



Carnegie Foundation for the Advancement of Teaching

Community College Pathways:

A Descriptive Report of Summative
Assessments and Student Learning

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COMMUNITY COLLEGE PATHWAYS
REPORT

EXECUTIVE SUMMARY

Carnegie’s Community College Pathways (CCP) offers two pathways, Statway® and Quantway®, that reduce the amount of time required to complete developmental mathematics and earn college-level mathematics credit. The Pathways aim to improve student success in mathematics while maintaining rigorous content, pedagogy, and learning outcomes.

It is essential that the Pathways’ success in securing college credit for participants does not come at the expense of the rigor of the curriculum or level of student learning. We have previously documented that Pathways students successfully complete their developmental mathematics requirements and earn college credit at rates two or three times higher than is typical, and do so in roughly half the time (Strother et al, 2013; Van Campen et al, 2013). To fully investigate the effectiveness of the Pathways, we must now address the question of whether successful completion of a Pathway also represents rigorous high levels of learning.

The use of a common independent measure of student learning, the Pathways summative assessments allowed such investigation in two ways. First, the manner in which the summative assessment systems were developed allowed us to investigate whether Pathways students acquired a level of knowledge comparable to that of students who took other mathematics or statistics courses during college. Second, correlational analyses between course grades and the summative assessments allowed exploration of whether those grades were positively associated with higher performance on the independent measure.

This report describes the comparative analyses from the Pathways summative assessment system. All items on the summative assessments were rigorously validated by field testing with over 500 members of a comparison sample who had taken a college mathematics or statistics course. Subsequently, all Pathways students took the summative assessments at the end of each term. This report describes analyses that use the development sample for comparison to Pathways students to assess their relative levels of knowledge.

This report then describes the relationship between students’ summative assessments and their end-of-term grades. This analysis is to provide further evidence that Pathways students are not just receiving high grades and successfully completing the Pathways at a higher rate, but that their grades are reflective of actual learning, as corroborated by the independent measure.

Key Findings

- *Pathways students acquire a level of knowledge comparable to students who take other mathematics or statistics courses during college.* We analyzed how Pathways students performed on each item of the summative assessment compared to the comparison sample. In the aggregate and on the vast majority of the array of concepts that were tested across two years of Pathways summative

assessments, the Pathways students consistently performed at or above the level of the comparison sample.

- *Summative assessment scores are related to students' end-of-term grades.* During each term of the first two years of the Pathways, students' grades were significantly correlated to their performance on the corresponding summative assessments. These results indicate that successful students who received higher grades genuinely achieved higher levels of knowledge.

PATHWAYS SUMMATIVE ASSESSMENTS

Purpose

Carnegie’s Community College Pathways (CCP) aim to improve the academic success rate of community college students in developmental mathematics. To accomplish this, there are two pathways, Statway and Quantway, that reduce the amount of time required to earn college credit while improving the content and pedagogy of developmental mathematics (Strother, Van Campen, & Grunow, 2013). While the Pathways’ streamlined structure is a major factor in its success, it is essential that the streamlining does not come at the expense of the rigor of the curriculum.

The Carnegie Foundation built a summative assessment system into the Community College Pathways to have a common measure that could determine the level of student knowledge across the varied institutions and populations of students who participated in the Pathways. The assessments measure Pathways students’ knowledge by using a secure, independent, and common assessment of outcomes that have been validated as appropriate for college-level mathematics. They also allow Carnegie to identify and guide needed improvements in the curricula or instructional materials. The assessments, which are common across all classrooms, also help identify potential, positive deviants, or bright spots, as sources of innovation and improvement ideas.

Carnegie wants to ensure that Pathways students are meeting the learning goals and outcomes that the Pathways require of them. The summative assessments allow Carnegie to ensure that Pathways students are completing each course with a high level of knowledge. The assessment development process allows Carnegie to explore if Quantway students understand quantitative reasoning and Statway students understand statistics at the same levels of performance as college students who have taken a traditional mathematics or statistics course, respectively. This report describes analyses that examine the performance of CCP students in comparison to students who took other college-level mathematics or statistics. It demonstrates that students who successfully completed a Pathways course acquired a level of knowledge comparable to that of college students taking other mathematics or statistics courses.

Background

Community College Pathways Networked Improvement Communities

The academic success rate of community college students in developmental math is alarmingly low. There now an estimated 12.8 million students enrolled in community college (American Association of Community Colleges, 2014) and 59 percent of the entering students are required to take at least one developmental mathematics class before they are eligible to enroll in college-credit courses (Bailey, Jeong, and Cho 2010). However, as many as 80 percent of the students who place into developmental mathematics do not successfully complete any college-level mathematics courses within three years (Bailey et al., 2010). Instead, many students withdraw from courses, spend long periods of time repeating courses, or more often do not enroll or drop between courses during their lengthy developmental mathematics sequence, ultimately leaving college without a credential (Bailey et al.,

2010). This means that millions of students each year fail to acquire essential mathematics skills and are unable to progress toward their career and life goals.

To address this national problem, the Carnegie Foundation for the Advancement of Teaching with support from the Bill and Melinda Gates Foundation, William and Flora Hewlett Foundation, Kresge Foundation, Carnegie Corporation of New York, and the Lumina Foundation created an innovative and transformative approach to developmental mathematics education, the Community College Pathways.

The CCP Networked Improvement Community is organized around two mathematics pathways, Statway and Quantway, that aim to facilitate students' progress through their developmental mathematics sequence and a college-level course for credit. The Pathways reduce the time required to earn college credit while improving the content and pedagogy of developmental mathematics.

Statway is designed as a two-semester college-level statistics course with appropriate developmental mathematics embedded within it. This single pathway merges elementary and intermediate algebra with college-level statistics. Statway integrates developmental mathematics skills and college-level statistics into a collaborative, problem-focused class.

Quantway is designed as two separate semester-long courses. The first semester, Quantway 1, fulfills the requirements for students' entire developmental mathematics sequence. The next semester, Quantway 2, is a college credit-bearing quantitative reasoning course.¹ Each semester of Quantway is designed to promote success in community college mathematics and cultivate quantitatively literate students.

Learning Outcomes

The summative assessments target key learning outcomes for each of these Pathways. In 2009 for Statway and 2010 for Quantway, the Carnegie Foundation convened a series of meetings to devise learning outcomes for each Pathway. The committee members represented the national mathematics and statistical societies, as well as university and community college faculty. These convenings drew upon participants' deep content knowledge and diverse experiences to debate and reach consensus on a list of core concepts and skills that mathematics students need to learn. Throughout this process, the committees made a deliberate effort to ensure that the Pathways' learning outcomes were comparable in content and rigor to those of typical college statistics (Statway) or general quantitative reasoning (Quantway) courses. Bernadine Chuck Fong, the senior managing partner of the Community College Pathways, then formally presented these learning outcomes to a number of national professional mathematics and statistics societies (the Mathematical Association of America, the American Mathematical Association of Two-Year Colleges, and the American Statistical Association) for review and critique. These societies subsequently validated that the learning outcomes were of equivalent quality and rigor as those of typical college mathematics courses.

¹ Colleges can use Quantway 1 alone to help students progress more efficiently through their developmental mathematics requirements, or they may offer Quantway 2 along with Quantway 1 as a full pathway option for students to earn college-level mathematics credit.

Creating Summative Assessments

Item Generation

The Pathways summative assessment items were created to assess student knowledge of the key learning outcomes. In this way, Carnegie ensured strong alignment of the Pathways' learning outcomes, curriculum, instruction and the assessment of those outcomes.

As the Pathways launched, Carnegie recruited Pathways faculty members who had the best grasp of the curriculum and learning outcomes to draft the first set of summative assessment items. During the second year, a measurement specialist worked with these faculty members to create standards and guidelines for item writing that all item writers have since used. (Sample items are included in Appendix A.) To maintain a replenishing pool of items, the faculty members periodically generated new items. Typically once or twice a year faculty item writers wrote items that targeted specific learning outcomes where we needed more quality items.

Item Reviews

After faculty members drafted items, each item underwent several checks to ensure they were of high quality. First, faculty item writers reviewed one another's work. Content experts then checked each item for clarity, rigor, content accuracy, and appropriate matching to the intended learning outcomes. Additional Pathway faculty members also reviewed the items with these criteria in mind. Next, a team at UCLA with expertise in language and literacy development reviewed the items to ensure that they were appropriately written for the range of language and reading abilities within our Pathways population. Last, there was a final review by a measurement expert.

Administration to Comparison Sample

Before using any items on the summative assessments, Carnegie ensured their technical quality by field testing all items with a sample of individuals comparable to those who would encounter the items in the summative assessments. Note that the primary purpose for gathering these item testing data was to support the development and refinement of the assessments through psychometric analyses. Thus Carnegie contracted with Luth Research who recruited and administered the items to a comparable sample.

To form a comparison sample, Luth Research screened its pool of users for those who were qualified to complete the items and offered the users a small monetary reward as compensation. Luth Research filtered potential survey completers to select those who best approximated the characteristics of the students with whom operational use was intended. For our purposes, members of the comparison sample had to meet the following criteria:

- 1) They reported their age in the range of 18-30
- 2) They reported their highest level of education as 'some college' or 'completed college'
- 3) For the question "During your time in college, which, if any, of the following courses did you take for at least 1 semester?", they indicated they had taken statistics (for Statway comparison) or mathematics (for Quantway comparison).

Drawing on the pool of draft items, we prepared forms for administration to the comparison sample. Each form contained approximately 60-70 items. We chose 60-70 items per form to maximize efficiency and minimize 'burnout.' Luth Research then administered each form to at least 500 individuals who qualified for the comparison sample.

During the first two years of the Pathways, Luth administered five forms of Statway items and two forms of Quantway 1 items to a total of 3,533 members of the comparison sample. For Quantway, this report focuses only on Quantway 1 since complete comparative data from Quantway 2 are not available.

Item Validation

Luth Research cleaned and sent all item test data to Carnegie. We then performed psychometric analyses on all items. We performed Rasch analysis, based on item response theory, to:

- examine the reliability among items;
- identify items that are misfit (items whose behavior does not conform the overall structure of the exam);
- identify items that have problematic response patterns; and
- establish the difficulty levels for each item.

This analysis also allowed misfitting students (such as those who randomly guessed at items or had a disingenuous response pattern, such as selecting 'C' for every problem) to be identified and filtered out of the analyses. Following these analyses, we added those items that functioned well psychometrically to an item bank from which we generated the operational forms of the summative assessments according to carefully constructed content specifications.

When Luth administered two forms in parallel, we embedded a number of 'anchor items' on both forms. We used anchor items to perform psychometric analyses on all items and persons in terms of a common metric. This helped control for any potential differences between groups of the comparison sample who completed separate forms. This process also generated more reliable item estimates and allowed us to create an equated item bank. We anchored between 11 percent and 42 percent of generated items during our various rounds of administration to members of the comparison sample. We anchored the smaller percentage across the first two forms in fall 2011, but then elected to anchor higher percentages of items as the assessment system grew and improved. The percentage was also higher in later rounds since we anchored items from previous forms to put new items on the same scale as previously validated items. We further describe this process in an upcoming technical report (see Strother & Yamada, in preparation).

Assessment Assembly and Review

The operational forms of the common assessments were approximately 40-item measures of student knowledge and skill. The Pathways leaders, along with a core group of expert advisors, selected which learning outcomes to target on the assessments. The committee felt the selected learning outcomes represented a set of core competencies at an appropriate level of rigor that spanned the breadth of the content in the course. Carnegie's measurement specialist selected from the pool of validated items to match these specifications. The specialist selected items with varying levels of difficulty and good psychometric properties. Once we assembled an assessment, we sent it to select faculty members who reviewed the assessment to detect any last minute issues. Since the curriculum was improving continuously and since items with flaws could make it through even this extensive vetting process, a small percentage of items were eliminated or adjusted during this last review.

Summative Assessment Administration

All Statway students take a 'Mid-Pathway Assessment' at the end of the first term and an 'End-of-Pathway Assessment' at the end of the second term. Similarly, students in Quantway 1 take a 'Summative Assessment' at the end of the course. We create a new assessment for each of these benchmark points every year. For example, students who began Statway in fall 2012 had a different Mid-Pathway Assessment than those that began the Pathway in fall 2011. However, up to 40 percent of items on each assessment are previously used so we can statistically equate all assessments. Institutions that implement either Pathway sign a Memorandum of Agreement with Carnegie that commits participation in the administration of the summative assessment. This allows Carnegie to gather data from every classroom across all participating faculty and institutions.

We provided the assessments to Pathways faculty along with an answer sheet. We also provided guidelines for administration to faculty members to ensure uniform testing conditions to make certain the consistency and validity of the data. For example, the exam should be proctored, completed individually, and counted as part of the course grade to maintain reasonable security and ensure a good faith effort. Additionally, faculty members received a form to describe any deviations from the assessment or administration procedures prescribed. Carnegie's assessment specialist then decided if any aberrations warranted that the data be excluded from future Pathway-wide analyses. Two researchers from Carnegie independently entered all students' responses into a spreadsheet. We compared these files and rectified all discrepancies, compiling all data into one database.

COMPARING PATHWAYS STUDENTS TO THE COMPARISON SAMPLE

Comparative Analyses: Goal and Limitations

The analyses below explored whether the Pathways students attained similar levels of knowledge and skill as college students who have taken other mathematics or statistics courses. The analyses compared the knowledge of Pathways students at the end of each course to that of the comparison sample who had taken at least one mathematics or statistics course while in college.

The analyses had several limitations that one should consider when interpreting the results. The explicit purpose of collecting the comparison data was to develop and refine the assessments. The ability to compare the performance of Pathways students and the comparison sample on each item was an ancillary benefit of this process. The comparison sample was self-selecting and received compensation for their efforts. Monetary rewards for completion may have affected how carefully and thoughtfully the comparison sample completed each item. There was also lag time, potentially as long as eight or nine years, between completing the comparable mathematics or statistics course and taking the assessment items for the comparison sample. The lag time was limited by using a restricted age range, but we could not determine precise lag.

Data Sources

We analyzed Pathways students' performance against the comparison sample's performance across the Pathways' first two academic years. This report includes data collected from fall 2011 through spring 2013. The data came from two sources:

Comparison Sample

As described above, Carnegie contracted with Luth Research who administered a total of seven forms of summative assessment items to 3,533 field test participants. This comparison sample excluded field test participants who either submitted incomplete forms or for whom the click records from the online platform administration suggested that they were completing the items too quickly to have even read them fully. Luth dropped approximately a third of the field test participants for these reasons.

As required to qualify for survey completion, all members of the comparison sample were between 18 and 30 years of age, reported their highest level of education as 'some college' or 'completed college', and indicated they had taken statistics (for Statway comparison) or mathematics (for Quantway comparison) during their time in college.

Table 1 shows summary statistics for their reported highest level of education. This information is limited since we do not know the exact types of colleges or programs in which members of the comparison sample enrolled.

Table 1

The highest level of education reported by the 3,533 members of the comparison sample.

	Statway Comparison Sample	Quantway Comparison Sample
Some College	40.6%	46.8%
Completed College	59.4%	53.2%

Table 2 displays summary statistics for age and other demographic data for the comparison sample and Pathways students. The Pathways students had a higher percentage from minority groups. The Pathways students more frequently grew up in homes where the language used was not English-only and had lower maternal education (e.g. 30 percent and 34 percent of Statway and Quantway students respectively reported that their mothers had a college degree compared to 46 percent of the comparison sample). The two groups did have comparable makeups in terms of gender.

Table 2

Demographic data for Statway and Quantway students and members of the comparison sample.

	Statway	Quantway	Comparison Sample
<i>N^a</i>	2,630	1,820	1,031
<i>Sex</i>			
Female	59.8%	62.8%	68.1%
Male	40.2%	37.2%	30.1%
<i>Age^b</i>			
Mean	27.6	24.6	24.6
S.D.	10.9	9.7	3.5
<i>Race</i>			
Hispanic	32.7%	11.9%	11.3%
Caucasian	31.7%	46.7%	62.6%
African American	24.3%	34.7%	7.7%
Asian	5.3%	2.5%	10.6%
American Indian/Alaskan Native	0.5%	0.1%	0.5%
Pacific Islander	1.2%	0.0%	0.2%
Other	0.8%	2.4%	0.6%
Multiple	3.5%	1.7%	6.6%
<i>Home Language Growing Up</i>			
English only	58.6%	72.4%	77.2%
English and another language	29.9%	18.2%	16.8%
A non-English language only	11.5%	9.5%	6.0%
<i>Maternal Education</i>			
Less than high school	14.8%	11.8%	8.4%
High school graduate or GED	28.6%	29.9%	12.9%
Some college but no degree	26.3%	24.2%	32.6%
2-year college degree	10.6%	12.7%	11.6%
4-year college degree	13.6%	13.8%	24.5%
Graduate or professional degree	6.1%	7.6%	10.0%

^a Pathways data reflect all students in our analytic samples from the first two years (Strother et al., 2013; Van Campen et al., 2013). For this comparison, we collected detailed demographic data from 1,031 Statway comparison sample members who completed one of two surveys in fall 2013. This data was not collected from the comparison sample prior to fall 2013.

^b Age was collected from all comparison sample members who completed any of the seven forms described in this report (n=2530 for Statway; n=1003 for Quantway). Data were aggregated since comparison sample members completing each form were similar.

Pathways Students: Summative Assessments

Over 3,000 different students took a summative assessment for at least one term during the first two years of the Pathways. Statway launched in fall 2011, so four semesters of Mid-Pathway Assessment data were available for analysis: fall 2011, spring 2012, fall 2012, and spring 2013. Data from the End-of-Pathway Assessment were available for the spring terms of both years. Quantway 1 launched in spring 2012, so three semesters of data were available: spring 2012, fall 2012, and spring 2013.

Pathways Students: Grades

Following every term, institutional researchers at participating colleges provided Carnegie with the final course grade for each student in the Pathways. Since the assessments were required to count as part of the course grade, we also collected the percentage of students' grade that was accounted for by the summative assessment starting in fall 2012.

Analytic Methodology

We provide below descriptive analyses of the performance of the Pathways students and the comparison sample on the summative assessments. We also examined the relationship between students' grade and their performance on the summative assessments.

Descriptive Analyses

One purpose of these analyses was to quantify and compare the performance of Pathways students to the performance of a comparison sample on the summative assessment items. For each item on each Pathways summative assessment, we determined the percent of Pathways students and the comparison sample who answered that item correctly. We aggregated these data across the items that comprised each summative assessment². For example, for the fall 2011 Mid-Pathway Assessment, we calculated the average percent of correct responses across all 44 of the assessment items.

We also wanted to compare how Pathways students and the comparison sample performed on specific topical content within the broader domains. To accomplish this, we aggregated the item-level results at the module level. The Statway curriculum includes 12 modules and Quantway 1 includes 4 modules that group learning outcomes into broader topical content areas. Appendix B includes information about each module and Appendix C includes the descriptive results at the module level.

We also wanted to determine if the summative assessments were consistent with faculty members' overall assessment of student performance in the course. We used grades as the faculty members' overall assessment, which typically included graded homework, quiz results, faculty members' judgments, and other faculty-developed tests. We performed correlational analyses to examine the relationship between Pathways students' grade and their summative assessment score. Since the

² A few items were significantly altered after they were administered to the comparison sample due to critical feedback during the last round of faculty review. Data from these items could not be fairly compared, so these items were excluded from the analyses.

summative assessments constituted a variable portion of the student's final grade, we also computed partial correlations to control for the percent of students' grade that was based on the summative assessment. In addition, as a further test, we ran a hierarchical linear model (HLM) analysis with students' assessment scores predicting their grade at level 1 and the percent of students' grade accounted for by the summative assessment, as reported by each faculty member, as a level-2 predictor.

RESULTS

Descriptive Analyses

Pathways versus Comparison Sample

Pathways students consistently performed equal to or higher on the summative assessments in relation to the comparison sample (see Table 3). For example, Table 3 shows that Statway students performed, on average, 4.9 percent higher across the items used on the fall 2011 Mid-Pathway Assessment. In fact, the Pathways students demonstrated a higher percent of correct responses, compared to the comparison sample, on every summative assessment in the Pathways' first two academic years.

We restricted the comparison group for the Statway Mid-Pathway Assessments to a subsample because we found a significant relationship between age and performance within this group, where the younger half of the sample (ages 18 to 24) performed at a higher level than the older half of the sample (ages 25 to 30). This may have been due to lag time between the time of their exposure to a statistics course in college and that of completing these items. We chose to restrict the ensuing comparison analysis with this group to include the younger members of the sample only to help control for this lag and create a more valid comparison sample. We used all members of the comparison sample in the other comparisons because we found no effect of age.

Table 3

Compares the Pathways students' and comparison sample's percent of correct responses across items on each Pathways summative assessments.

Term	# of Items ^a	Pathways Students		Comparison Sample		Pathways Difference ^d
		N	% Correct ^b	N ^c	% Correct ^b	
Statway Mid-Pathway Assessments						
Fall 2011	44	829	61.0	214+	56.2	+4.9
Spring 2012	44	68	63.4	214+	56.3	+7.2
Fall 2012	35	686	62.3	214+	58.8	+3.5
Spring 2013	35	358	62.9	214+	58.8	+4.1
Statway End-of- Pathway Assessments						
Spring 2012	39	565	59.9	500+	39.1	+20.8
Spring 2013	32	671	62.3	500+	44.9	+17.4
Quantway 1 Assessments						
Spring 2012	37	372	65.8	500+	50.0	+15.8
Fall 2012	39	469	63.7	500+	50.5	+13.2
Spring 2013	37	498	65.2	500+	53.6	+11.7

^a Items that were improved during the last faculty review are not included to facilitate exact comparison.

^b Since multiple forms were used, the standard deviations were not reported; instead, we will use the Rasch person estimates for inferential comparisons (see Strother & Yamada, in preparation).

^c Assessment items were pulled from multiple forms administered to the comparison sample, so the N varies slightly by item. All forms were completed by at least 500 comparison sample members. The N for Statway Mid-Pathway Assessments is lower since only comparison sample members aged 18-24 were used to control for the discovered lag effect.

^d Percentage points.

Pathways students also consistently performed higher on the items targeting each module within the summative assessments. Appendix B displays the main topics of the modules. Appendix C displays the performance of the Pathways and comparison sample on the items targeting these modules across all summative assessments.

Relation to Students' Grades

Students' grades were determined by each individual faculty member and typically included graded homework, quiz results, faculty members' judgments, and other faculty-developed tests. As part of participation in the Networked Improvement Community, we also asked faculty to include performance on the summative assessment as part of their grading system. Each faculty member was free to choose the weighting of the summative assessment towards students' final grade. We collected the amount of weighting chosen by faculty beginning in fall 2012. Table 4 displays the mean and range of weighting faculty used in their courses. We explored the effect of this weighting in the analyses below.

Table 4

Percent of students' grade that was accounted for by the summative assessment, averaged across faculty.

Term	Faculty	Mean	SD	Minimum	Maximum
Statway Mid-Pathway Assessments					
Fall 2012	36	19.0%	6.2%	5.0%	30.0%
Spring 2013	17	18.0%	7.9%	2.9%	30.0%
Statway End-of-Pathway Assessments					
Spring 2013	39	15.5%	6.1%	3.0%	30.0%
Quantway 1 Assessments					
Fall 2012 ^a	28	19.9%	3.9%	5.0%	25.0%
Spring 2013	33	20.3%	2.0%	17.0%	25.0%

^a These summary statistics exclude one outlier that reported 67 percent. However, the outlying data were included in the partial correlation and HLM analyses discussed below.

We found that the grades that Pathway students received in their courses were significantly related to the corresponding summative assessment (see Table 5).

Table 5

Correlation of Pathways students' summative assessments to their grade (on a 4-point scale) at the end of the term.

Term	N	Correlation to Students' Grade
Statway Mid-Pathway Assessments		
Fall 2011	659	.61**
Spring 2012	25	.44*
Fall 2012	671	.57**
Spring 2013	342	.64**
Statway End-of-Course Assessments		
Spring 2012	422	.60**
Spring 2013	653	.49**
Quantway 1 Assessments		
Spring 2012	252	.60**
Fall 2012	452	.66**
Spring 2013	434	.66**

*p < .05 **p < .001

These significant relationships persisted after controlling for the percentage of students' grade that was accounted for by the summative assessment. We performed partial correlation analysis on all data from fall 2012 and spring 2013 that controlled for the weighting of the assessment. All five correlations remained significant with nearly identical magnitude; hence we reported the simple bivariate correlations here.

These relationships again persisted when we controlled for the percentage of students' grade that was accounted for by the summative assessment in two-level HLM models. We ran HLM analyses with students' assessment scores predicting their grade at level 1 and the percent of students' grade accounted for by the summative assessment as the level-2 predictor. Students' assessment scores were a significant predictor in each analysis, as expected, and the weighting of the assessment did not have a significant effect on grade.

These results show that faculty members' overall assessments of student performance in the course were consistent with the summative assessments. This indicates that successful students who received higher grades were genuinely achieving higher levels of knowledge, as measured by the independent assessment.

CONCLUSIONS

The Pathways have had tremendous success in their first two years (Strother et al, 2013; Van Campen et al, 2013). Students' successful completion rates have been consistently near or slightly above 50 percent, which is approximately triple the success rate of the typical community college program in half of the time.

This report demonstrated that Pathways students are not just completing their path from developmental through college-level mathematics faster, but they are doing so while mastering the embedded conceptual knowledge at an equal or higher level as compared to other college students who have taken college-level mathematics or statistics courses. On virtually every comparison across the Pathways summative assessments, the Pathways students consistently performed at or above the level of the comparison sample.

On balance, it is difficult to assess the precise equivalence of the Pathways students and comparison sample. We designed test items to align with Pathways content and we administered the assessments at the conclusion of the course, which may have favored results from Pathways students. In addition, members of the comparison sample took these items some time well after course completion. In terms of the first consideration—the content of the items—as shown by the sample items in the appendix, these are the kinds of items that one might easily find in any test of college-level statistics and mathematics and are validated as such by the numerous expert reviews of program outcomes and assessment content built into the development process. So there is little reason to believe that the test items especially favored Pathways students. The second consideration, time differences between course completion and test administration, is potentially significant, although it is uncertain as to the direction of any possible bias. Members of the comparison sample could forget the mathematics they learned earlier or have gone on to have subsequent experiences that functioned to consolidate this knowledge. However, we controlled for this effect by restricting the comparison sample to ages 18-30 and even further to ages 18-24 when there existed any effect of age on performance.

One could also question whether the incentives for performance were equivalent in both groups. For Pathways students the assessment counted as part of their grade; members of the comparison sample were offered a very modest stipend for completion. One could argue that the incentives were likely greater for Pathways students. Counterbalancing this, the analyses excluded members of the comparison sample who did not complete the assessment or whose scores suggested possible random guessing. We would expect the latter to advantage the comparison sample.

The Pathways students' level of knowledge following each term is also reflected by their general success in the course. Students' performance on the end-of-term summative assessments was significantly correlated to their grades in every term. This demonstrates that the knowledge measured by the summative assessment does indeed reflect faculty members' overall evaluation of student performance in the course. The results provide further evidence that Pathways students are not just receiving high grades and successfully completing the Pathways at a high rate, but that grades in the courses are reflective of actual learning.

Taking all of this into account and being conservative in drawing inferences, we conclude that these data suggest that Pathways students did at least as well as students who had previously taken college-level statistics and mathematics at other institutions of higher education. When combined with evidence about much higher success rates in the Pathways, as noted above, this provides one more piece of evidence supporting a conclusion about the efficacy of the Pathways in advancing mathematical learning and success for students who traditionally have found this domain uninteresting, irrelevant, and extremely difficult to engage.

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APPENDIX A

Sample Summative Assessment Items: Statway

Learning Outcome: Given the description of a statistical study, determine if it is an observational study or an experiment

A researcher conducted a study to determine if aspirin reduces the chance of a heart attack. He randomly assigned 250 patients to take aspirin every day and 250 patients to take a placebo every day. After a certain length of time he reported the percentage of heart attacks for the patients who took aspirin every day and for those who did not take aspirin every day.

Is this an observational or an experimental study and why?

- a. The study is observational because it involves random assignment of treatments to patients.
- b. The study is observational because it involves observing who had heart attacks.
- c. The study is experimental because it involves random assignment of treatments to patients.
- d. The study is experimental because it involves observing who had heart attacks.

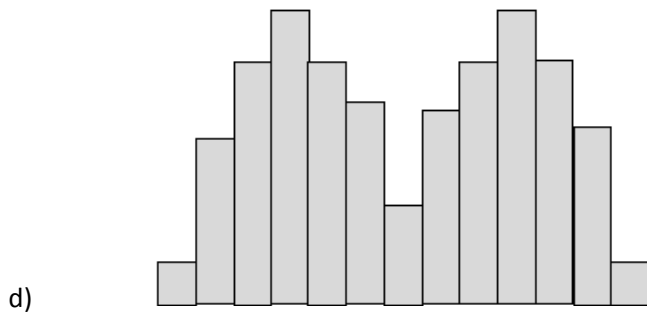
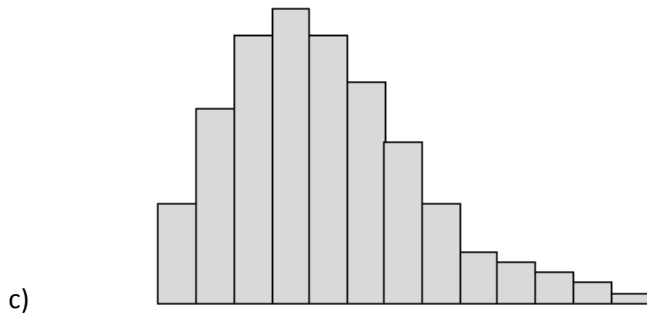
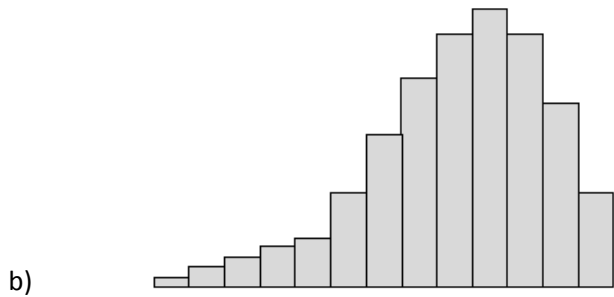
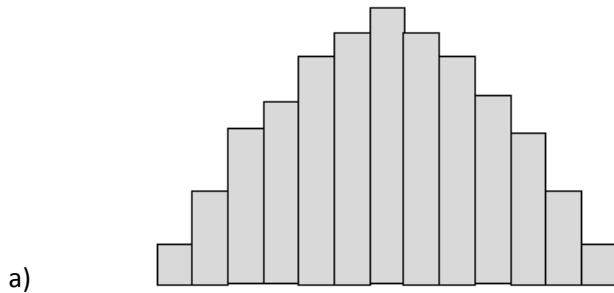
Learning Outcome: Recognize hypothesis testing situations where a chi-square goodness-of-fit test can be used to answer a question of interest

Which of the following scenarios would be an appropriate use of a chi-square goodness-of-fit test?

- a. Researchers want to determine if males spend more on video games than females.
- b. Researchers want to determine if more males eat ice cream than females.
- c. Researchers want to determine if a six-sided die is fair, or has an equal chance of landing (16.7%) on each number.
- d. Researchers want to determine if more females prefer to eat their ice cream in a cup than males.

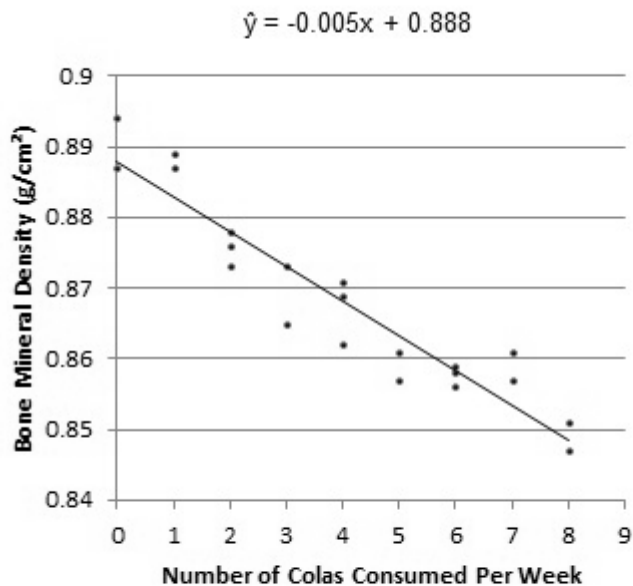
Learning Outcome: Explain how the relative values of the mean and median are related to the shape of the data distribution

Which histogram MOST LIKELY represents data with a mean that is less than the median?



Learning Outcome: Interpret (in context) the slope of the regression line.

Studies have been done to determine if there is a link between the number of colas (a type of carbonated beverage) that American women consume each week and their bone mineral density in g/cm^2 . The researcher asked women how many colas they consume each week. The researcher also measured the women's bone mineral density. The researcher recorded her data in a scatterplot. The following scatterplot shows the relationship between the number of colas consumed per week and the bone mineral density along with the least squares regression line.



Source: Based on data obtained from Katherine Tucker, et al. "Colas, but not other carbonated beverages, are associated with low bone mineral density on older women: The Framingham Osteoporosis Study." *American Journal of Clinical Nutrition* 2006

The slope of the regression line indicates that for every additional cola consumed per week, the predicted bone density:

- a) decreases by $.005 \text{ g}/\text{cm}^2$.
- b) increases by $.005 \text{ g}/\text{cm}^2$.
- c) decreases by $.888 \text{ g}/\text{cm}^2$.
- d) increases by $.888 \text{ g}/\text{cm}^2$.

Learning Outcome: *Given a two-way table summarizing a bivariate categorical data set, describe (in context) the relationship between the two variables used to construct the table in terms of independence or lack of independence.*

Researchers interested in the smoking habits of college students conducted a study. The following table shows the data researchers collected:

	Male	Female	Total
Smoker	260	78	338
Non-smoker	329	333	662
Total	589	411	1000

What do the conditional proportions of male smokers and female smokers tell you about the smoking habits of college students?

- Female college students are less likely to be smokers.
- Male college students are less likely to be smokers.
- Male and female college students are equally likely to be smokers.
- Cannot determine from the information given.

Sample Summative Assessment Items: Quantway

Learning Outcome: Estimate the percentage of a given number and the percentage one number is of another number

The US federal budget in 2011 was approximately \$3.360 trillion. Approximately 1.5% of the budget was spent on foreign aid. Which of the following is the best estimate for the amount of the US federal budget that was spent on foreign aid?

- a. \$34 billion
- b. \$48 billion
- c. \$336 billion
- d. \$480 billion

Learning Outcome: Compute absolute and relative changes

In January 2011, Sam made a new year's fitness goal. He decided he wanted to be able to work out a lot longer on the elliptical trainer. When he started, in January, 2011, he could only spend 20 minutes on the elliptical trainer before he needed to rest. By July, 2011, he was able to work out for 35 minutes on the elliptical trainer before he needed to rest. Which of the following expressions would give the *absolute* change in his workout time?

- a. 75%
- b. 43%
- c. 2.5 minutes per month
- d. 7 minutes per year
- e. 15 minutes

Learning Outcome: Read and use information presented in a two-way table

Suppose 3200 women received a mammogram to test for breast cancer. The mammogram provides test result information about whether the women do or do not have breast cancer. The table below summarizes the mammogram results. The table shows how often the mammogram correctly detected the presence of breast cancer in the 3200 women.

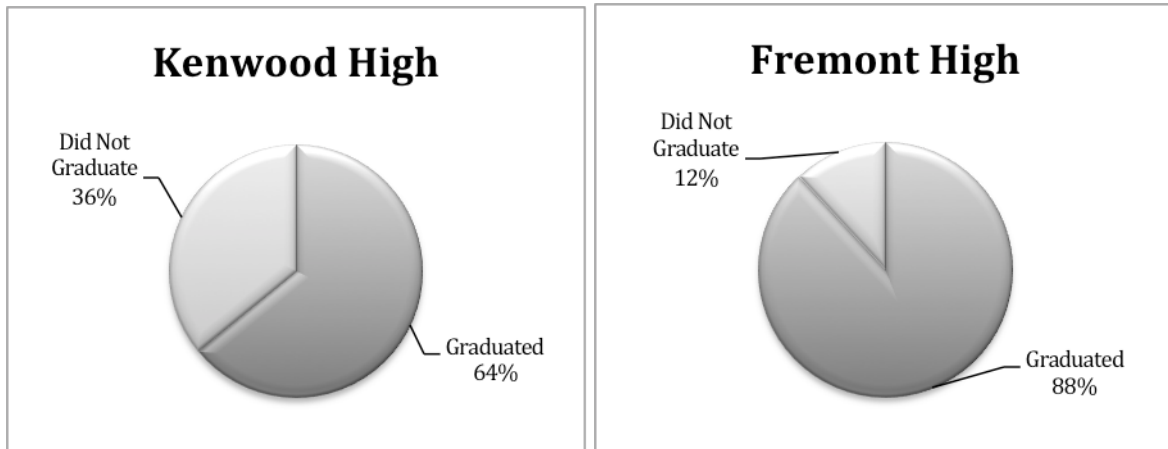
	Women with Breast Cancer	Healthy Women (no Breast Cancer)	Total
Positive test result	11	5	16
Negative test result	17	3167	3184
Total	28	3172	3200

If a woman gets a positive mammogram test result, what is the chance she has breast cancer?

- a. 0.3%
- b. 31%
- c. 40%
- d. 57%
- e. 69%

Learning Outcome: Understand and use graphical displays: know that the reference value must be known to fully understand a pie graph

The following two pie graphs display graduation rates for 2012 for two different high schools. At Kenwood High, there were 1397 seniors that year, and at Fremont High, there were 643 seniors that year.



Which of the following statements is true about the students who graduated from the two high schools?

- a. Kenwood High had more graduates, but a lower percentage of students graduated.
- b. Kenwood High had more graduates, and a higher percentage of students graduated.
- c. Fremont High had more graduates, but a lower percentage of students graduated.
- d. Fremont High had more graduates, and a higher percentage of students graduated.

Learning Outcome: Use the compound interest formula for different compounding periods

Chin has put \$5000 into a Certificate of Deposit (CD) that earns a 1.8% Annual Percentage Rate (APR) compounded quarterly. The equation for the amount the CD is worth is:

$$A = P\left(1 + \frac{r}{n}\right)^{n*t}$$

where:

A = amount the CD is worth

P = principal (initial amount invested)

r = Annual Percentage Rate (as a decimal)

t = time in years

n = the number of compounding periods in a year

How much money will Chin have at the end of 5 years?

- a. \$5,045
- b. \$5,470
- c. \$12,059
- d. \$25,453

APPENDIX B

Statway Modules (titles)

- Module 1: Types of Statistical Studies and Producing Data
- Module 2: Summarizing Data Graphically and Numerically
- Module 3: Examining Relationships: Quantitative Data
- Module 4: Non-Linear Models
- Module 5: Relationships in Categorical Data with Intro to Probability
- Module 6: Probability and Probability Distributions
- Module 7: Linking Probability to Statistical Inference
- Module 8: Inference for One Proportion
- Module 9: Inference for Two Proportions
- Module 10: Inference for Means
- Module 11: Chi-Square Tests
- Module 12: Mathematical Models

Quantway 1 Modules (main topics)

- Module 1: Large numbers, estimation and calculation, percentages and ratios
- Module 2: Using ratios, percentages, graphical displays, measures of central tendency
- Module 3: Making conversions, geometric reasoning, formulas and algebraic expressions, creating and solving equations
- Module 4: Linear and exponential models

Quantway 2 Modules (main topics)

- Module 5: Large numbers, estimation and calculation, percentage and ratio, graphical displays (in depth)
- Module 6: Probability and measures of central tendency (in depth)
- Module 7: Linear and exponential models (in depth)
- Module 8: Other types of modeling

APPENDIX C

Table 6

Compares the Statway students' and comparison sample's percent of correct responses across items on each module on the Mid-Pathways summative assessments.

	# of Items ^a	Fall 2011				Pathways Difference ^d	# of Items ^a	Spring 2012				Pathways Difference ^d
		Statway ^b	N ^c	Comparison ^b	N			Statway ^b	N	Comparison ^b	N	
Module 1	7	58.3	829	59.8	214+	-1.5	7	60.3	68	59.8	214+	+0.5
Module 2	9	66.0	829	60.7	214+	+5.3	9	68.6	68	60.7	214+	+8.0
Module 3	12	61.4	829	54.3	214+	+7.1	12	62.5	68	54.3	214+	+8.2
Module 4	7	51.8	654	50.0	214+	+1.8	7	58.2	68	50.0	214+	+8.2
Module 5	2	68.5	623	50.5	214+	+18.0	2	69.9	68	50.5	214+	+19.4
Module 6	7	63.8	465	57.7	214+	+6.1	7	64.9	68	57.7	214+	+7.2

^a Items that were improved during the last faculty review are not included to enable exact comparison.

^b Percentages.

^c The N varies since faculty were allowed to exclude items that targeted materials they did not cover and students occasionally skipped items.

^d Percentage points.

	# of Items ^a	Fall 2012				Pathways Difference ^d	# of Items ^a	Spring 2013				Pathways Difference ^d
		Statway ^b	N ^c	Comparison ^b	N			Statway ^b	N ^c	Comparison ^b	N	
Module 1	9	58.9	686	60.2	214+	-1.2	9	59.0	358	60.2	214+	-1.1
Module 2	7	56.9	686	51.5	214+	+5.4	7	57.2	358	51.5	214+	+5.7
Module 3	7	69.3	686	63.9	214+	+5.4	7	68.1	358	63.9	214+	+4.2
Module 4	5	75.8	686	70.3	214+	+5.5	5	75.5	358	70.3	214+	+5.2
Module 5	1	30.6	565	31.5	214+	-0.9	1	52.8	358	31.5	214+	+21.3
Module 6	6	59.5	404	54.2	214+	+5.4	6	60.4	315	54.2	214+	+6.2

^a Items that were improved during the last faculty review are not included to enable exact comparison.

^b Percentages.

^c The N varies since faculty were allowed to exclude items that targeted materials they did not cover and students occasionally skipped items.

^d Percentage points.

Table 7

Compares the Statway students' and comparison sample's percent of correct responses across items on each module on the End-of-Pathways summative assessments.

	# of Items ^a	Spring 2012				Pathways Difference ^d	# of Items ^a	Spring 2013				Pathways Difference ^d
		Statway ^b	N ^c	Comparison ^b	N			Statway ^b	N	Comparison ^b	N	
Module 1	0	-	-	-	-	-	1	53.4	671	48.3	500+	+5.1
Module 2	1	73.6	454	60.8	500+	+12.8	2	62.7	671	56.3	500+	+6.4
Module 3	1	48.2	444	44.2	500+	+4.0	2	77.0	671	65.8	500+	+11.2
Module 4	2	72.4	463	53.3	500+	+19.2	2	69.4	671	65.7	500+	+3.7
Module 5	1	61.4	425	47.3	500+	+14.1	0	-	671	-	500+	-
Module 6	3	58.8	522	46.3	500+	+12.5	3	66.1	671	46.0	500+	+20.1
Module 7	1	52.3	555	16.8	500+	+35.5	2	61.5	671	22.0	500+	+25.5
Module 8	9	57.7	565	37.2	500+	+20.5	8	69.6	671	45.7	500+	+23.9
Module 9	1	57.3	440	16.8	500+	+40.5	2	68.0	671	30.0	500+	+38.0
Module 10	6	58.0	450	34.3	500+	+23.7	6	44.8	671	32.3	500+	+12.6
Module 11	3	55.3	218	33.7	500+	+21.5	1	39.9	671	36.0	500+	+3.9
Module 12	5	65.9	411	43.6	500+	+22.3	3	69.2	671	51.9	500+	+17.3

^a Items that were improved during the last faculty review are not included to enable exact comparison.

^b Percentages.

^c The N varies since faculty were allowed to exclude items that targeted materials they did not cover and students occasionally skipped items.

^d Percentage points.

Table 8

Compares the Quantway 1 students' and comparison sample's percent of correct responses across items on each module on the summative assessments.

	# of Items ^a	Spring 2012				Pathways Difference ^d	# of Items ^a	Fall 2012				Pathways Difference
		Quantway ^b	N ^c	Comparison ^b	N			Quantway ^b	N	Comparison ^b	N	
Module 1	12	70.7	372	60.4	500+	+10.3	11	65.5	469	61.8	500+	+3.7
Module 2	6	62.3	372	46.8	500+	+15.6	7	54.8	469	47.2	500+	+7.6
Module 3	5	62.8	358	39.0	500+	+23.8	7	62.6	469	43.2	500+	+19.4
Module 4	14	64.1	372	46.3	500+	+17.8	14	67.3	469	46.9	500+	+20.4

^a Items that were improved during the last faculty review are not included to enable exact comparison.

^b Percentages.

^c The N varies since faculty were allowed to exclude items that targeted materials they did not cover and students occasionally skipped items.

^d Percentage points.

	# of Items ^a	Spring 2013				Pathways Difference ^c
		Quantway ^b	N	Comparison ^b	N	
Module 1	10	71.4	498	57.1	500+	+14.4
Module 2	6	64.6	498	50.4	500+	+14.2
Module 3	7	55.7	498	57.0	500+	-1.3
Module 4	14	65.8	498	50.7	500+	+15.1

^a Items that were improved during the last faculty review are not included to enable exact comparison.

^b Percentages.

^c Percentage points.



Carnegie Foundation
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