), many institutions and organizations have developed a "statistics pathway." There is growing evidence that implementing a carefully planned statistics pathway—in addition to the traditional algebra-intensive pathway needed for STEM majors—can result in striking increases in the number of students completing the college-level statistics course.

This *Statistics Resources Toolkit* is intended for departments that are planning to implement a statistics pathway. It contains resources and guidance on the design of course content, pedagogy, and technology, and on working with programs to identify statistics as an appropriate pathway. The toolkit also includes learning outcomes for the introductory statistics course, which can be adapted to meet local needs and state requirements. Additional topics cover assessment of student readiness for introductory statistics, the mathematical foundations necessary for success in introductory statistics, and models for providing support for underprepared students. Thoughtful consideration of all of these factors is critical in designing a meaningful educational experience for students pursuing a course of study that has statistics as the gateway mathematics course.

Section 2: Implementing an Effective and Relevant Statistics Pathway

Introduction

Implementing a successful statistics pathway requires careful planning. A first step is to form an implementation team that has representation from all stakeholder groups. This team would be responsible for assessing the readiness of the department and the institution to engage in this work.

The next step is to form a content design team that would ensure the introductory statistics course is rigorous and intellectually challenging, and that the course aligns with current recommendations from the relevant professional societies and meets the needs of the programs that would be served by the course. The design team must be thoughtful about both course content and pedagogy. Successful implementations have incorporated active learning in ways that contribute to student learning.

In addition to making sure that the introductory statistics course is concept focused and relevant, the content design team should think carefully about the necessary foundational skills and knowledge for success. The team should also consider placement policies that allow broader access to college-level statistics without compromising the level or content of the statistics course. To accommodate broader access and ensure student success in an accelerated statistics pathway, appropriate support should be provided for all students entering the statistics pathway, particularly those who may be underprepared in mathematics.

2.1 Laying the Groundwork for a New Pathway

While the responsibility for planning and implementing a new mathematics pathway lies with the mathematics department, this work requires the collaboration of many departments across an institution, especially in the early stages. Departments planning to implement the statistics pathway should begin on a solid foundation, involving stakeholders at each step and providing evidence of the need for change.

The Charles A. Dana Center's *DCMP Implementation Guide* contains tools and resources for implementing, scaling, and continuously improving math pathways. Specifically, the essential actions in the Institutional Progress Assessment can help the statistics implementation team determine the readiness of the department and the institution to engage in the work. Reviewing essential actions 1–5 at the outset can help determine if structures are in place for the work to proceed as smoothly as possible. The Institutional Implementation Planning Template may also be useful.

Expanding Access to Introductory Statistics

One of the fundamental principles of the Dana Center's mathematics pathways work is that students should receive mathematics content that is aligned to their programs of study. When having departmental discussions, it may be helpful to refer to the Dana Center's *A Call to Action to Expand Access to Statistics* (2015), which provides arguments in favor of implementing or expanding a statistics pathway, or to have the source documents from the mathematics and statistics professional associations when meeting with faculty. The MAA's Committee on the Undergraduate Program in Mathematics (CUPM) *Curriculum Guide 2004* lists introductory statistics as one of a suite of entry-level courses that should be offered as an alternative to college algebra (Mathematical Association of America, 2004, p. 28). The Dana Center's program of study briefs, described in more detail below, may also be useful when engaging in departmental discussions about the statistics pathway.

Working with Partner Disciplines

Launching a successful statistics pathway calls for more than simply creating and offering a statistics course; attention must be paid to realigning degree plans. Institutions seeking to implement a statistics pathway sometimes merely add an introductory statistics to the list of options. However, there are many students on campus for whom statistics is the most appropriate course and their degree plans should clearly reflect this recommendation. When the implementation team is ready to meet with partner disciplines about changing to a statistics requirement, refer to the *Guide to Aligning Mathematics Pathways to Programs of Study* (DCMP, 2017).

The following additional resources may also be helpful: sample math pathways list, the Indiana meta-majors graphic, and the emerging Texas math pathways graphic. Institutions can use them as starting points for discussion and then customize for their local context, depending on the student population and major programs served. Institutions may also find the Dana Center's program of study briefs for criminal justice, social work, communications, business, and pre-service elementary (K-5) teacher education useful in learning about recommendations from the relevant professional associations about the level of statistics and quantitative reasoning needed to be effective in those fields.

If your institution is implementing guided or structured pathways*, that work should be integrated into that process.*

2.2 Recommendations for the Introductory Statistics Course

The recommendations and student learning outcomes in this section are based on guidelines from the American Statistical Association (ASA) and on a scan of the content and learning outcomes for introductory statistics courses at research universities, public comprehensive universities, liberal arts colleges and two-year colleges in five states (Arkansas, California, Colorado, Texas and Washington).

Overview of the *Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report*

In 2016, ASA endorsed the Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report. These guidelines were also endorsed by the American Mathematical Association of Two-Year Colleges (AMATYC).

The GAISE report shared six recommendations for the college-level introductory statistics course.

1. Teach statistical thinking.
   - Teach statistics as an investigative process of problem solving and decision making.
   - Give students experience with multivariable thinking.
2. Focus on conceptual understanding.
3. Integrate real data with a context and purpose.
4. Foster active learning.
5. Use technology to explore concepts and analyze data.
6. Use assessments to improve and evaluate student learning.

The report also includes a discussion of suggested learning objectives, examples that illustrate multivariable thinking, sample assessment items, and ideas on how the GAISE recommendations can be implemented in different learning environments.

A first step in the design and implementation of a successful statistics pathway is to ensure that the introductory statistics course offered by the institution is consistent with the GAISE guidelines.

Student Learning Outcomes for the Introductory Statistics Course

To assist in developing an introductory statistics course as part of the statistics pathway or in revising/updating an existing introductory statistics course, Appendix A offers an example of an appropriate set of student learning outcomes. These outcomes are informed by the recommendations and learning outcomes in the GAISE guidelines and by a scan of the content and learning outcomes for introductory statistics courses at research universities, public comprehensive universities, liberal arts colleges and two-year colleges in Arkansas, California, Colorado, Texas and Washington.

The learning outcomes represent what is typical for a modern introductory statistics course. However, depending on local and regional requirements, some outcomes might not be included as part of the course. These outcomes are optional. *Note: These learning outcomes might not be optional in your context.*

In addition, some outcomes might be included in introductory statistics courses for specific student audiences, such as students majoring in health sciences or social sciences. These outcomes are discipline specific and might not be included in an introductory statistics course designed for a more general audience.

When considering this list of outcomes as a starting point for designing or revising your introductory statistics course, we recommend that you resist the temptation to include many additional or optional outcomes. Having too many outcomes may result in a course that is overcrowded in terms of content, consequently not allowing the opportunity for students to fully engage with important concepts.

The outcomes in Appendix A can serve as a starting point for discussing the content of the introductory statistics course. They are organized in the following broad categories:

A. Statistics as an Investigative Process
B. Collecting Data to Answer Research Questions
C. Summarizing and Describing Data Distributions
D. Reasoning About Probability and Probability Distributions
E. Describing Sampling Variability—Probability as a Foundation for Inference
F. Using Data to Learn About the World

Content List for the Introductory Statistics Course

Appendix B provides a sample content list of topics for the introductory statistics course, which can serve as the basis for a syllabus or expanded course outline. The content topics are organized and linked to the student learning outcomes in Appendix A.

As was the case for the learning outcomes, these topics represent what is typical for a modern introductory statistics course. However, depending on local and regional requirements, some topics might not be included as part of the course and are optional. *Note: These topics might not be optional in your context.* In addition, some topics are discipline specific and might not be included in an introductory statistics course designed for a more general audience (e.g., social sciences, health sciences).

Sample Syllabi

When developing an introductory statistics course as part of a statistics pathway or when revising/updating the introductory statistics course, it may be helpful to look at this course at other institutions. Appendix C includes a link to the Dana Center Mathematics Pathways (DCMP) course, *Introductory Statistics: Analyzing Data with Purpose*, as well as links to sample syllabi for introductory statistics courses from two- and four-year colleges (i.e., Cape Cod Community College, El Paso Community College, California Polytechnic State University).

Pedagogy

Research in statistics and mathematics education has shown improved student outcomes in courses with active learning strategies. This research led to the development of curriculum materials and classroom strategies that promote student learning. For example, the Dana Center Mathematics Pathways (DCMP) created the following design standards to guide the curriculum development process.

- A Student-Centered Culture of Learning
- Supporting Students in Developing as Learners
- Communication
- Technology
- Context and Interdisciplinary Connections
- Assessment

The detailed explanation included in the *DCMP Curriculum Design Standards* gives guidance for the design of the DCMP curricular materials. The *DCMP Annotated Bibliography* provides the research supporting the DCMP design standards.

Research in mathematics education supports the belief that student learning is enhanced when students experience mathematics in an active way, engaging in activities that develop conceptual understanding and working collaboratively to solve meaningful problems. Findings from many of these research studies are summarized in *Active Learning in Post-Secondary Mathematics Education* (Conference Board of Mathematical Sciences, 2016).

CBMS is an organization whose membership includes the 19 mathematics professional societies in the U.S. In 2016, fifteen of the presidents of the member societies signed a statement that called "on institutions of higher education, mathematics departments and the mathematics faculty, public policymakers, and funding agencies to invest time and resources to ensure that effective active learning is incorporated into post-secondary mathematics classrooms." This statement clearly applies to the introductory statistics course. Exemplary statistics pathway models—such as Dana Center Mathematics Pathways, Carnegie Math Pathways (Statway), and the courses in the programs mentioned earlier in this section—all provide rigorous and intellectually challenging statistics curricula that embrace active learning. As diversity in the student population in the statistics course increases, attention to pedagogy becomes even more critical.

The GAISE report cautions that "instructors should not underestimate the learning gains that can be achieved with activities or overestimate the value of lectures to convey information. Embedding even brief activities within lectures can break the natural occasional dips in attention associated with passive or minimally engaged listeners" (2016, p. 18).

Introductory statistics courses are ideally suited to the use of labs and activities that engage students and promote students' conceptual understandings. The GAISE report offers the following recommendations for those seeking to implement active learning strategies in introductory statistics (2016, p. 19).

- Ground activities in the context of real data with a motivating question. Do not "collect data to collect data" for its own sake.
- Consider the student need for physical explorations (e.g., die rolling, card drawing) prior to the use of computer simulations to illustrate or practice concepts.
- Encourage predictions from students about the results of a study that provides the data for an activity before analyzing the data. This motivates the need for statistical methods. (If all results were predictable, we would not need either data or statistics.)
- Avoid activities that lead students step-by-step through a list of procedures. Instead, allow students to discuss and think about the data and the problem.
- When planning activities, be sure there is enough time to explain the problem, let the students work through the problem, and wrap-up the activity during the same class period.
- Consider low-/no-stakes peer assessment (where students comment on or rate a classmate's work) within class to provide quick feedback and to improve the quality of final assessments.

The report contains examples of in-class activities and offers guidance on how active learning and the use of real data can be implemented in both face-to-face and online classes and in classes with limited access to technology.

Technology

While technology is an integral part of a modern introductory statistics course, it should be used for data analysis as well as for exploring statistical concepts and developing conceptual understanding. The use of technology for summarizing and analyzing data allows for more time to select appropriate methods for analysis and to interpret and communicate results.

The modern practice of statistics necessitates the use of computing and software to answer data-based questions. With the use of real data and authentic contexts in a course that focuses on learning from data, exploring multivariable relationships, and communicating results through a variety of data visualizations, it is not reasonable to rely entirely on a graphing calculator or Excel. The design of the introductory statistics course should incorporate the use of a statistics software or statistics apps. Quality, freely available statistics online apps work on a variety of platforms, including smart phones, which facilitate data analysis and exploration. These apps can also be used to support the development of understanding important concepts such as sampling variability. Appendix D of the GAISE report discusses these types of technology.

One example of a free app collection is the DCMP Data Analysis Tools.

2.3 Assessing Student Readiness for Introductory Statistics

As introductory statistics is made available to more students, it is essential to determine whether students have the foundational skills necessary for success and, if not, to provide supports. While more systems and states are implementing corequisite support, some are still using a prerequisite developmental structure. The role of assessing student readiness is very different under these two systems.

Examining Traditional Placement Methods

Many institutions, systems, and states have assessment tools to determine college readiness or placement into one or more levels of developmental instruction. These tools are most often algebra intensive, and the same placement levels are set regardless of whether the student will take calculus, introductory statistics, or another gateway mathematics course. At some institutions, college algebra is actually a prerequisite for entry into the statistics course. However, as is described more fully in Section 2.4, the level of algebra needed for success in introductory statistics is roughly equivalent to high school Algebra I, and the use of technology in the statistics course means that conceptual understanding is valued more than the repetitive practice of algebraic procedure. Therefore, these assessment tools are ill suited for determining the likelihood of success in statistics.

Moreover, when the assessment tool places students into traditional developmental mathematics, the algebra-intensive focus often indicates that little time is spent on other skills that are crucial in a statistics course, such as reading for understanding, analyzing results, and communicating those results in a clear manner. The traditional placement methods and developmental mathematics courses are unnecessary barriers and do not provide students with a complete and relevant preparation for statistics.

The report *A Call to Action to Improve Math Placement Policies and Processes* (Couturier & Cullinane, 2015) explores the barriers created by traditional placement policies, and makes recommendations for increasing student success and decreasing existing racial and income gaps.

Multiple Measures Placement

In an environment of developmental education, students must be accurately assessed for their readiness for the college-level content. Studies have repeatedly shown that high school grade point average provides valuable evidence of student readiness and, when combined with other measures, becomes an even more powerful predictor. Other assessments include measures of grit, self beliefs, conscientiousness, and more. Some institutions even consider the student's preparation in reading and writing in placement decisions for the statistics pathway. The use of these measures can result in students "moving up the placement ladder" or even placing directly into college level, as opposed to having their single, algebra-based standardized test sending them to a sequence of multiple developmental courses.

MDRC and the Community College Research Center released *Toward Better College Course Placement* (2018), a guide for implementing multiple measures assessment. Additional research publications and resources are available from the RP Group's Multiple Measures Assessment Project and from the Center for the Analysis of Postsecondary Readiness (CAPR).

The Changing Role of Assessing Readiness: Moving to a Corequisite Model of Support

As more systems and states implement corequisite supports, the role of assessing readiness is changing. Rather than assessing if—and how many levels of—developmental mathematics is needed, institutions now seek to determine how much concurrent support to provide to students who are placed directly into college-level courses. In some ways, this change may seem to indicate that assessing readiness is less crucial, but it must still be as accurate as possible.

In a structure of corequisite supports, an accurate assessment of readiness can indicate whether an hour of mandatory tutoring each week will be sufficient support, whether a three-contact-hour support course is needed, or whether another option is more appropriate. Too little support may result in failure, but more support than is needed comes with opportunity costs. The use of multiple measures gives a more complete picture of student readiness or support needs.

Directed Self-Placement

Institutions are beginning to give students more decision-making agency. These institutions engage in multiple measures analysis and provide the information to the student along with guidance on the recommended level of support. However, ultimately, it is the student who makes the decision to enroll in the offered supports.

2.4 Mathematical Foundations for the Introductory Statistics Course

With growing recognition that the statistics pathway is the most appropriate for students in many different programs of study and with the implementation of placement policies designed to broaden access to the introductory statistics course, it is sensible to consider the mathematical foundations for success in introductory statistics.

For many years, the default prerequisite for college-level mathematics courses was—and still is in some places—intermediate algebra. While intermediate algebra can provide a foundation for success in statistics, much of the content in the intermediate algebra course is not directly relevant to the introductory statistics course. Moreover, the typical intermediate algebra course does not provide students with opportunities to improve reading and communications skills, which are necessary for success in introductory statistics.

To help remove barriers to access and create a better foundation for introductory statistics, many institutions no longer require intermediate algebra as a prerequisite for entry. In support of this movement, in 2014, AMATYC released a position statement on *The Appropriate Use of Intermediate Algebra as a Prerequisite Course*. It states that prerequisites other than intermediate algebra can adequately prepare students for courses of study that do not lead to calculus.

Understanding the mathematical foundations for statistics allows for the efficient design of prerequisite and corequisite support courses for students entering the statistics pathway. Starting with each learning outcome, faculty can reflect on the mathematics skills required for a student to be able to achieve that outcome. The set of skills identified in this manner can then inform the mathematics content of any support courses for student success in the introductory statistics course. See Peck, Gould, and Utts (2019) for an example of mathematics prerequisites identified in a similar process.

Once the mathematical foundations are identified, appropriate support courses can be developed. One approach, the "pre-stat model," requires underprepared students to take a one-semester developmental course prior to enrolling in the statistics course. A second approach, the corequisite model, has students enroll directly in the college-level statistics course. Those students determined to be underprepared are also enrolled in a corequisite support course that is taken concurrently with the statistics course or which may even be integrated into the statistics course itself. While courses designed for either of these models need to build the same necessary mathematics foundation, the way in which the content is structured for the two approaches will be different. The pre-stat developmental course can be organized around the big mathematical ideas (e.g., the six content areas identified in Peck et al, 2019). On the other hand, the mathematics content in a corequisite support course can organized based on when particular mathematical skills are needed in the statistics course (e.g., what is needed for a later chapter in the course).

Both the pre-stat model and the corequisite model have increased student success in introductory statistics courses. However, current research found that success rates are noticeably higher for the corequisite model by reducing attrition; as a result, this model is becoming more evident at institutions. This approach is discussed more fully in Section 2.5.

2.5 Support for Underprepared Students: Corequisite Models

As access to a college education broadened, the number of students designated as underprepared increased. Developmental courses were designed to give those students more time to master mathematical concepts and to improve success in the college-level course. However, the results have been disappointing, with developmental students being more likely to accumulate debt rather than earn a college degree (Bailey, Jeong, & Cho, 2010; Xu & Dadgar, 2018). The negative effect of long developmental sequences is even worse for minority and other underrepresented students.

Early experimentation with placing students directly into college-level courses and providing additional supports revealed the potential for improved success rates (Adams, Gearhart, Miller, & Roberts, 2009; Asera, 2001; Denley, 2016; Denley & Knox, 2016; Jenkins, Brown, Fink, Lahr, & Tanagiura, 2018). *Corequisite Remediation: Spanning the Completion Divide* (Complete College America (2016) makes a compelling case for corequisite support.

Corequisite support courses take many forms: extended hours each week with embedded support content; separate but linked support courses within the semester; compressed courses; stretch courses; mandatory tutoring; boot camps for students near the placement cut score; and other structures. All of these formats enable a student to complete a college-level course while receiving immediate and relevant developmental mathematics support. (Note: Some of these structures may not be considered true corequisites for the purposes of some legislative mandates.) For more information on various forms of corequisites, as well as other issues related to corequisite design, see Chapter 5 of the *Emerging Issues in Mathematics Pathways* (Hartzler & Blair, 2019).

A key factor in the success of corequisite courses is using appropriate content. As noted in Section 2.4, historically, all underprepared students received the same developmental instruction. This instruction focused on looking backward at a standard of high school algebraic topics that had the incorrect mix of skills for statistics. Course designers are now starting to look forward: What knowledge, skills, and strategies will meet the underprepared students where they are and move them forward to success in their statistics course? The University System of Georgia signals this focus in its use of the term *learning supports* rather than *corequisites*. The content of the corequisite course must support the learning objectives in the gateway course.

In a support course for statistics, underprepared students typically spend time on foundational quantitative skills, such as the fraction and decimal skills needed for probability topics, and the algebraic reasoning and skills needed for regression. In addition, these students are often supported with extra instruction in decoding statistics problems, determining which statistical test is appropriate, and analyzing results. The designers of the gateway course and the support course must work together closely to ensure that the supporting content aligns and that the design teams engage in regular continuous improvement cycles. Roane State Community College created a corequisite instructor manual with a common course calendar and student worksheets for its statistics support courses.

Prerequisite developmental instructors often focus not only on mathematics content but also on supporting students in becoming better learners and understanding college expectations. With the shift to the corequisite model, underprepared students are now entering college-level mathematics in their first semester. Designers of corequisites should consider incorporating instruction in success strategies into the support courses, which may call for increasing the contact hours. Also, incorporating early interventions and fostering peer study groups in both the college-level and the support courses can result in improved success.

2.6 Implementing a Statistics Pathway in Social or Health Sciences Departments

Although not typical at two-year colleges, the introductory statistics course at many four-year colleges is taught in departments other than mathematics or statistics (e.g., psychology, sociology, kinesiology, nursing, and health sciences). The learning outcomes and content topics given in Section 2.2 contain some entries that are discipline specific or optional. Some topics marked as discipline specific or optional might be included in introductory statistics courses for specific student audiences, such as students majoring in health sciences or social sciences. For example, in courses taught in psychology departments, it is not uncommon for analysis of variance and multiple regression to be included. Courses taught in psychology and health sciences departments may include more breadth in terms of the sampling methods covered and also more depth in areas related to the design of experiments (e.g., blocking and randomized block experiments). To accommodate inclusion of these discipline-specific topics, other topics may need to be de-emphasized.

When a discipline-specific statistics pathway is implemented, special attention should be given to designing appropriate student supports (see Sections 2.4 and 2.5). Associated corequisite courses should be aligned with the additional content, as some of these topics will require additional developmental mathematics support.

Section 3: Recommendations on Qualifications for Teaching Statistics

The American Statistical Association and the Mathematical Association of America have codeveloped recommended qualifications for an instructor teaching a modern introductory statistics course. In the joint statement, *Qualifications for Teaching an Introductory Statistics Course*, the two organizations encourage effective teaching in undergraduate statistical education. They provide recommendations and resources to assist departments in hiring qualified candidates or in supporting existing faculty members whose training is not in statistics to acquire the necessary skill set for teaching the course.

The recommendations on qualifications include the following:

1. A minimum of two statistical methods courses including content knowledge of data collection methods, study design and statistical inference, and
2. Experience with data analysis beyond the material taught in the introductory statistics course. This experience could come from advanced coursework, projects, consulting or research.

Section 4: Recommendations on Support for Faculty Teaching Statistics

Institutions that implemented a statistics pathway noted a marked growth in enrollment in the introductory statistics course, which in turn created challenges that should be anticipated. The increased enrollment in statistics has staffing implications, and the demand for faculty, especially adjunct faculty, who are qualified to teach statistics has increased and will continue to increase. Even faculty who previously taught statistics may find themselves uncomfortable with the changes in the course content and the changes in the ways in which it is taught (see Section 2.1). Professional development and support for faculty who are teaching statistics for the first time, or who may be transitioning into a mode of teaching that is not entirely lecture based, are greatly needed.

4.1 Professional Learning for Faculty Teaching Statistics

Effective professional learning should enhance content knowledge, with a primary focus on concepts rather than procedural fluency. It should also provide training that allows faculty to explore equity-minded strategies designed to promote student engagement, strengthen conceptual understanding, and successfully implement a variety of active learning strategies.

One example of a focused professional learning series for introductory statistics faculty is part of the Dana Center's FOCI Professional Learning Series. Series 7, titled "Strengthening Conceptual Understanding in Introductory Statistics: Incorporating Active and Inclusive Teaching and Learning Strategies," is designed for statistics faculty who are interested in creating a student-centered learning environment. Each interactive session covers on an important concept in the introductory statistics course. The six session topics are described in Appendix D.

For those interested in developing this type of support for faculty who are new to teaching statistics, find more information on the Dana Center's FOCI: Focused Online Collaborative Interactions webpage.

Faculty should be encouraged to take advantage of professional learning opportunities and be given necessary support. For example, several conferences focus specifically on teaching the introductory statistics course, including USCOTS (The U.S. Conference on Teaching Statistics) and eCOTS (The Electronic Conference on Teaching Statistics).

Annual conferences of the American Mathematical Association of Two-Year Colleges and American Statistical Association hold seminars related to teaching the introductory statistics course.

Other resources for individual faculty are available through ASA Education Resources for Undergraduate Faculty; ASA/AMATYC Joint Committee Statistics Classroom Resources Page; and http://www.statprep.org/.

4.2 Supporting and Evaluating Faculty

ASA and MAA jointly developed resources for *Supporting and Evaluating Statisticians Within Mathematics Departments*.

It may be useful for departments to consider portions of the 2000 MAA Guidelines for Programs and Departments in Undergraduate Mathematical Sciences, especially the ASA's endorsement of these guidelines. Below are some key points from the endorsement regarding support.

- Once a mathematical sciences department has successfully hired statistics faculty, it should provide sufficient resources and mentoring to enable them to succeed in their teaching and professional development. While travel funds are important for all new faculty members, they can be especially important for statisticians who are housed in a department of nonstatisticians.

These faculty members have a particular need for travel to conferences and workshops to meet with collaborators and gain new ideas about the teaching of statistics.

- Mathematical sciences departments should also recognize the value of statistical consulting as a legitimate and important form of scholarship and professional development.
- If the department has only one or two statistics faculty members, it should seek outside persons to serve as advisers for the department and mentors for these isolated faculty members early in their careers.
- When a department with only one statistician is evaluating the person's teaching, the department should seek input from statisticians at nearby institutions or from the ASA. Since the teaching of statistics differs from that of mathematics in several ways, this input can help the department assess whether the statistician's teaching is consistent with expectations and recommendations in the field.
- The ASA strongly supports the position that mathematics and statistics are separate disciplines and that statistics courses should be taught by those trained in the subject. "In cases where a department offers a course or courses in a particular discipline, but does not have a faculty member with expertise in that discipline, the department should take special care to consult the curricular guidelines of the relevant professional society in that discipline" (MAA Guidelines, Section D.1.g).

References

Adams, P., Gearhart, S., Miller, R., & Roberts, A. (2009). The accelerated learning program: Throwing open the gates. *Journal of Basic Writing, 28*(2), 50–69.

American Mathematical Association of Two-Year Colleges (AMATYC). (2014). *Position on the appropriate use of intermediate algebra as a prerequisite course.* https://amatyc.org/page/PositionInterAlg?&hhsearchterms=%22prerequisites%22

American Statistical Association. (2000). *Endorsement of the Mathematical Association of America (MAA) "Guidelines for programs and departments in undergraduate mathematical sciences."* https://www.amstat.org/asa/files/pdfs/POL-ASAEndorsementMAA2000Guidelines.pdf

American Statistical Association. (n.d.). *Resources for department chairs.* https://www.amstat.org/asa/education/Resources-for-Department-Chairs.aspx

American Statistical Association and the Mathematical Association of America. (n.d.). *Qualifications for teaching an introductory statistics course*. https://www.amstat.org/asa/files/pdfs/EDU-TeachingIntroStats-Qualifications.pdf

Asera, R. (2001). *Calculus and community: A history of the Emerging Scholars Program.* The College Board.

Bailey, T., Jeong, D., & Cho, S. (2010, April). Referral, enrollment, and completion in developmental education sequences in community colleges. *Economics of Education Review, 29*(2), 255–270.

Charles A. Dana Center. (2015). DCMP *A call to action to expand access to statistics.* https://dcmathpathways.org/sites/default/files/resources/2017-05/Call%20to%20Action%20to%20Expand%20Access%20to%20Statistics.pdf

Charles A. Dana Center. DCMP Program of study briefs: Recommendations from professional organizations and sample requirements from institutions of higher education.

Mathematics for business. https://dcmathpathways.org/sites/default/files/resources/2016-10/DCMP%20Issue%20Brief_business%20education_20161019.pdf

Mathematics for communications. https://dcmathpathways.org/sites/default/files/resources/2019-02/DCMP%20Issue%20Brief_COMMUNICATIONS_20190225.pdf

Mathematics for criminal justice. https://dcmathpathways.org/sites/default/files/resources/2019-06/DCMP_issue_brief_criminal_justice_20190612.pdf

Mathematics for pre-service elementary (K–5) teacher education. (2016). https://dcmathpathways.org/sites/default/files/resources/2016-10/DCMP%20Issue%20Brief_preservice%20elementary%20education_20161019.pdf

Mathematics for social work. https://dcmathpathways.org/sites/default/files/resources/2019-08/DCMP-Issue-Brief-SOCIAL-WORK-2019.pdf

Charles A. Dana Center. (2017). DCMP *Guide to aligning mathematics pathways to programs of study.* https://dcmathpathways.org/resources/guide-aligning-mathematics-pathways-programs-study

Charles A. Dana Center. (2023). *Dana Center Mathematics Pathways: Annotated bibliography (revised).* https://dcmathpathways.org/resources/dcmp-curicular-design-standards-annotated-bibliography

Charles A. Dana Center. (2023). *Dana Center Mathematics Pathways: Curriculum design standards (revised)*. https://dcmathpathways.org/resources/dcmp-curriculum-design-standards

Community College Research Center. (n.d.). *Guided pathways: What and how to educational series.* https://ccrc.tc.columbia.edu/research-project/guided-pathways-educational-series.html

Complete College America. (2016). *Corequisite remediation: Spanning the completion divide.* http://completecollege.org/spanningthedivide

Conference Board of Mathematical Sciences (CBMS). (2016). *Active learning in post-secondary mathematics education.* https://www.cbmsweb.org/2016/07/active-learning-in-post-secondary-mathematics-education/

Couturier, L., & Cullinane, J. (2015). *A call to action to improve math placement policies.* https://dcmathpathways.org/sites/default/files/2016-08/A%20Call%20to%20Action%20to%20Improve%20Math%20Placement%20Policies%20and%20Processes.pdf

Cullinan, D., Barnett, E., Ratledge, A., Welbeck, R., Belfield, C., & Lopez, A. (2018). *Toward better college course placement: A guide to launching a multiple measures assessment system.* MDRC and Community College Research Center.

Denley, T. (2016). *Co-requisite remediation full implementation analysis* (Technical Brief Number 3). Tennessee Board of Regents.

Denley, T., & Knox, P. (2016). *Building student success with a co-requisite remediation model and mindset know-how* (Technical Brief Number 5). Tennessee Board of Regents.

Douglas, D., Logue, A. W., & Watanabe-Rose, M. (2023). The long-term impacts of corequisite mathematics remediation with statistics: Degree completion and wage outcomes. *Educational Researcher, 52*(1), 7–15.

GAISE College Report ASA Revision Committee. (2016). *Guidelines for Assessment and Instruction in Statistics Education (GAISE) college report 2016.* https://www.amstat.org/asa/files/pdfs/GAISE/GaiseCollege_Full.pdf

Hartzler, R., & Blair, R. (Eds.) (2019). *Emerging issues in mathematics pathways: Case studies, scans of the field, and recommendations.* Charles A. Dana Center at The University of Texas at Austin. https://dcmathpathways.org/resources/emerging-issues-mathematics-pathways-case-studies-scans-field-and-recommendations

Indiana Math Innovation Council Recommended Gateway Math. (2016). https://dcmathpathways.org/sites/default/files/2016-08/Indiana%20Meta-Majors%20List.pdf

Jenkins, D., Brown, A. E., Fink, J., Lahr, H., & Tanagiura, T. (2018). *Building guided pathways to community college student success: Promising practices and early evidence from Tennessee.* Community College Research Center, Teachers College, Columbia University.

Mathematical Association of America. (2000). *Guidelines for programs and departments in undergraduate mathematical sciences.*

Mathematical Association of America. (2004). *Undergraduate programs and courses in the mathematical sciences: CUPM Curriculum Guide 2004.*

MDRC and the Charles A. Dana Center. (2017). *Sample math pathways list.* https://dcmathpathways.org/sites/default/files/resources/2017-05/Sample%20Math%20Pathways%20List.pdf

Peck, R., Gould, R., & Utts, J. (2019). *Mathematics foundations for success in introductory statistics.* https://dcmathpathways.org/resources/mathematics-foundations-success-introductory-statistics

The RP Group. *Multiple Measures Assessment Project (MMAP)*. (2014). https://rpgroup.org/RP-Projects/All-Projects/Multiple-Measures/MMAP

Xu, D., & Dadgar, M. (2018). How effective are community college remedial math courses for students with the lowest math skills? *Community College Review, 46*(1), 62–81.

Appendices

Appendix A: Introductory Statistics Course Learning Outcomes

Big Picture

A. **Statistics as an Investigative Process**
B. **Collecting Data to Answer Research Questions**
C. **Summarizing and Describing Data Distributions**
D. **Reasoning About Probability and Probability Distributions**
E. **Describing Sampling Variability—Probability as a Foundation for Inference**
F. **Using Data to Learn About the World**

A. Statistics as an Investigative Process

1. Students will demonstrate an understanding of the steps in the data analysis process (collect data based on research objective, summarize and describe data, analyze data, communicate results).

B. Collecting Data to Answer Research Questions

1. Students will demonstrate the ability to distinguish between an observational study and a statistical experiment.
2. Students will demonstrate an understanding that the conclusions that can be drawn from a statistical study depend on the type of study and the way in which the data were collected.
3. Students will be able to explain why random selection is important in observational studies.
4. Students will demonstrate the ability to explain why random assignment is important in statistical experiments.
5. Students will demonstrate the ability to evaluate whether conclusions drawn from a statistical study are appropriate given the way in which the data were collected.
6. Students will demonstrate the ability to critically evaluate the design of an observational study.
7. Students will demonstrate the ability to critically evaluate the design of a statistical experiment.
8. Students will demonstrate the ability to select a random sample from a given population.
9. (optional/discipline specific) Students will demonstrate the ability to distinguish between different types of potential bias in an observational study.
10. (optional/discipline specific) Students will demonstrate the ability to distinguish between different sampling methods (stratified, cluster, systematic).
11. (optional/discipline specific) Students will demonstrate the ability to design a completely randomized experiment.
12. (optional/discipline specific) Students will demonstrate the ability to design a randomized block experiment.

C. Summarizing and Describing Data Distributions

1. Students will demonstrate the ability to summarize univariate data using appropriate graphical displays and numerical summary statistics.
2. Students will demonstrate the ability to describe the distribution of a numerical variable in terms of shape, center, variability, and outliers.
3. Students will demonstrate the ability to compare groups based on graphical and numerical summaries of univariate categorical data.
4. Students will be able compare groups based on graphical and numerical summaries of univariate numerical data.
5. Students will demonstrate the ability to display bivariate numerical data graphically.
6. Students will demonstrate the ability to use the value of the correlation coefficient to describe the strength and direction of a linear relationship between two numerical variables.
7. Students will demonstrate the ability to model a linear relationship between two numerical variables using the least-squares regression line.
8. Students will demonstrate the ability to assess the usefulness of a linear model for describing the relationship between two numerical variables.
9. Students will demonstrate the ability to use graphical and numerical methods to explore relationships between variables in large multivariable data sets.

D. Reasoning About Probability and Probability Distributions

1. Students will demonstrate the ability to interpret probabilities in context.
2. Students will demonstrate the ability to estimate probabilities empirically, using data summarized in two-way tables.
3. Students will demonstrate the ability to use probability rules to calculate probabilities.
4. Students will demonstrate an understanding of the difference between unconditional and conditional probabilities.
5. (optional/discipline specific) Students will demonstrate the ability to use simulation to estimate probabilities.
6. Students will demonstrate the ability to use information provided by a probability distribution to describe the long-run behavior of a random variable.
7. Students will demonstrate the ability to interpret the mean and standard deviation of a probability distribution in terms of the long-run behavior of a random variable.
8. Students will demonstrate an understanding that areas under a continuous probability distribution curve that specifies the distribution of a continuous random variable are interpreted as probabilities.
9. Students will demonstrate the ability to use the normal distribution to calculate probabilities.
10. (optional/discipline specific) Students will demonstrate the ability to use the binomial distribution to calculate probabilities.

E. Describing Sampling Variability—Probability as a Foundation for Inference

1. Students will demonstrate an understanding of sampling variability—that the value of a sample statistic varies from sample to sample.

2. Students will demonstrate an understanding that the sampling distribution of a statistics describes its behavior in repeated sampling.
3. Students will demonstrate an understanding that the standard deviation of a statistic is related to sample size.
4. Students will know the properties of the sampling distribution of the sample proportion.
5. Students will know the properties of the sampling distribution of the sample mean.
6. Students will demonstrate the ability to use sample data and properties of the sampling distribution of a sample proportion to reason informally about the value of a population proportion.
7. Students will demonstrate the ability to use sample data and properties of the sampling distribution of a sample mean to reason informally about the value of a population mean.

F. Using Data to Learn About the World

1. Students will demonstrate the ability to distinguish between questions that can be answered by using sample data to estimate a population characteristic and questions that can be answered by using sample data to test hypotheses about population characteristics.
2. Students will demonstrate an understanding that there is risk involved when drawing conclusions based on sample data.
3. Students will demonstrate an understanding of the relationship between sample size and margin of error.
4. Students will demonstrate the ability to use confidence intervals to estimate population parameters and interpret confidence intervals in context.
5. Students will demonstrate an understanding of the meaning of the confidence level associated with a confidence interval estimate.
6. Students will demonstrate the ability to translate a research question into a null and alternative hypothesis.
7. Students will demonstrate an understanding that rejecting a null hypothesis implies strong support for the alternative hypothesis but that failing to reject the null hypothesis does not imply strong support for the null hypothesis.
8. Students will demonstrate an understanding of the reasoning used to reach a conclusion in a hypothesis test and interpret a *P*-value in context.
9. Students will demonstrate the ability to carry out a hypothesis test and communicate conclusions in context.
10. Students will demonstrate an understanding of the meaning of “significantly different” in the context of a hypothesis test about a difference in population means or proportions.
11. Students will demonstrate the ability to explain the difference between statistical significance and practical significance.

Appendix B: Course Content List

Big Picture

A. **Statistics as an Investigative Process**
B. **Collecting Data to Answer Research Questions**
C. **Summarizing and Describing Data Distributions**
D. **Reasoning About Probability and Probability Distributions**
E. **Describing Sampling Variability—Probability as a Foundation for Inference**
F. **Using Data to Learn About the World**

Content List (Related Learning Outcomes listed in parentheses)

A. **Statistics as an Investigative Process**
   1. The data analysis process (A1)

B. **Collecting Data to Answer Research Questions**
   1. Types of statistical studies—observational studies vs. statistical experiments (B1)
   2. Sampling methods
      a. Random sampling (B3, B6, B8)
      b. (optional/discipline specific) Other sampling methods (stratified, cluster, systematic) (B10)
      c. (optional/discipline specific) Types of bias (response bias, selection bias, etc.) (B9)
   3. Designing a statistical experiment
      a. Random assignment (B4)
      b. Other design strategies (direct control, control group, blinding) (B7)
      c. (optional/discipline specific) Blocking and randomized block experiments (B11, B12)
   4. Appropriate conclusions and scope of inference for observational studies vs. statistical experiments (B2, B5)

C. **Summarizing and Describing Data Distributions**
   1. Graphical displays of numerical data, including dotplots, histograms and boxplots (C1, C2)
   2. Graphical displays of categorical data, including bar charts and segmented bar charts (C1)
   3. Comparative graphical displays, including comparative bar charts, comparative dotplots, and comparative boxplots (C3, C4)
   4. Numerical summary measures, including mean, median, variance, standard deviation and interquartile range (C1, C2)
   5. Measures of relative standing, including quartiles, percentiles and z-scores (C1)
   6. Scatterplots for bivariate numerical data (C5)
   7. Correlation coefficient (C6)
   8. Least-squares regression line (C7)
      a. Outliers and influential observations (C8)

9. Assessing a linear model
    a. Residuals and residual plots (C8)
    b. coefficient of determination (r^2) (C8)
    c. standard deviation about the regression line (s_e) (C8)
10. Use of graphical displays and numerical summaries as a foundation for multivariable thinking (e.g., looking at the relationship between two variables for different values of a third variable) (C9)

D. Reasoning About Probability and Probability Distributions

1. Interpreting probabilities (D1)
2. Estimating probabilities empirically (D2)
    a. Joint, marginal, and conditional relative frequencies (D2)
3. Chance experiments, sample spaces, and events (D3)
4. Calculating probabilities of events for chance experiments with equally likely outcomes (D3)
5. Mutually exclusive events and independent events (D3)
6. Conditional probability (D4)
7. Random variables and probability distributions (D6)
    a. Probability distribution of a discrete random variable (D6)
    b. Probability distribution of a continuous random variable (D6, D7)
    c. Mean and standard deviation of a probability distribution (D7)
8. Normal distribution (D9)
    a. Calculating probabilities for a normal distribution (D9)
    b. Identifying extreme values for a normal distribution (D9)
9. (optional/discipline specific) Binomial distribution (D10)
10. (optional/discipline specific) Estimating probabilities via simulation (D5)

E. Describing Sampling Variability—Probability as a Foundation for Inference

1. Sampling distributions (E1, E2, E3)
    a. Sampling distribution of a sample proportion (E4, E6)
    b. Sampling distribution of a sample mean (E5, E7)

F. Using Data to Learn About the World

1. Estimating population parameters (F1, F2)
    a. Margin of error when estimating a population proportion (F3)
    b. Confidence interval for a population proportion (F4, F5)
    c. Margin of error when estimating a population mean (F3)
    d. Confidence interval for a population mean (F4, F5)
    e. (optional/discipline specific) Confidence interval for a difference in population proportions (F4)

f. (optional/discipline specific) Confidence interval for a difference in population means using paired samples (F4)

g. (optional/discipline specific) Confidence interval for a difference in population means using independent samples (F4)

2. Testing hypotheses about population parameters (F1, F2, F6, F7, F8, F11)

   a. Testing hypotheses about a population proportion (F9)

   b. Testing hypotheses about a population mean (F9)

   c. (optional/discipline specific) Testing hypotheses about a difference in population proportions (F9, F10)

   d. (optional/discipline specific) Testing hypotheses about a difference in population means using paired samples (F9, F10)

   e. (optional/discipline specific) Testing hypotheses about a difference in population means using independent samples (F9, F10)

3. (optional/discipline specific) Additional topics

   a. Chi-square goodness of fit test

   b. Chi-square tests for independence and homogeneity

   c. Testing hypotheses about the slope of a population regression line

   d. Analysis of variance—testing hypotheses about more than two means

      i. Multiple comparison procedures

   e. Multiple regression

   f. Nonparametric methods

Appendix C: Sample Syllabi

Dana Center Mathematics Pathways (DCMP) Course

The Charles A. Dana Center's introductory statistics course has been implemented at a variety of institutions as a part of the statistics pathway. *Introductory Statistics: Analyzing Data with Purpose* is an openly available course designed for active and collaborative learning, with a focus on data analysis and exploration.

The learning outcomes, table of contents, and access to the DCMP Data Analysis Tools (apps) are available at the site linked above.

Cape Cod Community College (two-year college, semesters)

The course description below is for the introductory statistics course at Cape Cod Community College.

> Students are introduced to descriptive and inferential statistics focusing on conceptual understanding and statistical literacy. Topics include: techniques for organizing and presenting data, measures of central tendency and dispersion, probability, discrete and continuous probability distributions, sampling distributions, estimation, one-sample hypothesis tests, and correlation and regression. (4 contact hours)

A sample syllabus that includes student learning outcomes and a content outline can be found at https://www.capecod.edu/media/capecodedu/content-assets/documents/syllabi/mat150.pdf

El Paso Community College (two-year college, semesters)

The catalog description below is for the introductory statistics course at El Paso Community College.

> Provides the collection, analysis, presentation and interpretation of data, and probability. Provides analysis which includes descriptive statistics, correlation and regression, confidence intervals, and hypothesis testing. Recommends the use of appropriate technology.

A course description with learning outcomes can be found at https://www.epcc.edu/academics/catalog/2018/MATH1342.pdf

California Polytechnic State University, San Luis Obispo (four-year university, quarters)

The catalog description below is for the introductory statistics course at Cal Poly.

> Sampling and experimentation, descriptive statistics, confidence intervals two-sample hypothesis tests for means and proportions, Chi-square tests, linear and multiple regression, analysis of variance. Substantial use of statistical software.

An expanded course outline with learning outcomes and a content outline can be found at https://content-calpoly-edu.s3.amazonaws.com/statistics/1/documents/Courses/ECOs/217-2158.pdf

Appendix D: FOCI Professional Learning Series

Strengthening Conceptual Understanding in Introductory Statistics: Incorporating Active and Inclusive Teaching and Learning Strategies

Session 1: Guiding Student Thinking About Implications of Data Collection

Participants will:

- Establish a safe, supportive, participant-centered learning environment for the cohort and set goals for participation and growth.
- Explore types of statistical studies.
- Engage in activities that illustrate various types of biases and potential confounding variables in the context of a statistical study.
- Consider how to develop understanding of the relationship between study design and the types of conclusions that are appropriate.

Session 2: Developing Student Understanding of Sampling Variability

Participants will:

- Use simulation to explore sampling variability.
- Consider ways to motivate understanding of sampling distributions and how a sampling distribution provides information about the long-run behavior of a sample statistic.
- Reflect on ways to develop conceptual understanding of statistical inference.

Session 3: Fostering Understanding of Statistical Significance and Practical Significance

Participants will:

- See how an activity can be used to develop a conceptual understanding of hypothesis testing and p-values.
- Engage in an activity that develops understanding of the meaning of “statistically significantly different.”
- Explore the meaning of statistical significance and of practical significance, and understand the difference between them.

Session 4: Building a Foundation for Selecting Appropriate Data Analysis Methods and Graphical Displays

Participants will:

- Consider how an understanding of basic statistical terms, including population, parameter, sample, statistics, and variable types, provides a foundation for data analysis methods.
- Engage in activities that allow students to focus on selecting methods of analysis appropriate for a given research question.
- Explore how understanding of variable types in a dataset equips students for choosing suitable graphical displays.

Session 5: Providing Experience with Describing Relationships and Building Linear Prediction Models

Participants will:

- Experience activities that use applets to develop an understanding of correlation and least squares regression.
- Build linear regression models and assess their usefulness for making predictions.
- Explore the difference between a statistical relationship and a cause-and-effect relationship.

Session 6: Developing Conceptual Understanding of Probability and Addressing Probability Misconceptions

Participants will:

- Consider ways to help students develop the ability to communicate effectively using probabilities.
- Explore common student probability misconceptions and discuss ways to address them.