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Chapter 4

The Evolving Statistics Pathway

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Abstract

Statistics is the gateway mathematics course for a large and growing number of students. Institutions across the country are exploring ways to broaden access to college-level introductory statistics courses through new placement and prerequisite policies. As access to introductory statistics is opened to accommodate a group of students that is more diverse with respect to mathematics preparation, support structures are being put in place to enable mastery of student learning outcomes that are consistent with course guidelines for the introductory statistics curricula that have been endorsed by the American Statistical Association (ASA). These support structures include courses for mathematically underprepared students, such as co-requisite courses and pre-statistics courses that are clearly focused on the mathematics that is needed for success in introductory statistics. This chapter considers issues related to placement, course content recommendations, and support course models designed to provide a meaningful educational experience for students pursuing a course of study that has statistics as the gateway mathematics course.

Introduction

The need to rethink how students experience college-level mathematics is clear and compelling. In California alone, every year more than 100,000 community college students who are judged to be unprepared for college-level mathematics and placed into a traditional developmental mathematics sequence never go on to complete a college-level gateway mathematics course (Huntsman, Hern, & Snell, 2016). This is far from the intended outcome of developmental education, which was to help students be successful in postsecondary coursework. Hern and Brezina (2016) aptly noted that "the policies and curricula that higher education has developed to help students who are considered 'underprepared' are actually making them less likely to succeed in college." In response, and with the support of mathematics and statistics professional societies, many institutions are exploring and implementing other approaches. Providing multiple entry-level mathematics pathways that are better able to accommodate diverse student interests and career goals is proving to be an effective approach.

Because introductory statistics was noted as the appropriate gateway mathematics course for a large and growing number of students (Mathematical Association of America, 2004), many institutions and organizations have worked to develop a "statistics pathway." There is now 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 success has been documented at a number of two-year and four-year institutions. For example, the Tennessee Board of Regents (2016) reported that after full implementation of statistics pathways at both two-year colleges and four-year universities, there was a substantial increase in the number of students passing the credit-bearing statistics course in their first year. This increase was seen at both the two-year and the four-year institutions, and across all levels of student preparation in mathematics. The California Acceleration Project (CAP) has worked to promote and support accelerated statistics pathways (pathways that enable students traditionally placed into the developmental mathematics sequence to complete transfer-level statistics in one or two semesters). CAP reported that accelerated pathways improved student completion of the introductory statistics course for students at all placement levels and for students of all ethnic backgrounds (Hayward &Willett, 2014). Other notable success stories are described in Huang and Yamada (2017) and Henson, Hern, and Snell (2017).

Considering these documented early successes, both individual institutions and statewide systems (such as in Tennessee and Texas) are implementing statistics pathways (as well as quantitative reasoning and STEM/calculus pathways) on a grand scale. The Conference Board of the Mathematical Sciences (CBMS) 2015 Statistical Abstract of Undergraduate Programs in the Mathematical Sciences in the United States (Blair, Kirkman, & Maxwell, 2018, Table TYE.11) reported that 58 percent of responding community colleges have implemented a pathways course sequence, and 63 percent of those who have one or more pathway sequences have implemented a statistics pathway. Others are just at the beginning of this process and may benefit from careful thought around several key issues, including placement, the content and pedagogy of the college-level introductory statistics course, and the design of support structures for students who may be underprepared in mathematics upon entry to the introductory statistic course. These issues will be addressed in the sections that follow.

Placement

The shift to implement a statistics pathway requires rethinking how entering students are placed into their first college-level mathematics course. In the traditional system, the thinking was that if students could be appropriately positioned at the correct entry point in the traditional sequence of three developmental mathematics courses, it would improve the rate at which they moved on to and completed the college-level mathematics course appropriate to their chosen program of study. However, research on the "accuracy" of various placement instruments found that most were only weakly correlated to pass rates in either developmental or college-level gateway courses (for examples, see Belfield & Crosta, 2012; Jenkins, Jaggers, & Roksa, 2009). The resulting call for improved placement tests did little to improve the situation. The long sequence of developmental mathematics courses and the implicit message to students placed into these courses that they are not ready for college were at the heart of the problem—not necessarily just the placement tests.

In the multiple pathways model, placement takes on a new meaning, and there are two types of placement that need to be considered. The first is placement into the appropriate pathway—for example, statistics, quantitative reasoning, or STEM/calculus. This placement is critical and requires good advising to ensure that students enter a pathway that is appropriate for their anticipated area of study. A full discussion of this type of placement can be found in *A Call to Action to Improve Math Placement Policies and Processes* (Couturier & Cullinane, 2015).

The second type of placement that institutions must grapple with is which students are permitted entry into the college-level introductory statistics course. Some implementations still require students to complete a developmental pre-statistics, or "pre-stat," course prior to entering the introductory statistics course. The difference between this and the traditional developmental pathway is that this pre-statistics course is focused on the mathematics that students need to be successful in statistics (which is a subset of the content in the traditional three course developmental sequence), and it is only one semester (compared to as many as three in the traditional developmental sequence), allowing students to complete the college-level course in the first year of study. In the pre-stat model, a determination will need to be made about who is required to take pre-statistics and who goes directly to the college-level statistics course. This approach is similar to the more traditional placement decisions, but valid placement instruments that assess for just the statistics-relevant mathematics content do not currently exist.

In contrast to the pre-stat model, what appears to now be emerging as the dominant statistics pathway model is the co-requisite, or "co-req," model, which allows all students to move directly into the introductory statistics course and provides additional support for those students who need it. Many people were skeptical of this approach, but institutions that have experimented with the co-req model have surprisingly positive results, as illustrated in the discussion below.

Based on data from a randomized controlled experiment, Logue, Watanabe-Rose and Douglas (2016) concluded that there is evidence that many students directed into developmental mathematics can pass the college-level statistics course without full remediation. In the study, 717 students who placed into developmental mathematics were randomly assigned to one of three groups. Those in the first group were enrolled directly into a college-level statistics course with a two-hour workshop support. Those in the second group were required to enroll in the traditional developmental algebra course prior to taking statistics, and those in the third

group were enrolled in the developmental algebra course with a two-hour workshop support prior to taking statistics. Researchers found that at the end of the semester, 56 percent of the students assigned to the college-level statistics group passed the course, whereas the pass rates in the developmental algebra course for students assigned to the two developmental algebra groups (with and without workshop support) were 39 percent and 44 percent, respectively. In follow-up, they also found that the students who were placed directly into and passed statistics were no less likely to have passed other general education courses (including science).

In California, in the last few years some community colleges have also dramatically altered placement policies for entering students, including using multiple criteria in addition to or as a replacement for traditional placement tests. College of the Canyons now offers direct placement into statistics for any student who meets any one of five criteria, including a high school GPA of 3.0 or higher or a grade of B- or higher in high school algebra (Saxena, Meuschke, & Gribbons, 2017). These changes in placement resulted in 71 percent of entering students being considered eligible to enroll in college-level statistics. Of 408 students who would previously have been required to take developmental algebra but who enrolled directly in statistics, 66 percent were successful in their first attempt (Henson, Hern, & Snell, 2017). At Cuyamaca College, prior to revising its placement policy, only 24 percent of entering students were considered eligible to enroll in statistics. After implementing changes to placement procedures, 84 percent of entering students were considered eligible for statistics with co-requisite support. Pass rates in the statistics course were unaffected by broadening access, with an overall pass rate of 74 percent (Henson, Hern & Snell, 2017). At Long Beach City College, with the implementation of a new placement policy, the percentage of students placed directly into college-level mathematics courses increased by 23 percentage points. Follow-up studies showed no significant differences in mathematics course success rates after the placement change was implemented (Long Beach City College Institutional Research, 2014).

Content and Pedagogy of the Introductory Statistics Course

Of course, increasing student success and progress to degree is not as simple as just opening access to the college-level statistics course by changing placement policies. Placement is only one component in what needs to be a comprehensive approach to designing a successful statistics pathway. The institutions that have been successful have also taken care to ensure that the content and pedagogy of the statistics course are appropriate and that additional support is provided for students who need it. When considering broadening access to statistics, a good starting place is a close look at the existing statistics course. It makes sense to review existing content prior to determining what sort of support structure would be most beneficial.

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 a report on active learning published by the Conference Board of Mathematical Sciences (CBMS), an organization whose membership comprises the 17 mathematics professional societies in the U.S. This CBMS report (2016) included the following statement: "We call on institutions of higher education, mathematics departments and the mathematics faculty, public policy-makers, 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, and this is an important part of the design of the statistics course intended as the gateway course in a statistics pathway. Exemplary statistics pathway models, such as Dana Center Mathematics Pathways, Carnegie Math Pathways (Statway™), and the courses in the programs mentioned earlier in this chapter, all provide rigorous and intellectually challenging statistics curricula that embrace active learning. As diversity in the student population in the statistics course increases, the more important attention to pedagogy becomes.

Further guidance on content, pedagogy, and focus of the introductory statistics course can be found in *Guidelines for Assessment and Instruction in Statistics Education College Report* (GAISE College Report ASA Revision Committee, 2016), published by the American Statistical Association (ASA). In addition to articulating goals for the college-level introductory statistics course, the report also contains recommendations that include teaching statistical thinking, teaching statistics as an investigative process of problem solving and decision making, giving students experience with multivariable thinking, focusing on conceptual understanding, fostering active learning, and integrating real data with a context and a purpose.

Statistics courses that are planned as the entry-level mathematics course in a statistics pathway should be aligned with these CBMS and ASA recommendations. Once faculty have aligned (or verified that an existing course is already in alignment) with the recommendations of the professional community, learning outcomes for the course can be articulated. It is important that these be student learning outcomes and not just a list of content topics because this will make the next step (developing appropriate support) easier.

Models of Support for Underprepared Students

There are currently more examples of fully implemented successful statistics pathways (such as the ones referenced in the previous sections) than is the case for other pathways because it was the first pathway to be fully developed. It is also currently the appropriate pathway for a large number of students. There is no single "right" way to provide support for underprepared students embarking on the statistics pathway, and several different approaches have proven to be successful.

One approach requires that underprepared students take a one-semester developmental course prior to enrolling in the statistics course. While this pre-stat model still requires the student to take a developmental course, the pre-stat course is focused on the mathematics and other cognitive and affective skills that are thought to be directly related to success in statistics. Completed in a single semester, the course accelerates student progress toward completion of the college-level statistics course in the first year. In planning this type of support course, it is helpful to begin with the learning outcomes for the statistics course. For each learning outcome, faculty can reflect on what prerequisite skills will be required for a student to be able to achieve that outcome. The set of skills identified in this manner then leads to the learning outcomes of the support course and, in turn, the content of the support course. For an example of mathematics prerequisites identified in a process similar to the one described here, see Peck, Gould, and Utts (2015).

The co-requisite support or co-req model is currently the most common model, a consequence of work supporting the effectiveness of the approach (e.g., Vandal, 2014) and legislative pressure to reduce or eliminate remedial courses in many states. In this model, students enroll directly in the college-level

statistics course. Then those students determined to be underprepared are also enrolled in a co-requisite support course that is taken concurrently with the statistics course or may even be integrated into the statistics course itself. There are many interesting and functional variations on this theme. For a deeper discussion of co-requisite support courses, see Richardson and Dorsey (this volume). While the co-req model is a support model that is different from the pre-stat model, the process described earlier for developing course learning outcomes and content is also appropriate for the design of a co-requisite course.

Conclusion

There is compelling evidence that underprepared students for whom statistics is the appropriate gateway college-level mathematics course are far better served by being placed in an accelerated statistics pathway that allows completion of statistics in a single semester or by the end of the first year of study. There are now a few models (e.g., co-requisite, pre-statistics) that have been shown to be successful in increasing student success in statistics and in facilitating progress to degree. Although these models differ in various ways, the successful models discussed here have common elements.

- They have all ensured that the introductory statistics course is a rigorous and intellectually challenging course for students and that the course is aligned with current recommendations from the relevant professional societies.
- They have addressed issues of pedagogy and have incorporated active learning in a way that contributes to student learning.
- At the same time, they have modified placement policies to allow broader access to college-level statistics without compromising the level or content of the statistics course.
- To accommodate broader access, they all have taken steps to provide appropriate support for all students entering this accelerated statistics pathway, with a particular attention to support for those students who may be underprepared in mathematics.

Because of documented successes like the ones described here, many institutions are looking to implement a statistics pathway. Institutions that have made this change have noted a marked increase in enrollment in the introductory statistics course, which in turn can create 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 continued to increase. Even faculty who have previously taught statistics may find themselves uncomfortable with the changes in the course and the ways in which it is taught that come with alignment with the CBMS and ASA recommendations. The need for 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 is greatly needed.

While the challenges are not ones that have a quick or easy solution, institutions should not be deterred from addressing them head-on and moving to implement a statistics pathway. If student success and progress toward degree completion are a priority, it is imperative to consider an accelerated statistics pathway, alternative placement policies, and support structures for underprepared students. The evidence is compelling and calls for action.

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