

The Impact of COVID-19 on Undergraduate Mathematical Sciences Education: Report on a CBMS Survey

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The following report is a summary of results from a survey of undergraduate mathematical and statistical sciences programs in two-year and four-year institutions in the US about how the COVID-19 pandemic has affected these programs, and what changes to future instruction might occur as a result of the experience. Administered on behalf of the Conference Board of the Mathematical Sciences (CBMS) in October and November 2020 by the American Mathematical Society in conjunction with Westat, Inc., and with funding from the National Science Foundation, the survey consists of six multiple-choice questions, a request for enrollments, and two free response questions. The survey instrument is located at www.ams.org/profession/data/cbms-survey/cbms2020, where response data is also available, broken down by department type, highest degree offered, institutional size, and institutional control (public/private). The Appendix is also available at that site.

In this report, the headings generally indicate take-away messages from the responses, and they generally follow the sequence of the survey instrument questions. Within the headings, the discussion, figures, and tables

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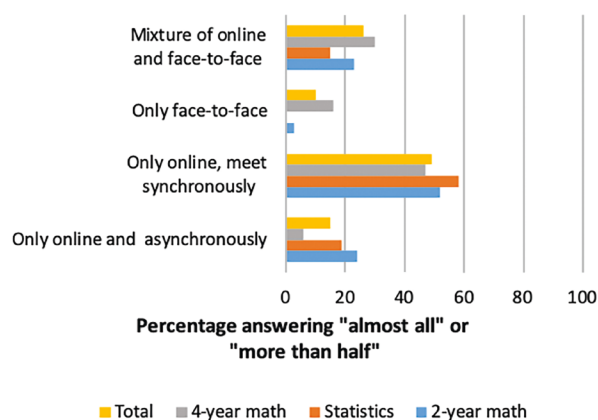
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summarize or highlight the authors' findings. Information about methodology, response rates, and other statistical matters appear in the appendices along with tables giving fuller breakdowns on responses.

"Online Synchronous" Was Most Commonly Used Format

The first question on the survey was designed to get at departments' choice of instructional delivery method under pandemic conditions. Figure 1 shows how various types of departments addressed class formats through the question, "Based on your current plans for the fall 2020 term, what

Figure 1. Distributions of class format, by department level



NOTE: Department chairs could choose more than one response. Percentages may add to more than 100.

proportion of your department's mathematical sciences sections are taught in the following formats?"

- Considering the total of all respondents and combining the two categories of "almost all" and "more than half of courses," the format "only online synchronous" was the most frequently used option (50%), followed by "a mixture of online and face-to-face sessions" (26%; Figure 1).
- "Only online and asynchronous" and "only online synchronous" together accounted for the responses from 53% of the mathematics departments at four-year institutions, 77% of the statistics departments, and 76% of the mathematics departments at two-year colleges.
- The least used format in all the departments combined was "only face-to-face" (10%).
- There was more frequent use of the "only online only asynchronous" format at two-year colleges (24%) and in statistics departments (19%) than at four-year mathematics departments (7%).
- Private four-year mathematics departments reported offering "almost all" or "more than half" of their courses in "face-to-face" or a "mixture" format (60%) than departments at public universities (30%).

Schedule and Staff Changes: Class Sizes Reduced, Part-timers Released, and Full-timers Teach More

In light of pandemic conditions, many departments may have changed their fall 2020 term length, number of sections offered, enrollment limits, and assignments to instructional staff, and the second question on the survey was designed to elicit information about these changes. Figure 2a gives insight to schedule changes that departments made. The percentages shown are of "yes" responses to the indicated changes. Note that these numbers are not meant to sum together. Figure 2b also shows "yes" responses to statements regarding staffing changes. The results indicate that the most frequently utilized personnel changes—except in the statistics group—were reductions in part-time faculty numbers and more sections assigned to full-time faculty. Table 2 in the Appendix gives further breakdowns for these two figures.

- Among the total of all responses, terms were subdivided at few (7%) departments, and the terms were shortened at 19% of departments (31% of four-year mathematics departments).
- Thirty-three percent of all departments cancelled some classes. Classes were more likely to be cancelled at two-year college mathematics departments (43%).
- Changes in the number of faculty hired or fired were most likely for part-time faculty (Figure 2b).
- Full-time faculty were asked to teach additional classes at 20% of all departments.

Figure 2a. Changes in course schedule and size limits, by department type

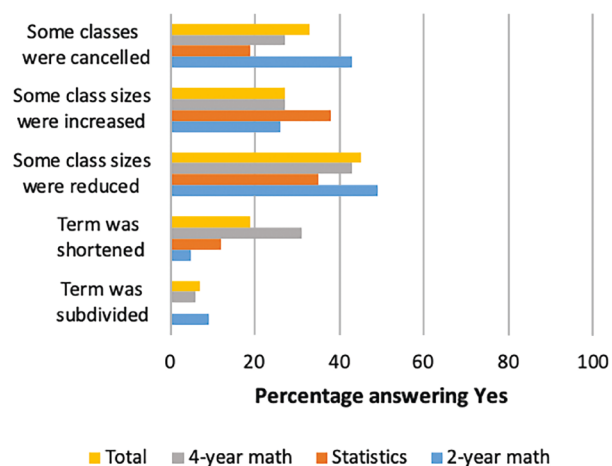
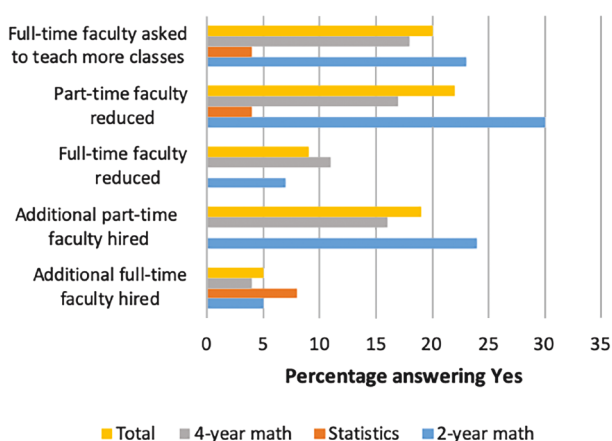


Figure 2b. Instructional personnel changes, by department type



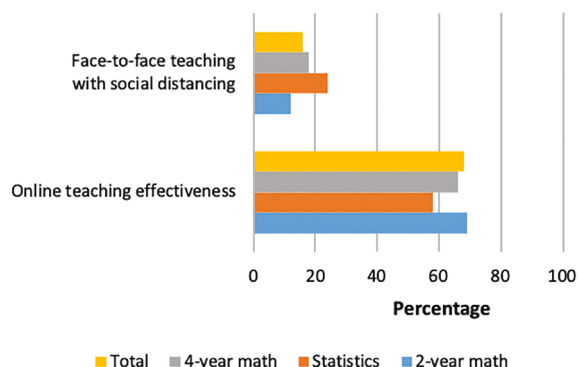
- The responses to these questions were quite similar for four-year and two-year college mathematics departments. In statistics departments there were few departments reporting changes in numbers of faculty hired, fired, or full-time faculty asked to teach additional courses.

Training for Teaching in the Pandemic: Emphasis on Online over In-person

Approximately two-thirds of respondents indicated that "more than half" or "almost all" of their staff received training in online instruction, and much smaller numbers cited similar training for in-person/socially-distanced teaching. Figure 3 shows these percentages across the three groups of departments.

- At all departments combined "almost all" plus "more than half" of their faculty received training in online instruction at 68% of departments and training in

Figure 3. Percentages of departments reporting training for instructional staff, by department type



face-to-face instruction with social distancing at 16% of departments (Figure 3).

- The percentages in the table above were relatively consistent over all three types of institutions. More mathematics departments at four-year private colleges and universities provided instruction than at public institutions.

Face-to-face is Better, and Not Because Students are Ill-equipped

Department respondents voiced opinions on the effectiveness of face-to-face instruction, students' ability to choose their mode of instruction, and students' equipment. Figure 4a gives a breakdown of responses on these questions across the three main department types. Overwhelmingly, respondents felt that face-to-face outcomes are better. Their responses showed a mix of opinion regarding whether students have a choice of modality. While mathematics and statistics respondents felt that students were adequately equipped for online learning, there was disagreement among two-year respondents about how well students were equipped.

"Students' learning outcomes from a face-to-face learning experience are better in an online experience": 72% of all respondents agreed (i.e., "agreed" or "strongly agreed"), and this response was relatively consistent over the three types of institutions (Figure 4a).

- "Students have a choice of which mode of instruction they receive": 47% of all respondents agreed and 38% disagreed, but this percentage was different across different types of institutions.
 - In four-year college mathematics departments, the percentage of those "(strongly) agreeing" was about the same as the percentage as those "(strongly) disagreeing."
 - A larger percentage of statistics departments "(strongly) disagreed" than "(strongly) agreed."
 - More two-year college mathematics departments "(strongly) agreed" than "(strongly) disagreed."
- "Students taking courses online have the equipment and internet connections required for taking courses online": across the total of all respondents, 52% (strongly) agreed and 30% (strongly) disagreed.
 - In two-year college mathematics departments, there were about the same percentage of departments (strongly) agreeing (42%) as departments (strongly) disagreeing (43%).
 - In four-year college mathematics departments, more departments (strongly) agreed (59%) than (strongly) disagreed (20%).
 - In statistics departments, almost all departments (strongly) agreed (69%) as opposed to those that (strongly) disagreed (4%).

Instructional Staff Have Adequate Technology, Prefer to Teach Face-to-face, and Have a Choice of Teaching Mode

Figure 4b provides insight to faculty experiences teaching under pandemic conditions. Very broadly, respondents felt that instructional staff (1) have access to adequate

Figure 4a. Percentages of department with various views on student experiences

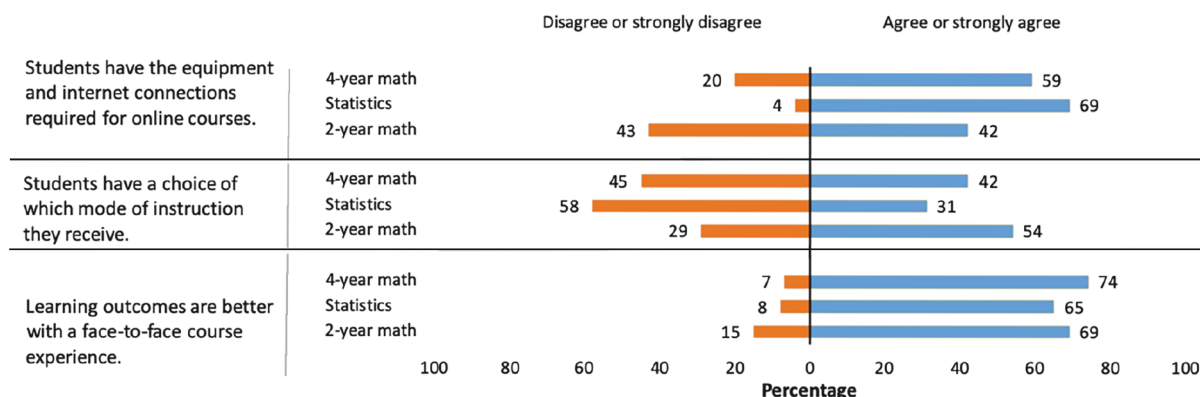


Figure 4b. Percentages of department with various views on faculty experiences

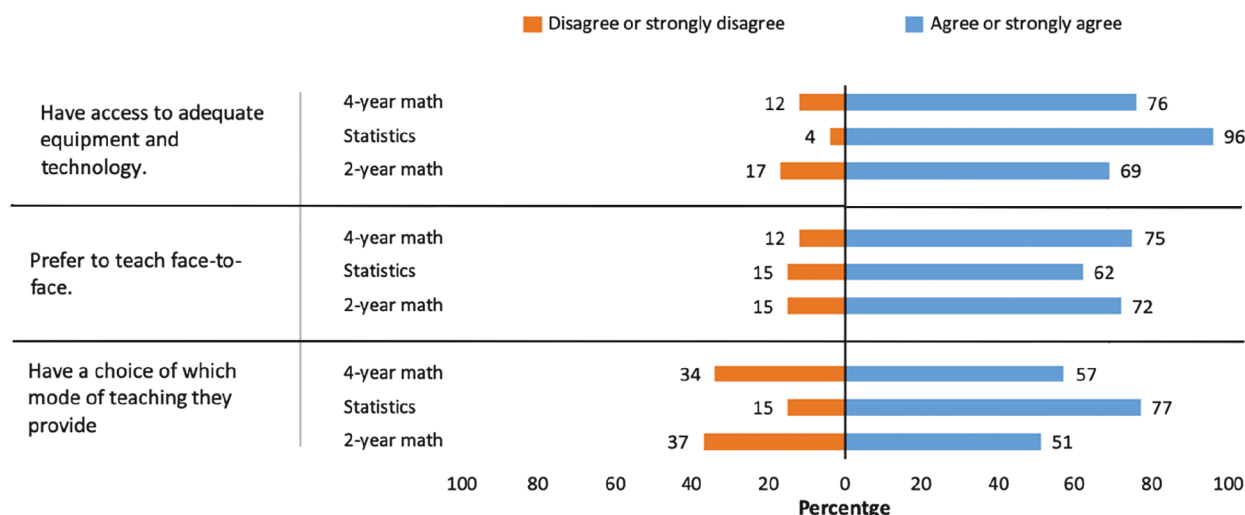
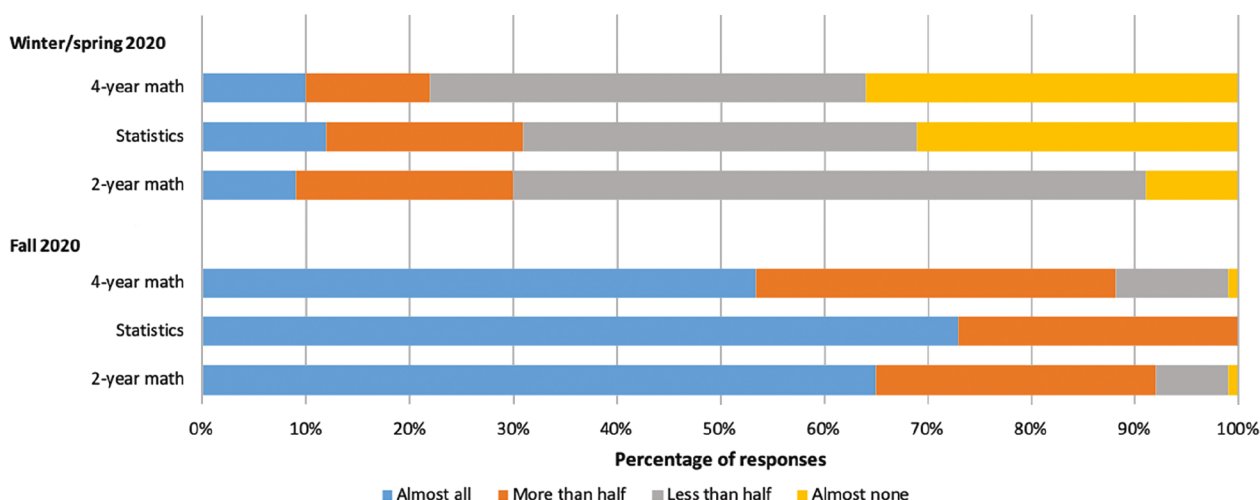


Figure 5. Comparison of instructor preparedness for online teaching between winter/spring 2020 and fall 2020



equipment for online teaching, (2) prefer face-to-face teaching, and (3) have choices about teaching modality.

- “Instructional staff teaching online have access to adequate equipment and technology for teaching online”: 96% of statistics departments, 76% of four-year college mathematics departments, and 69% of two-year college mathematics departments (strongly) agreed.
- “Instructional staff prefer to teach face-to-face classes”: across all respondents combined 73% (strongly) agreed and 13% (strongly) disagreed, and this percentage was relatively consistent across all three types of departments.
- “Instructional staff have a choice of which mode of teaching they provide”: across all respondents combined 55% (strongly) agreed and 35% (strongly) disagreed. These percentages were about the same over four-year

and two-year college mathematics departments, with the percentages in statistics departments showing more agreement (75% (strongly) agreeing and 15% (strongly) disagreeing). When data from Tables 1 and 4 are combined, we see that at departments where almost all sections were in a particular format, there was less agreement with the statement that the instructor could choose their mode of instruction because choice was not possible.

Training for Online Teaching Increased Dramatically with the Pandemic

Figure 5 shows a dramatic shift in preparedness to teach online between the winter/spring 2020 and fall 2020 terms. Chairs were asked the question, “During the terms listed below, what proportion of your department’s instructional

staff were/are adequately prepared to teach online?” and by fall, it was quite rare for instructors to be unprepared for online teaching.

- At each of the three types of department, the largest percentage was “less than half” of the faculty were adequately prepared to teach online prepandemic. Faculty were better prepared prepandemic at two-year college mathematics departments than at statistics departments or at four-year college mathematics departments, as the percentage of “almost none” were adequately prepared was 9% at two-year college mathematics departments, 31% at statistics departments, and 36% at four-year college mathematics departments.
- Twenty-five percent of all departments combined had “almost all” or “more than half” of their faculty adequately prepared prepandemic. Ninety percent of all departments had “almost all” or “more than half” of their faculty adequately prepared after the pandemic—a dramatic change.
- The percentage of departments with “almost all” or “more than half” of their faculty adequately prepared in fall 2020 was relatively consistent across all types of institutions. In fall 2020 statistics departments had the largest percentage of “almost all” adequately prepared to teach online (73%), followed by two-year college mathematics departments (65%), and then by four-year college mathematics departments (54%).

Two-year Departments Most Interested in Expanded Online Offerings

Faculty and leaders in departments in two-year institutions overall show the strongest interest in more and broadened online course offerings, and smaller four-year mathematics and private institutions showed the least interest in these sorts of future changes. Overall, though, a majority of departments believe that more faculty are interested in

teaching online courses and possibly more sections of online courses will be offered. Figure 6 summarizes.

- “We are considering offering a greater number of distance learning mathematical sciences classes.” Combining all respondents, 47% (strongly) agreed while 31% (strongly) disagreed. The percentage of two-year college mathematics departments (strongly) agreeing was 61%, while at four-year mathematics departments the percentage was 35%.
- Private mathematics departments at four-year colleges had the lowest (strongly) agreed percentage of departments considering offering more online courses in the future (25%).
- “We are considering offering a broader range of distance learning formats in mathematical sciences classes (e.g., more types of mathematics courses).” Overall, 37% of respondents (strongly) agreed and 37% (strongly) disagreed. Across all types of departments, a larger percentage (strongly) disagreed than (strongly) agreed, except for statistics departments and two-year college mathematics departments.
- “Additional faculty are showing interest in participating in distance learning.” Across all respondents 45% (strongly) agreed and 30% (strongly) disagreed, with 52% of two-year college mathematics departments (strongly) agreeing. The percentage of departments (strongly) disagreeing was greater at smaller four-year college mathematics departments and at private four-year college mathematics departments.

Falls 2019 to 2020, a Third of Departments Experienced Small Enrollment Changes, but Almost as Many Had Decreases of More than 10%

Departments were asked, “What are the total Fall enrollments in mathematics and statistics courses in your department for 2019 and 2020? If your Fall term has been

Figure 6: Departments' future course-delivery planning

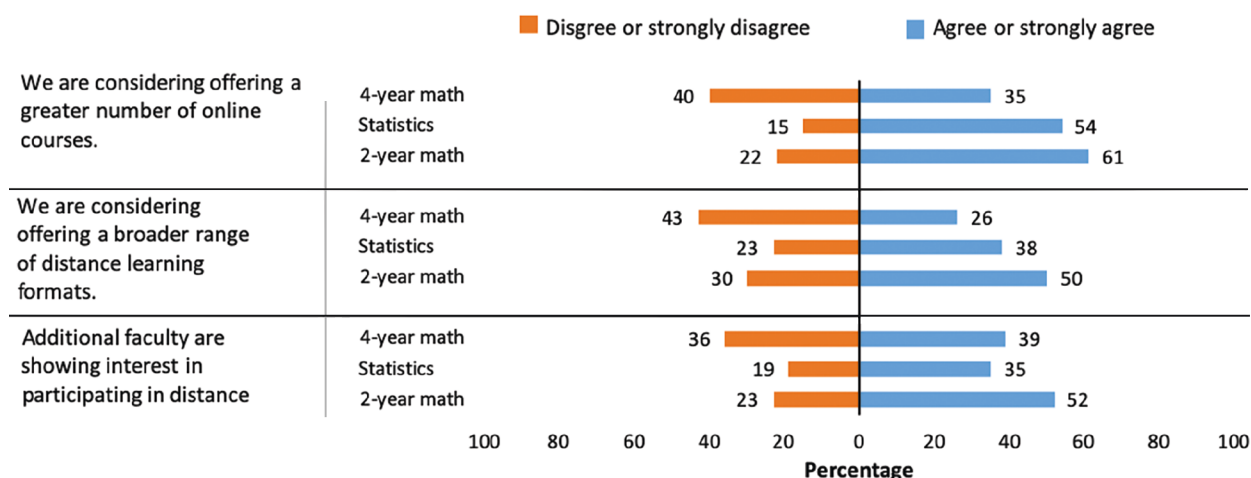
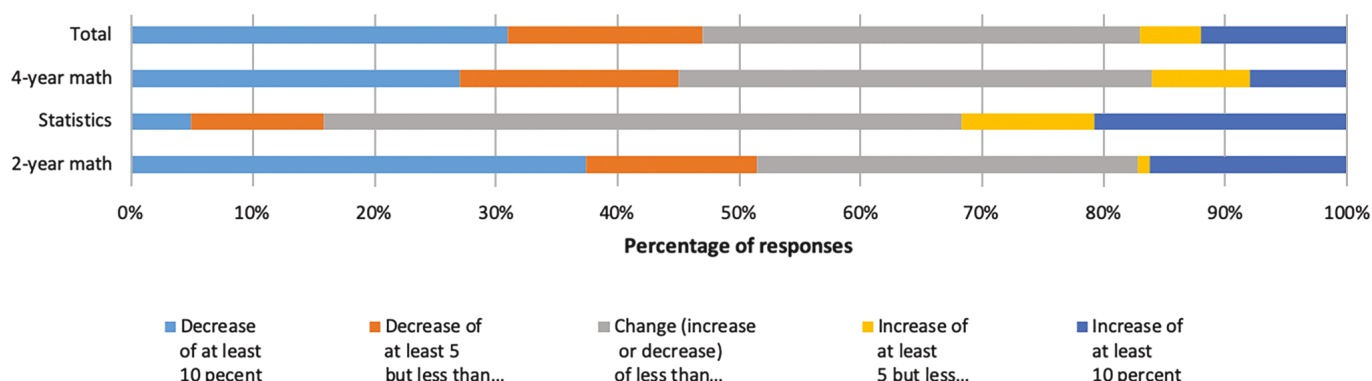


Figure 7: Percentages of departments with various changes in fall enrollments from 2019 to 2020



split into shorter blocks, combine enrollments for all of the blocks in the term." Overall, more departments reported essentially no change in enrollment between the two fall terms than any other size change. That said, nearly a third of departments reported enrollment decreases of more than 10%. The department group with the largest percentage citing enrollment increase was statistics. Figure 7 provides details.

- The three types of departments each reported the largest percentage of departments had some decrease in enrollment (i.e., both categories of decrease added together). Generally, the next largest percentage of departments had little change in enrollment, and the lowest percentage of departments had some increase in enrollment (both categories of increase added together). Over all departments combined these percentages were 31% of all departments reported a decrease at least 10%, 16% a decrease of 5–10%, 26% less than 5% change (either increase or decrease), 5% an increase of 5–10%, and 12% an increase of at least 10%.
- Statistics was the only type of department reporting a larger percentage of departments with some increase (both categories of increase added together) than some decrease (both categories of decrease added together).
- In most of the types of departments, the largest single category was a change of under 5% (i.e., little change) in enrollment—except at two-year college mathematics departments (where the largest percentage is a decrease of at least 10% in enrollment).
- Statistics departments are the type of department with the highest percentage of departments (21%) reporting at least 10% increase in enrollment—the next largest percentage occurs at two-year college mathematics departments, where 16% of departments reported at least a 10% increase in enrollment.

Challenges: Student Engagement, Assessment, and Integrity; Institutional and Faculty Inertia

The survey incorporated two free-response questions, designed respectively to get at the respondents' sense of

key challenges and opportunities presented by pandemic conditions. First, the challenge question was, "What stands out to you as the greatest difficulty your department has faced with relation to the COVID-19 pandemic? Describe only one."

In the free responses to this question from two-year college mathematics departments, **student assessment** and **making connections with students** emerged as frequently-cited challenges.

In connection with assessment, respondents mentioned both academic integrity and faculty time and expertise with online testing:

- Increase number of academic dishonesty incidents on exams. "Rampant cheating online, inability to stop it." "Continual struggle how to ensure academic integrity of exams."
- Proctoring exams: faculty felt online test proctoring software was an equity issue or an invasion of student privacy.
- Grades not a reflection of student learning and grade inflation.
- "Determining how to effectively do testing."
- Additional time required by instructor to enforce showing all workspace during tests to "ensure students are not using cell phone online solvers."
- "Providing students with annotate corrections on tests and quizzes."

Regarding the theme of making connections to students, respondents addressed the motivation of students, engaging students, and employing active learning strategies:

- "Interactions between students and faculty have reduced in quality and quantity to a point where students feel that they have issues with comprehension, mentorship, and competitiveness." Faculty and students feel isolated.
- "Online communication is a poor substitute for in-person."
- "Students are choosing to join class remotely out of convenience. It is difficult to connect with these students and they have various distractions at home."

- Keeping students engaged and working on new materials and assignments.
- Replicating active learning in a virtual environment and how to do group activities online.

Other difficulties reported by two-year college respondents included:

- Ensuring the integrity and quality of instruction.
- Lack of bandwidth and technology equipment.

Students not technically prepared for online classes. "Access to adequate equipment. Most technology in faculty hands are centered around face-to-face classes."

- Converting to/from face-to-face instruction to remote instruction.
- Training faculty.

Among respondents in four-year mathematics and statistics programs, a wide variety of difficulties were reported. Indeed, one response was: "that there are SO MANY challenges at once."

- Students and faculty rapidly pivoting to new modalities (including online, face-to-face with distancing, and mixed) for which they were initially unprepared, for which they had little training and without established departmental norms.
- Maintaining quality instruction: "the median quality of teaching is lower, and the variation is bigger." Replicating active learning, group work, and office hours in online courses.
- Institutions using "HyFlex" modalities, where students could choose their modalities, and accommodating quarantined students, forced faculty to teach in different modalities in the same section.
- Supervising TAs and inexperienced faculty.
- Maintaining the usual course content.
- Engaging students in the new modalities and helping students who were struggling.
- Designing appropriate assessments and problems with student cheating was a frequently mentioned greatest difficulty in online courses.
- Building and maintaining community: among faculty, among students, and between students and faculty were frequently mentioned greatest difficulties.
- Finding adequate classrooms for face-to-face classes, given social distancing requirements; the inability to use computer labs compromised instruction.
- The administration's uncertain and changing plans, cuts in budgets, poor communication, and lack of faculty involvement in decision-making.
- Cuts in numbers of faculty and increasing teaching loads. The new modalities required more faculty time resulting in low morale and burn-out.
- Concern that other responsibilities of faculty such as research were compromised
- A lack of equipment and technical support for faculty. Remote students having inadequate equipment, internet

access, and good working environments; accommodating students abroad in different time zone.

- Addressing student and parent complaints.
- Pressure to offer face-to-face courses, and faculty reluctance to teach face-to-face.

Opportunities: Learning New Teaching Methods and Styles, Greater Faculty Sympathy for Students, and More Inclusiveness

The second free-response question was, "What is the greatest benefit, if any, that you see as arising because of the COVID-19 pandemic? Describe only one." Among responses from two-year college department chairpersons, the chief benefit cited was the **opportunity to learn new methods and styles of teaching, learn new technology, and engage in professional development.**

- "Faculty have learned online teaching strategies and technology that will help them in their future classes."
- "Potential development of web sections for courses that were not under consideration before."
- "We are learning to use tools that we've had access to for a long time but sat dormant for lack of perceived need."
- "Instructors have learned many things; using Zoom, using drawing tablets, e.g., to help the learning environment in different situations."
- "More students and instructors were educated on the use of technology."
- "More instructors are aware of technology that can be used to enhance their traditional classes."

Two-year college chairs also mentioned the following:

- Faculty became more creative about instructional delivery.
- Meetings were streamlined and more convenient.
- Faculty realization that students are able to learn mathematics remotely.
- "More students are realizing they can succeed in online sections."

Almost ten percent of respondents felt there was **no benefit**:

- "None. It has been an excruciating and problematic transition with no upside."
- "None—too many changes and knee jerk reactions, enrollment down 13%."

The following list is illustrative of the benefits cited by four-year mathematics and statistics program respondents:

- Faculty and students now are better equipped to teach and learn remotely (e.g., instead of cancelling class on hurricane or snow days classes might continue remotely, some office hours might occur online), and some departments might offer online courses in the future.
- Faculty are now familiar with new technologies (e.g., making videos, using learning management systems, having students submit assignments electronically) that will be used in the return to normal instruction.

- Faculty found teaching techniques such as “flipped” classes, new assessments, additional materials for students, and new ways of capturing student attention (e.g., putting course content into modules) effective. These techniques are likely to be used in normal times.
- Faculty are now more open to trying new teaching methods and to rethinking course content.
- Learning Centers provided remote tutoring that may continue and serve more students.
- Faculty have become more sympathetic to the problems of students and colleagues, which may help inclusiveness and response to underrepresented groups.
- Faculty discovered online instruction has some advantages over face-to-face instruction, including breakout groups that worked better than some face-to-face group work settings, that some students were more willing to write questions in the Zoom chat than to ask a question in class, that online classes solved some space problems on campus, that online courses may be more convenient for non-traditional students, and they can provide students from around the world expanding enrollments.
- Teaching remotely saved time that was usually lost commuting.
- Recordings of class sessions provided students the ability to watch class sessions again.
- Students have learned skills such as scanning and turning in assignments online.
- Some respondents stated that students spent more time on their classes due to lack of conflicting activities.
- Some chairs stated that videos of class sessions provided good ways of assessing teaching.
- Some departments were able to host and to participate in more seminars and colloquia with remote speakers, and faculty found it easier and cheaper to participate in some conferences.
- Some departments found enrollments increased due to the greater availability of courses, and that it was easier to find adjunct instructors for classes that were taught remotely.
- Technology resources in some departments increased because of the pandemic.

Virtual meetings were seen by some as more efficient and easier to schedule than face-to-face meetings, and virtual honor ceremonies and teas allowed alumni, donors, and parents to participate.

Similar to the two-year group, eight percent of four-year departments responded that there was no benefit. To some departments the pandemic provided confirmation that remote instruction is not effective, and it helped them understand the limitations of online instruction better. The pandemic experience made students and the public appreciate the privilege and value of face-to-face instruction. If nothing else, as one respondent noted, the pandemic has provided some good modeling problems.

CBMS Surveys: Tracking the Mathematical and Statistical Sciences in Higher Education Since 1965

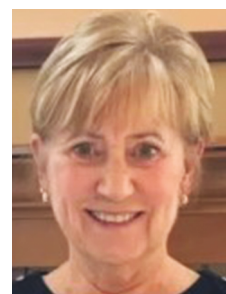
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This COVID-focused survey has been possible through the flexibility of the NSF, which has been the underwriter of the CBMS Surveys of Undergraduate Mathematical Sciences Programs every five years since 1965. Like many regularly-occurring activities, the full 2020 Survey has been postponed to 2021, and this targeted COVID survey has been incorporated into the overall CBMS Survey project.

Examining programs at two- and four-year institutions, these national surveys are sponsored by the Conference Board of the Mathematical Sciences (CBMS), a consortium of nineteen professional associations. The project is administered by the American Mathematical Society, and survey reports can be downloaded from www.ams.org/profession/data/cbms-survey/cbms-survey. See www.ams.org/profession/data/cbms-survey/cbms2020 for further information about the survey to be conducted in the fall of 2021.



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