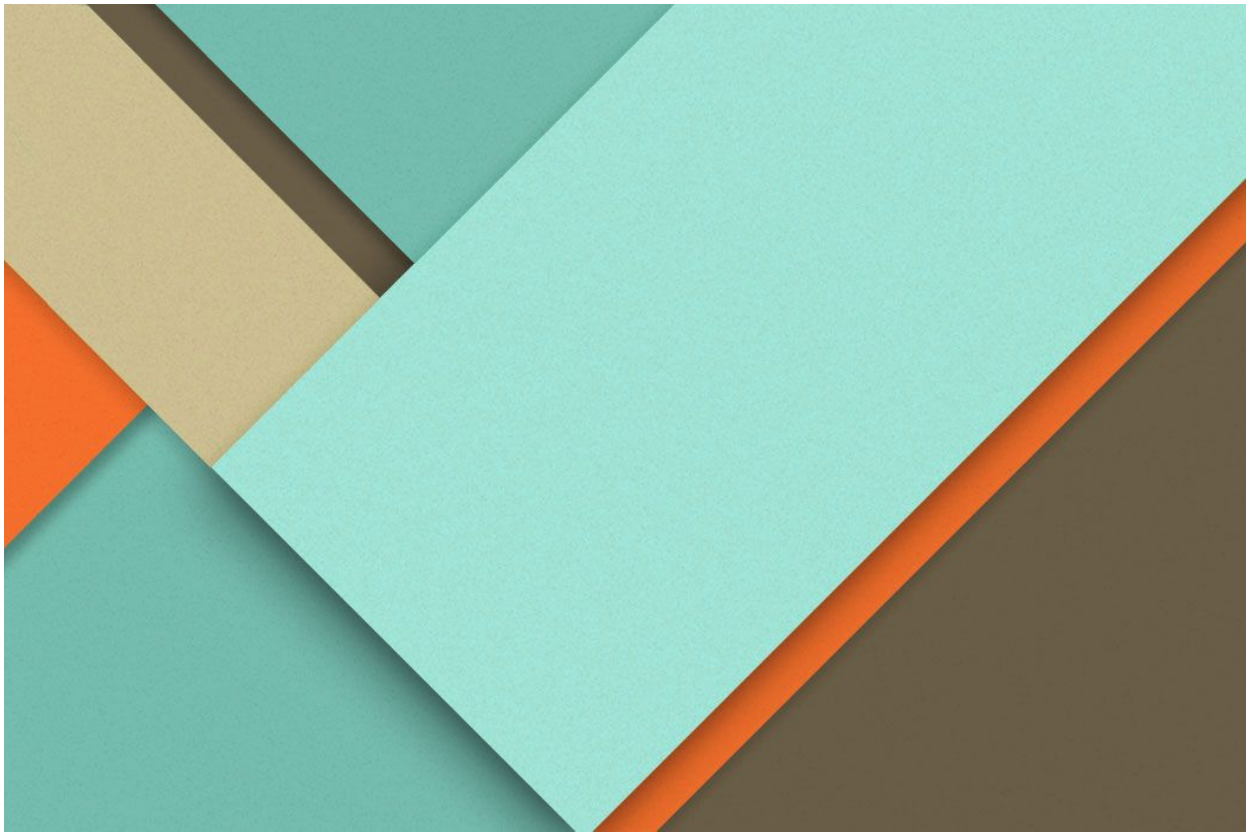

Baby, how do you sleep when you lie to me with stats?

A quantitative reasoning report

Harold Washington College Assessment Committee

September 2019

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Introduction

Recently, some members of the Harold Washington College Assessment Committee (HWCAC) attended an event at an educational institution which will remain unnamed. The keynote presenter was an administrator who showed a graph similar to Figure 1. We have removed the labels and changed the numbers a bit to hide the identities of the institution and the administrator, yet the basic characteristics are the same.

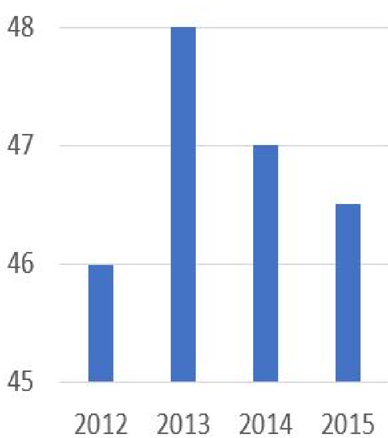

Figure 1. A generic time graph with a zoomed-in y-axis not starting at zero.

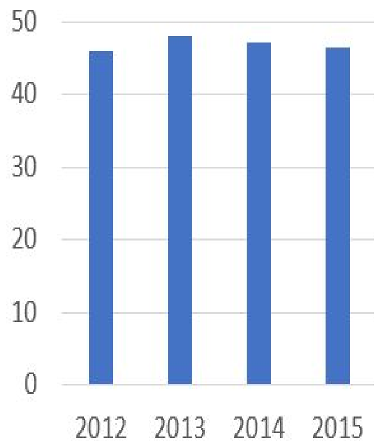

Figure 2. Same data as Figure 1 with y-axis starting at zero.

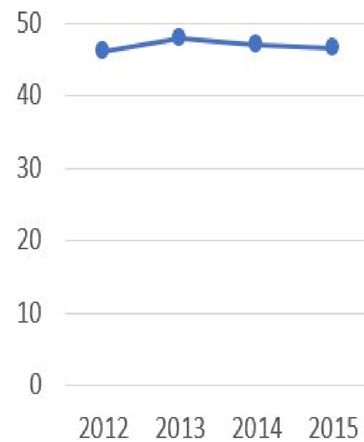

Figure 3. Same data as Figures 1 & 2 as a line graph with y-axis starting at zero.

A modification of the y-axis is a classic statistical trick designed to exaggerate either growth or decline. Consequently, when the presenter showing the graph emphasized the growth from 2012-2013, then compared the growth to the decline in the following years [without mention of the manipulation of the y-axis (i.e., y-axis = 45, not 0)], we noticed the modification of the y-axis. However, we guessed that most of the audience assumed the measure had tripled from 2012 to 2013. Yet the actual growth was only from 46 to 48, which is 2 out of 48 or about 4.17%.

To be fair, y-axis manipulation may be done for honest reasons to make the graph easier to read. Notice in Figure 2 how difficult it is to distinguish the heights of the bars. Turning the bar graph into a line graph may help a bit. Notice in Figure 3 that the slopes of the line may be easier to distinguish than the heights of bars. Yet perhaps the best way to present this data is simply a table, as in Figure 4. Although perhaps not pretty, the table makes the data easy to read and free of potential misinterpretations.

Year	Amount
2012	46
2013	48
2014	47
2015	46.5

Figure 4. Simply the raw data for Figures 1, 2, and 3.

All of this made us think of Sam Smith (2019) singing about a fictional lover's dishonesty in the song, "Baby, how do you sleep when you lie to me" (timestamp 1:16). And we jokingly wondered, "how can someone sleep at night when they are purposefully dishonest with stats?" More importantly, though, we thought about the importance of teaching students to catch such a trick, and that made us happy that our recent general education assessment of quantitative reasoning had focused on statistics.

One of the many tasks of the HWCAC is to assess general education; it is a process which involves the following steps:

- Creating or reviewing a broad general education goal.
- Creating or reviewing specific s*tudent learning outcomes*.
- Formulating research questions.
- Finding an already-existing tool or develop a tool from scratch.
- Piloting the tool.
- Administering the tool to a representative sample of students.
- Analyzing the results.
- Making recommendations.
- Sharing those recommendations with various college stakeholders in order to support necessary change.

Our committee has assessed one general education goal per year for most years since 2003. We keep a cyclical calendar of what goals to assess, and the goal scheduled for 2017 was quantitative reasoning. We had first assessed quantitative reasoning in 2009 and created our own tool with a focus on percents and graphs. For 2017, we modified the 2009 tool to contain more emphasis on *statistical literacy*. Although statistical literacy is not defined consistently in statistics education circles, most authors agree that people with statistical literacy skills have the ability to interpret and critically evaluate data-based information and arguments that may be presented in various ways (such as tables, numeric summaries, graphs, etc.). Moreover, they have the ability to discuss their opinions regarding such statistical information. See Rumsey (2002) for a further discussion of statistical literacy goals.

We administered our tool to students in fall 2017 and collected a sample of 1128 through instructors volunteering their classes and students volunteering on their own. Broadly speaking, we found that all students, even those in STEM (science, technology, engineering, and mathematics) fields, struggle to explain why some statistical graphs may be misleading or why certain statistical methods are more appropriate for given real-life situations. Our main recommendation, therefore, is that *statistical literacy should become an integral part of student learning across the curriculum*.

Methodology

Our committee began this project by developing a *framework* in spring 2017, which included our broad general education goal, a definition of quantitative reasoning that we adopted from the Association of American Colleges and Universities (AACU), specific student learning outcomes aligned to the question numbers which can be found in the appendices, and research questions of interest. All of this is very similar to our 2009 frame with only minor updates.

General Education Goal

To use mathematics for computation, reasoning, and problem solving.

Definition

According to the AACU (2014), statistical literacy includes, “The application of basic mathematics skills, such as algebra, to the analysis and interpretation of real-world quantitative information in the context of a discipline or an interdisciplinary problem to draw conclusions that are relevant to students in their daily lives” (para. 7).

Student Learning Outcomes

Below are the student learning outcomes, and the numbers in parentheses refer to the assessment tool’s corresponding questions. Also see Appendix A.

The student will be able to…

1. Interpret mathematical models such as formulas, graphs, and tables. (2a, 2b, 5a, 5b, 5c)
2. Represent mathematical information symbolically, visually, numerically, and verbally. (3c)
3. Apply arithmetical, algebraic, geometric or statistical methods in order to solve problems. (3a, 3b, 4)
4. Estimate values with reasonable accuracy when exact calculations are impossible, impractical, or unnecessary. (2a)
5. Recognize and use connections within mathematics and between mathematics and other disciplines. (1, 2b, 3c)

Research Questions

1. What kind of attitudes towards mathematics do students have?

2. Do the number of completed courses (of any subject) correlate with performance on the content questions?
3. Do STEM-oriented students perform differently than non-STEM students? (STEM-oriented, roughly speaking, means taking many STEM classes. In essence, STEM-oriented students are those leaning toward a STEM career. See Appendix E for more on the precise definitions we used.)
4. What kinds of short answers do we get in questions 2b and 3c? How do these answers illustrate our students' ability to verbally explain their math reasoning?

Implementation

Throughout spring 2017, our committee used the above frame to develop a tool with the following outline:

- One multipart indirect question on math attitudes;
- Two multipart questions on statistical literacy, each including one part with an open-ended qualitative answer;
- One question on percentages;
- One multipart question on interpreting graphs.

We were especially interested to see the results of the two open-ended questions: 1 of them asking students to explain the effectiveness and honesty of a statistical chart, and the other asking students to compare different methods of calculating unemployment. (The full tool is found in Appendix A.)

In the summer of 2017, we piloted the tool with students (n=101) using a survey format in Google Forms. We asked students for feedback on the readability of the tool and the usability of the Google Form. There were no reported issues, so we administered the same tool in fall 2017.

Throughout the fall 2017 semester, we advertised the tool in various ways, including email and word of mouth, to students and instructors. Since we do not force students or instructors to participate, our sample was determined by voluntary participation. Our sample included 17.5% (n=1128) of the fall 2017 semester enrollment (n=6415) (CCC, 2017). We achieved the minimum sample size (n=915) for a standard 95% confidence interval with 3% margin of error for this population. Our sample was sufficient for standard statistical inference procedures. (More details about the sample size are given in Appendix D.)

Google Forms automatically tallied the results for the indirect math attitudes questions and the closed-ended math problems. The two open-ended qualitative questions required more careful ratings. We formed a group of five professor-raters, including 2 from the math department, 2 from the physical sciences department, and 1 from the biological sciences department. They first met together multiple times to form a rubric using sample answers, practice rating sample answers, and to norm their ratings. They then divided up the responses and scored them, one rater for each response. The raters finished their work in spring 2018 and were compensated for their time by the HWC administration with release from some of the mandatory hours of registering students during the week before the fall 2018 semester. (The full rubric is in Appendix B.)

Results

Indirect Assessment Questions

The first question was a five-part indirect assessment of attitudes towards math. Students specified their level of agreement with five different statements using a scale of *strongly disagree*, *disagree*, *agree*, or *strongly agree*. Interestingly, the 2 parts that were simply focused on math in the classroom had higher student agreement than the 3 parts focused on math's connection to other aspects of life. About 90% of students agreed that math problems often have many methods of solution, and 93% of students agreed that hard work results in success in math. Students' agreement was lower for statements about math's connection to career goals, other subjects, and current events, though still all 69% or higher. The rough results are shown below with the percentage of students answering *agree* or *strongly agree* for each statement. (More detailed results are shown in Appendix C.)

Questions	% Agree or Strongly Agree
1a.) There are often many ways to solve a math problem.	89.79%
1b.) If I work at it, I can do well in math.	92.72%
1c.) I need a good understanding of math to achieve my career goals.	75.61%
1d.) Math is an important tool to help me learn other subjects.	77.51%
1e.) Math helps me to understand current events and make intelligent decisions.	69.36%

Table 1. Percent of students answering agree or strongly agree for each indirect assessment question on the tool.

Direct Assessment Questions

The other questions were all direct assessment questions about various math skills. Of the 9 total parts of direct assessment questions, 7 were multiple choice. and 2 were open-ended requiring written explanations. The multiple choice questions each had a best answer that was quite clear, while the open-ended questions had certain qualitative aspects of a best answer that we were looking for. Below is a table showing the percentage of students giving the best answer for each question.

Questions	% Students Giving Best Answer
2a.) misleading graph, multiple choice	54.08%
2b.) misleading graph, open-ended explanation	16.93%
3a.) unemployment rate, multiple choice	65.08%
3b.) unemployment rate, multiple choice	62.79%
3c.) unemployment rate, open-ended explanation	37.59%
4.) percentages, multiple choice	51.97%
5a.) interpreting a graph, multiple choice	79.81%
5b.) interpreting a graph, multiple choice	82.18%
5c.) interpreting a graph, multiple choice	75.00%

Table 2. Percent of students giving best answer for each direct assessment question on the tool.

The following are notable findings from the results:

- The open-ended questions had the lowest percentage of students giving the best answer.
- Completing a large number of STEM classes (6 or more classes) did not appear to give students any advantage in explaining how the graph in question 2b was misleading.
- Completing a somewhat large number of Business-Economics classes (6 or more classes) did not appear to give students any advantage in explaining the differences in unemployment rate calculations in question 3c.
- Students who did not fit a STEM or Business-Economic profile (see the Student Profiles section of the appendices) did not appear to perform higher than others.
- The total number of classes taken (overall) did not appear to be related to performance.
- Students were strongest at interpreting graphs in question number 5. Yet it should be noted that these graphs had no purposeful misleading characteristics.

Reflections

The graph shown in question 2 of the tool, replicated below, uses a classic statistical trick of modifying the y-axis to make the difference in the data look more extreme.

Similar to the example in the introduction, people may misinterpret this graph to mean that the amount in 2015 is triple the amount in 2010. Yet this is a manipulation achieved by starting the y-axis at a higher value than zero. In fact, the 2015 amount of about 12,000 is 20% greater than the 2010 amount of about 10,000, which is a much smaller difference than 300%, or triple.

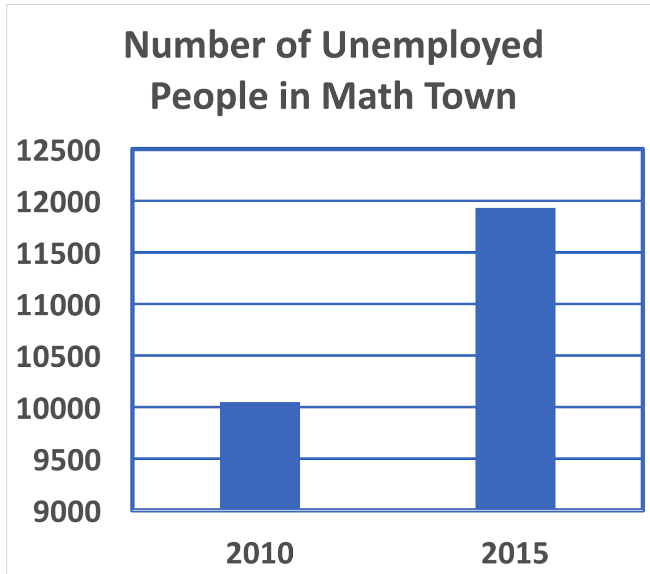

Figure 2. Sample graph about unemployment. Notice the zoomed-in y-axis.

Question 2b, which involved explaining the effectiveness of this graph, had the lowest percentage of students giving the best answer. Very few students, therefore, were able to recognize and explain the manipulation on the y-axis. David Spiegelhalter (2019) writes, “In an age in which data plays an ever-more prominent role in society, the ability to spot ways in which numbers can be misused, and to be able to deconstruct claims based on statistics, should be a standard civic skill” (para. 4). We must therefore teach students the basic methods that can be used to dishonestly display statistics, not so that they will be dishonest themselves but rather so that they will better catch and not be misled by such statistics in the future.

We were especially interested by the finding that STEM students struggled with these statistics questions about the same as other students. Upon reflection, however, we realized that many STEM students are led toward calculus and away from statistics. This is even true for one member of our committee who was strongly discouraged from taking a statistics class to supplement a masters program in pure math. Ironically, other non-STEM fields such as psychology and political science are more encouraged to take statistics.

We should also briefly mention our 2009 quantitative reasoning assessment, in which we found students similarly comfortable with interpreting graphs. We also found in 2009 that students were weakest in concepts of percents, which are foundational to the statistical concepts we focused on this time around.

Instructors of all fields may find helpful resources in *How to Lie with Statistics* by Darrell Huff (1954) and *Damned Lies and Statistics* by Joel Best (2001). More broadly, Marilyn

Frankenstein (1998) writes about how important it is to immerse mathematics teaching into the messiness of real life. She challenges students to look beyond calculations at how data is collected and how results are communicated. Finally, there are two well-supported open source statistics textbooks called OpenIntro Statistics (Diez, Cetinkaya-Rundel & Barr, 2019) and OpenStax Introductory Statistics (Illowsky & Dean, 2018).

Recommendations

Based on the results, we recommend:

1. Faculty and staff explicitly show connections between math and other subjects, careers, current events, and everyday life.
2. Faculty and staff encourage all students (especially STEM students) to take a statistics class.
3. Instructors include discussions about misleading graphs, as appropriate to their disciplines.
4. Instructors consider more real-world discussion problems that involve contrasting two or more numerical results.
5. Instructors expose students to more real-world situations with uncertain and incomplete information.
6. Administration and faculty offer professional development opportunities for instructors across the college regarding their own statistical literacy and how to plan learning opportunities involving statistical literacy for students.
7. Sharing findings with College Advisors so they can inform advisees of the importance of quantitative reasoning and statistics.
8. Faculty and staff hold our own institution accountable in presenting honest statistics.

Conclusion

Our main finding in this study was that there were no predictors of higher performance in questions designed to assess students' statistical literacy. It may therefore seem like we found nothing new at all. Yet we find it quite interesting that all students struggled with these questions, even those deemed to have an advantage over other peers with less exposure to such types of real-world settings, such as STEM, Economics, and Business students. Indeed, anecdotal evidence from some faculty in quantitative fields indicates that, when it comes to being *fooled* by statistics, we are all *equally fooled*.

Our college mission statement includes that we "foster global citizenship for social justice" (HWC, 2019). How can students know what is best for society if they cannot recognize when people lie with statistics, or when statistics misrepresent our society? Statistical literacy must therefore be a more integral part of our students' learning experiences.

We are encouraged to learn that approximately 90% of surveyed students agreed that math problems often have many methods of solution, and that even more (93% of students) agreed that hard work results in success in math. We believe this applies to our assessment work too (there are many routes, and hard work and attention to detail lead to more meaningful results). We encourage faculty to further support the development of a growth-mindset in students as it relates to quantitative reasoning and to model that themselves as they seek professional development opportunities.

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Appendices

- Appendix A: Quantitative Reasoning Tool 2017
- Appendix B: Rubric for Open-Ended Questions
- Appendix C: Basic Results for Each Question
- Appendix D: Sample Size
- Appendix E: Student Profiles
- Appendix F: Tables on Performance, Profiles, and Classes Taken
- Appendix G: Various Graphs
- Appendix H: Exploratory Analysis
- Appendix I: Notes on Methodology

Appendix A: Quantitative Reasoning Tool 2017

Introduction:

Thank you SO MUCH for volunteering to participate in the 2017 HWC Quantitative Reasoning Assessment. Your participation will help to inform curriculum development, pedagogical practices, and policy decisions at Harold Washington College. Your participation is voluntary and your responses confidential. You can stop your participation at any time. And whether you participate in the survey or not, it will have no impact on your grade. We will only analyze the data in the aggregate (the big picture), not individual responses.

Please answer the following questions honestly and based on your own knowledge, without any help from other people or resources. This is a three-part response. We hope you will use your best effort to help us gather valid data, but you have the right to stop answering questions at any time.

If you have questions or concerns about this assessment process, please contact Carrie Nepstad, Chair of the HWC Assessment Committee at cnepstad@ccc.edu or call 312-553-6095.

Throughout the survey, remember to click the NEXT button to continue to each section. Also remember to never click the browser's back or forward buttons, as this will mess up the survey.

_____I have read the above statement and consent to continue. (Check here.)

Student Identification:

Please enter your 9 digit student ID. Providing this information allows us to reduce the time of this survey and improve its reliability. Again, this information is confidential and not linked to individual student performance.

Give ID Number Here: ________________________

Where are you taking this survey?

____During class

____Outside of class yet on campus

____Off campus

The following survey contains five multi-part questions. Make sure to finish to the end. Thanks so much!

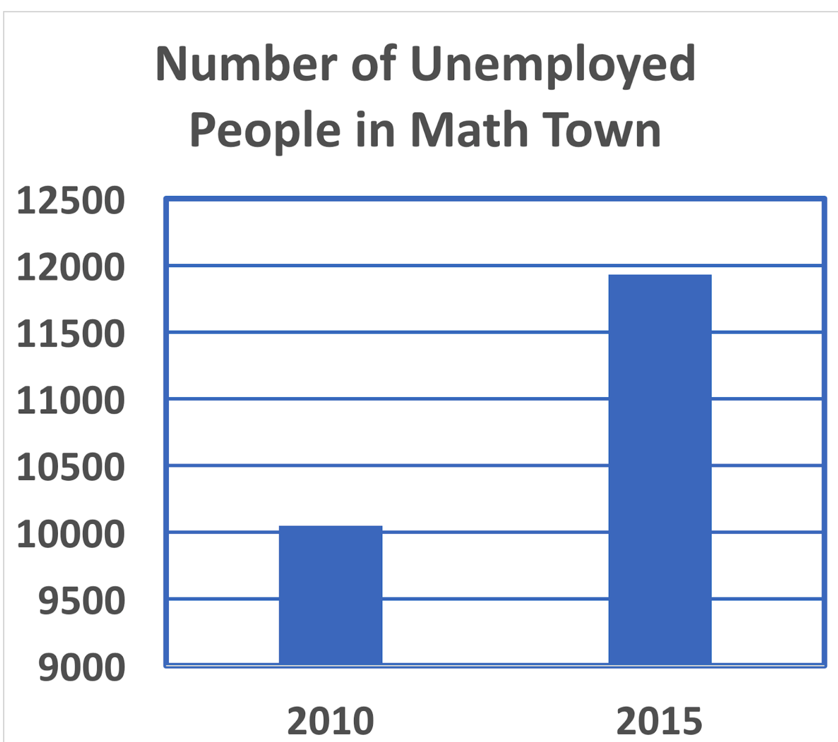
QUESTION #1:

Please indicate your agreement level with each of the following:

	Strongly Disagree	Disagree	Agree	Strongly Agree
1a.) There are often many ways to solve a math problem.	O	O	O	O
1b.) If I work at it, I can do well in math.	O	O	O	O
1c.) I need a good understanding of math to achieve my career goals.	O	O	O	O
1d.) Math is an important tool to help me learn other subjects.	O	O	O	O
1e.) Math helps me to understand current events and make intelligent decisions.	O	O	O	O

QUESTION #2:

Consider the following graph.



2a.) Regarding the above graph, which of the following is ***the best*** approximation of comparing the 2010 and 2015 data?

a. The number of unemployed in 2015 was 2% more than in 2010
b. The number of unemployed in 2015 was 20% more than in 2010
c. The number of unemployed in 2015 was 100% more than in 2010
d. The number of unemployed in 2015 was double what it was in 2010
e. The number of unemployed in 2015 was triple what it was in 2010

2b.) Regarding the above graph, do you think this data is being displayed effectively, or are there problems with the graph? Why? Give a one-sentence answer.

Short answer:

QUESTION #3:

There are many ways to calculate unemployment. Here are two of the most common (Thoma, 2014).

U-3 Unemployment Rate	$\frac{number\ unemployed}{number\ unemployed\ +\ number\ employed}$
U-5 Unemployment Rate	$\frac{number\ unemployed\ +\ number\ marginally\ attached\ to\ labor\ force}{number\ unemployed\ +\ number\ marginally\ attached\ to\ labor\ force\ +\ number\ employed}$

The following definitions are also necessary.

Employed	A person currently working a job, including full-time, part-time, and temp work.
Marginally Attached to the Labor Force	A person who is not working a job and has not sought work within the last 4 weeks, yet wants to work and has sought work within the last 12 months.
Unemployed	A person who is not currently working a job yet has looked for work within the last 4 weeks.

3a.) Considering the definitions above, suppose a certain neighborhood in a large city has 9,000 residents who are employed, 1000 residents who are unemployed, and 2000 residents who are marginally attached to the labor force. What is the U-3 Unemployment Rate as a percent?

a. 10%
b. 15%
c. 20%
d. 25%
e. 30%

3b.) Considering the definitions above, suppose again that a certain neighborhood in a large city has 9,000 residents employed, 1000 residents unemployed, and 2000 residents marginally attached to the labor force. What is the U-5 Unemployment Rate as a percent?

a. 10%
b. 15%
c. 20%
d. 25%
e. 30%

3c.) Considering the definitions above, suppose a city council member from the previously mentioned neighborhood is running for re-election on a platform of continuing the good economic work done for the neighborhood over the past four years. Which unemployment rate do you think this council member is more likely to cite, and why? Give a one-sentence answer.

Short answer:

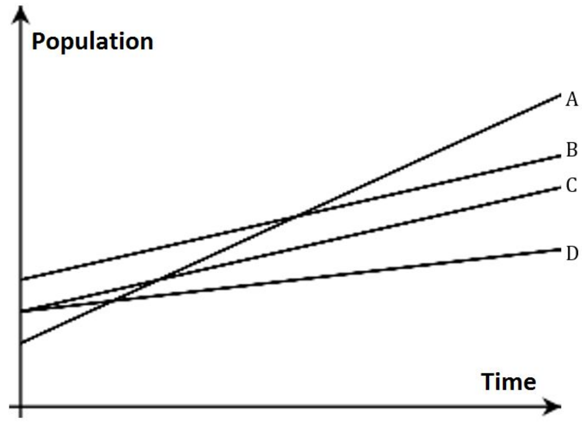
QUESTION #4:

Suppose it's Black Friday tomorrow and Best Buy is advertising a flat screen TV on sale for 40% off the regular price of $499.99, and it will be further reduced by 15% off of that sale price if you make it there by 7am! Target is selling the same tv throughout the day tomorrow at 50% off the same original price. Which of the following do you think is the accurate statement?

a. Best Buy has the better deal.
b. Target has the better deal.
c. They are the same.

QUESTION #5:

Consider the following graph.



5a.) Consider the graph above, which two populations begin with the same number of members?

a. A and B
b. B and C
c. C and D
d. A and C
e. There is not enough information provided to answer the question.

5b.) Considering the graph above, after how much time do populations A and B have the same population?

a. 5 years
b. 10 years
c. 15 years
d. 20 years
e. There is not enough information provided to answer the question.

5c.) Considering the graph above, which two populations grow at the same rate?

a. A and B
b. B and C
c. C and D
d. A and C
e. There is not enough information provided to answer the question.

Feel free to share any comments you have about this survey that you want us to know.

____

____

____

Thank you SO much for your time!

Appendix B: Rubric for Open-Ended Questions

Question 2b Qualitative Codes:

- ***A: no, not effective, because of y-axis or vertical scale (best answer)***
- B: no, not effective, with some other intelligible reason given other than the one in option A
- C: yes, displayed effectively, with some intelligible reason given
- D: blank, or no intelligible reason given, or no reason at all given

Question 3c Qualitative Codes:

- ***A: answers U-3, mentions lower unemployment looking better for re-election (best answer)***
- B: answers U-3, with some other intelligible reason given other than the one in option A
- C: answers U-3, with no intelligible reason or no reason at all given
- D: answers U-5, with some intelligible reason given
- E: answers U-5, with no intelligible reason or no reason at all given
- F: blank, or not clearly specifying U-3 or U-5

Is this set of answers interesting? (Answer yes if this student's set of qualitative answers are interesting for further discussion.)

Would you like the other graders to look at this set of answers? (Answer yes if you have trouble choosing the best code for either of these answers.)

Appendix C: Basic Results for Each Question

QUESTION #1:

Please indicate your agreement level with each of the following:

	Strongly Disagree	Disagree	Agree	Strongly Agree
1a.) There are often many ways to solve a math problem.	O	O	O	O
1b.) If I work at it, I can do well in math.	O	O	O	O
1c.) I need a good understanding of math to achieve my career goals.	O	O	O	O
1d.) Math is an important tool to help me learn other subjects.	O	O	O	O
1e.) Math helps me to understand current events and make intelligent decisions.	O	O	O	O

Results:

Question 1a	Number	Percent
Str Dis	34	2.69%
Dis	94	7.44%
Agr	721	57.09%
Str Agr	413	32.70%

Question 1b	Number	Percent
Str Dis	34	2.69%
Dis	55	4.35%
Agr	583	46.16%
Str Agr	588	46.56%

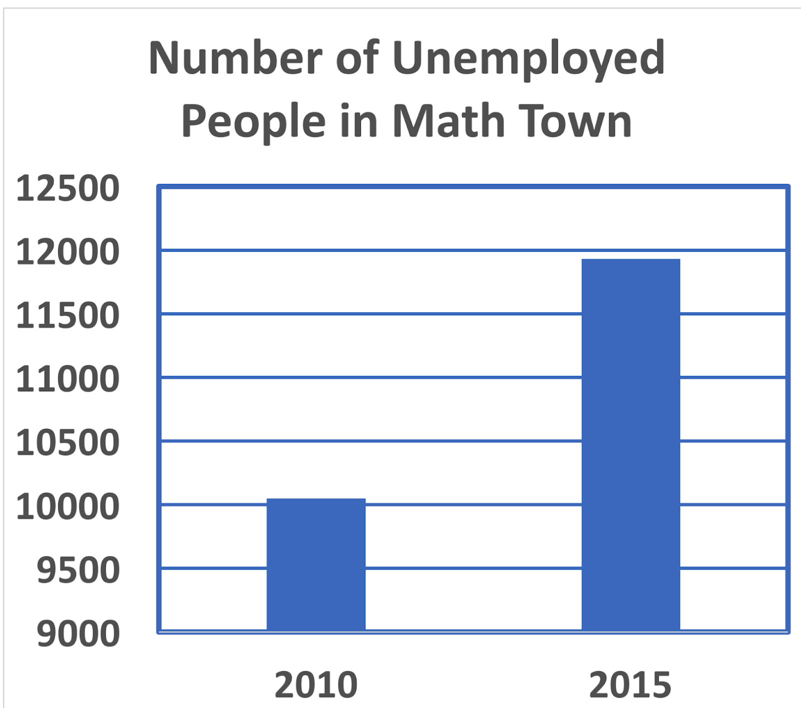
Question 1c	Number	Percent
Str Dis	65	5.15%
Dis	239	18.92%
Agr	608	48.14%
Str Agr	347	27.47%

Question 1d	Number	Percent
Str Dis	56	4.43%
Dis	227	17.97%
Agr	698	55.27%
Str Agr	281	22.25%

Question 1e	Number	Percent
Str Dis	84	6.65%
Dis	299	23.67%
Agr	655	51.86%
Str Agr	221	17.50%

QUESTION #2:

Consider the following graph.



2a.) Regarding the above graph, which of the following is ***the best*** approximation of comparing the 2010 and 2015 data?

a. The number of unemployed in 2015 was 2% more than in 2010
b. The number of unemployed in 2015 was 20% more than in 2010 (correct answer)
c. The number of unemployed in 2015 was 100% more than in 2010
d. The number of unemployed in 2015 was double what it was in 2010
e. The number of unemployed in 2015 was triple what it was in 2010

Results:

Question 2a	Number	Percent
a.) 2% more	220	17.42%
b.) 20% more	***683***	***54.08%***
c.) 100% more	44	3.48%
d.) Double	113	8.95%
e.) Triple	204	16.15%

2b.) Regarding the above graph, do you think this data is being displayed effectively, or are there problems with the graph? Why? Give a one-sentence answer.

Results:

Question 2b Qualitative Codes:

- ***A: no, not effective, because of y-axis or vertical scale (best answer)***
- B: no, not effective, with some other intelligible reason given other than the one in option A
- C: yes, displayed effectively, with some intelligible reason given
- D: blank, or no intelligible reason given, or no reason at all given

Student performance on Question 2(b):

Qualitative Code	***A***	B	C	D
Frequency	***191***	221	253	463
Percentage	***16.93***	19.59	22.43	41.05

(Some students commented that the lack of a label on the horizontal axis of the graph in Question 2b prevented them from answering with certainty.)

QUESTION #3:

There are many ways to calculate unemployment. Here are two of the most common (Thoma, 2014).

U-3 Unemployment Rate	$\frac{\text{number unemployed}}{\text{number unemployed} + \text{number employed}}$
U-5 Unemployment Rate	$\frac{\text{number unemployed} + \text{number marginally attached to labor force}}{\text{number unemployed} + \text{number marginally attached to labor force} + \text{number employed}}$

The following definitions are also necessary.

Employed	A person currently working a job, including full-time, part-time, and temp work.
Marginally Attached to the Labor Force	A person who is not working a job and has not sought work within the last 4 weeks, yet wants to work and has sought work within the last 12 months.
Unemployed	A person who is not currently working a job yet has looked for work within the last 4 weeks.

3a.) Considering the definitions above, suppose a certain neighborhood in a large city has 9,000 residents who are employed, 1000 residents who are unemployed, and 2000 residents who are marginally attached to the labor force. What is the U-3 Unemployment Rate as a percent?

a. 10% (correct answer)
b. 15%
c. 20%
d. 25%
e. 30%

Results:

Question 3a	Number	Percent
a.) 10%	***822***	***65.08%***
b.) 15%	118	9.34%
c.) 20%	176	13.94%
d.) 25%	78	6.18%
e.) 30%	64	5.07%

3b.) Considering the definitions above, suppose again that a certain neighborhood in a large city has 9,000 residents employed, 1000 residents unemployed, and 2000 residents marginally attached to the labor force. What is the U-5 Unemployment Rate as a percent?

a. 10%
b. 15%
c. 20%
d. 25% (correct answer)
e. 30%

Results:

Question 3b	Number	Percent
a.) 10%	*90*	*7.13%*
b.) 15%	126	9.98%
c.) 20%	165	13.06%
d.) 25%	***793***	***62.79%***
e.) 30%	78	6.18%

3c.) Considering the definitions above, suppose a city council member from the previously mentioned neighborhood is running for re-election on a platform of continuing the good economic work done for the neighborhood over the past four years. Which unemployment rate do you think this council member is more likely to cite, and why? Give a one-sentence answer.

Results:

Question 3c Qualitative Codes:

- ***A: answers U-3, mentions lower unemployment looking better for re-election (best answer)***
- B: answers U-3, with some other intelligible reason given other than the one in option A
- C: answers U-3, with no intelligible reason or no reason at all given
- D: answers U-5, with some intelligible reason given
- E: answers U-5, with no intelligible reason or no reason at all given
- F: blank, or not clearly specifying U-3 or U-5

Student performance on Question 3(c):

Qualitative code	***A***	B	C	D	E	F
Frequency	***424***	34	84	130	98	358
Percentage	***37.59***	3.01	7.45	11.52	8.69	31.74

QUESTION #4:

Suppose it's Black Friday tomorrow and Best Buy is advertising a flat screen TV on sale for 40% off the regular price of $499.99, and it will be further reduced by 15% off of that sale price if you make it there by 7am! Target is selling the same tv throughout the day tomorrow at 50% off the same original price. Which of the following do you think is the accurate statement?

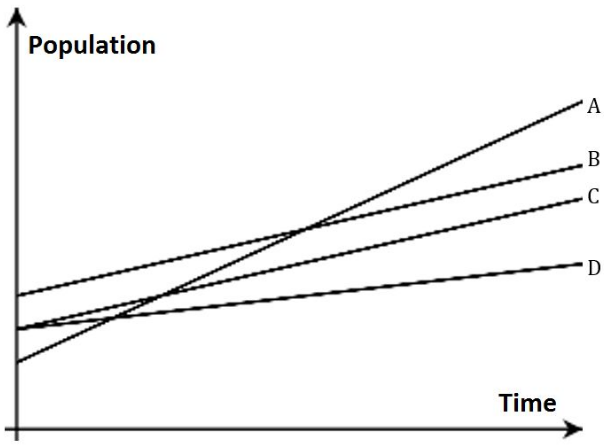
a. Best Buy has the better deal.
b. Target has the better deal. (correct answer)
c. They are the same.

Results:

Question 4	Number	Percent
a.) Best Buy	487	38.41%
b.) Target	***659***	***51.97%***
c.) Same	114	8.99%

QUESTION #5:

Consider the following graph.



5a.) Consider the graph above, which two populations begin with the same number of members?

a. A and B
b. B and C
c. C and D (correct answer)
d. A and C
e. There is not enough information provided to answer the question.

Results:

Question 5a	Number	Percent
a.) A and B	25	1.97%
b.) B and C	119	9.38%
c.) C and D	***1012***	***79.81%***
d.) A and C	19	1.50%
e.) Not enough info	83	6.55%

5b.) Considering the graph above, after how much time do populations A and B have the same population?

a. 5 years
b. 10 years
c. 15 years
d. 20 years
e. There is not enough information provided to answer the question. (correct answer)

Results:

Question 5b	Number	Percent
a.) 5 years	58	4.57%
b.) 10 years	69	5.44%
c.) 15 years	60	4.73%
d.) 20 years	19	1.50%
e.) Not enough info	***1042***	***82.18%***

5c.) Considering the graph above, which two populations grow at the same rate?

a. A and B
b. B and C (correct answer)
c. C and D
d. A and C
e. There is not enough information provided to answer the question.

Results:

Question 5c	Number	Percent
a.) A and B	35	2.76%
b.) B and C	***951***	***75.00%***
c.) C and D	92	7.26%
d.) A and C	21	1.66%
e.) Not enough info	152	11.99%

Appendix D: Student Profiles

1. Three student "profiles" were considered for analysis: Students that fit a "STEM Profile," students that fit a "Business-Economics Profile," and students that do not fit either of these two profiles, a "Neither STEM nor Business Profile."
2. Rationale behind this division: One might expect that students who have taken a somewhat large number of STEM or Business-Economics classes would have a higher level of comfort with the assessment's questions and, hence, would perform better.
3. Profile definitions (course history was downloaded from our internal CCC analytics portal OpenBook):
    - *STEM Profile:* Students that successfully completed (grade C or better) 6 or more STEM classes (defined as classes within these categories: Astronomy, Biology, Chemistry, CIS, Math, Microbiology, Physical Science, Physics).
    - *Business-Economics Profile:* Students that successfully completed (grade C or better) 6 or more Business or Economics classes (defined as classes within these categories: Business, Economics).
    - *Neither STEM nor Business-Economics Profile:* Students that did not have 6 or more successfully completed STEM or Business-Economics classes (i.e. did not fit either of the previous two profiles).
4. The definition of "STEM Profile" is based on 6 or more classes since STEM majors would be expected to take 3 or 4 STEM classes per semester (hence 6 or 8 classes in two years).
5. Notice that some students had both a STEM and a Business-Economics profile, so the three groups above *are not mutually exclusive,* and each required a separate analysis.
6. The total number of courses completed was also considered as a possible (quantitative) predictor of student performance, as one might expect students who completed a large number of classes would perform better than peers with fewer completions.

Appendix E: Sample Size

This statistical analysis was performed on a sample of 1128 students for which at least a successful class record (at least one class with a grade of C or better, or S) existed during the Fall 2017 semester. The HWC enrollment for the fiscal year of 2017 was 12,830, which includes Summer 2016, Fall 2016, and Spring 2017 (CCC, 2017). Thus we can assume that the Fall 2017 enrollment was approximately half of that at 6415. The minimum sample size needed for a standard 95% confidence interval with 3% margin of error on this population would be 915 students. Thus our sample of 1128 students is sufficient for standard statistical inference procedures. The table below shows more detail on the sample.

Original total responses	1267
Duplicate ID (more than one response to assessment; kept the 1st one)	64
Unmatched ID (not found in OB)	39
NA (No ID given)	8
Matched (found in OB)	1156
Missing rating (Faculty rater forgot to complete?)	1
No OpenBook course data (Found in OB, but no course info; likely dropped all classes)	27
Sample size	**1128**

Appendix F: Tables on Performance, Profiles, and Classes Taken

This appendix presents several tables with numeric summaries which are relevant to our analysis of data.

Student Combined Performance in Questions 2(b) and 3(c)

These two-way tables display the overall student combined performance in questions 2(b) and 3(c). A two-way table is useful for examining relationships between categorical data, as it is the case with the qualitative codes we assigned to these two questions. Frequences (number of responses) and percentages are presented on separate tables.

Frequency (two-way table):

	Q3(c)					
Q2(b)	**A**	**B**	**C**	**D**	**E**	**F**
A	***121***	6	11	18	9	26
B	97	8	9	34	22	51
C	99	9	28	24	29	64
D	107	11	36	54	38	217

Percentages (two-way table):

	Q3(c)					
Q2(b)	**A**	**B**	**C**	**D**	**E**	**F**
A	***10.73***	0.53	0.98	1.60	0.80	2.30
B	8.60	0.71	0.80	3.01	1.95	4.52
C	8.78	0.80	2.48	2.13	2.57	5.67
D	9.49	0.98	3.19	4.79	3.37	19.24

Student Profiles (Number/Percentage of Students)

These tables display the composition of each of the three student profiles considered for analysis.

STEM Profile:

STEM Profile?	**NO**	**YES**
Totals	973	155
Percentage	86.26	13.74

Business-Economics Profile:

Business-Economics Profile?	NO	YES
Totals	1113	15
Percentage	98.67	1.33

Neither Profile:

Non-STEM/Bus-Econ Profile?	NO	YES
Totals	165	963
Percentage	14.63	85.37

STEM Profile Performance

These tables summarize the distribution of responses in questions 2(b) and 3(c) for the "STEM Profile" group.

Question 2(b) frequency and percentage:

	STEM Profile?	
Q2(b) Code	**NO**	**YES**
A	168 (14.89%)	23 (2.04%)
B	193 (17.11%)	28 (2.48%)
C	217 (19.24%)	36 (3.19%)
D	395 (35.02%)	68 (6.03%)

Question 3(c) frequency and percentage:

	STEM Profile?	
Q3(c) Code	**NO**	**YES**
A	371 (32.89%)	53 (4.70%)
B	29 (2.57%)	5 (0.44%)
C	72 (6.38%)	12 (1.68%)
D	111 (9.84%)	19 (1.44%)
E	82 (7.27%)	16 (1.42%)
F	308 (27.30%)	50 (4.43%)

Business-Economics Profile Performance

These tables summarize the distribution of responses in questions 2(b) and 3(c) for the "Business-Economics Profile" group.

Question 2(b) frequency and percentage:

	Bus-Econ Profile?	
Q2(b) Code	**NO**	**YES**
A	188 (16.67%)	3 (0.27%)
B	219 (19.41%)	2 (0.18%)
C	252 (22.34%)	1 (0.09%)
D	454 (40.25%)	9 (0.80%)

Question 3(c) frequency and percentage:

	Bus-Econ Profile?	
Q3(c) Code	**NO**	**YES**
A	420 (37.23%)	4 (0.35%)
B	32 (2.84%)	2 (0.18%)
C	83 (7.36%)	1 (0.09%)
D	130 (11.52%)	0 (0.00%)
E	95 (8.42%)	3 (0.27%)
F	353 (31.29%)	5 (0.44%)

Neither STEM/Bus-Econ Profile Performance

These tables summarize the distribution of responses in questions 2(b) and 3(c) for the "Neither STEM/Business-Economics Profile" group.

Question 2(b) frequency and percentage:

	Non-STEM/Bus-Econ Profile?	
Q2(b) Code	**NO**	**YES**
A	26 (2.30%)	165 (14.63%)
B	29 (2.57%)	192 (17.02%)
C	37 (3.28%)	216 (19.15%
D	73 (6.47%)	390 (34.57%)

Question 3(c) frequency and percentage:

	Non-STEM/Bus-Econ Profile?	
Q3(c) Code	**NO**	**YES**
A	57 (5.05%)	367 (32.54%)
B	6 (0.53%)	28 (2.48%)
C	13 (1.15%)	71 (6.29%)
D	19 (1.68%)	111 (9.84%)
E	17 (1.51%)	81 (7.18%)
F	53 (4.70%)	305 (27.04%)

Number of Successfully Completed Classes

Student course history was downloaded from CCC analytics portal OpenBook. These tables present some summary statistics regarding the number of courses successfully completed, as defined in Appendix E.

All classes summary:

Minimum	1.00
1st Quartile	4.00
Median	10.00
Mean	10.62
3rd Quartile	15.00
Maximum	39.00

STEM classes summary:

Minimum	0.00
1st Quartile	1.00
Median	2.00
Mean	2.74
3rd Quartile	4.00
Maximum	16.00

Business-Economics classes summary:

Minimum	0.00
1st Quartile	0.00
Median	0.00
Mean	0.55
3rd Quartile	1.00
Maximum	13.00

One of our main questions was to see if there was any link between performance in qualitative questions 2(b) and 3(c). These tables present the overall conditional performance in these two questions (conditioned on the "best answer" defined on the rubric for open-ended questions, in Appendix B).

Student performance on Question 2(b), if the qualitative code was A in 3(c):

Qualitative code	A	B	C	D
Percentage	28.54	22.88	23.35	25.24

Student performance on Question 3(c), if qualitative code was A in 2(b):

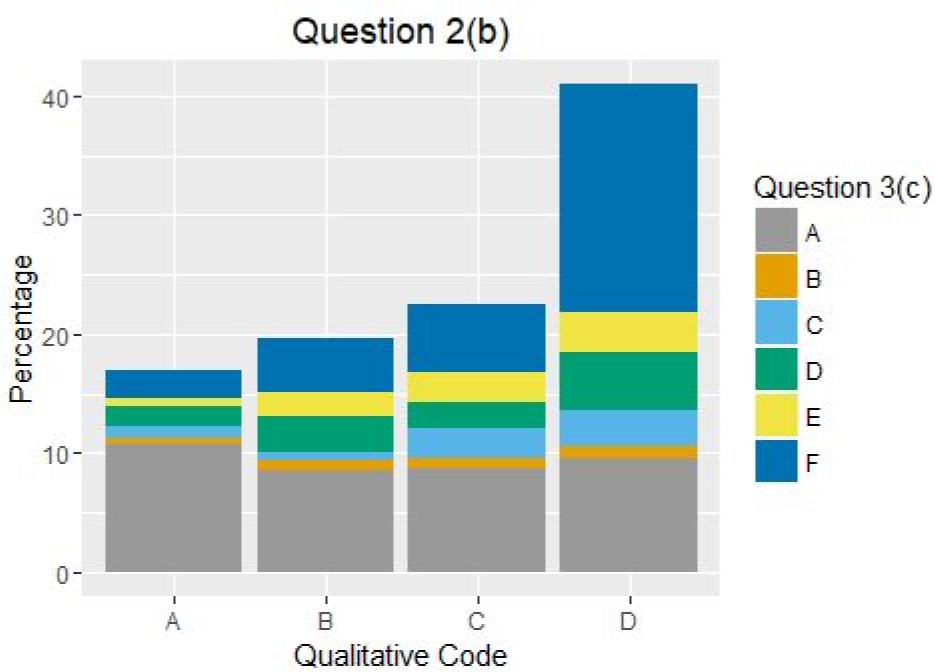
Qualitative code	A	B	C	D	E	F
Percentage	63.35	3.14	5.76	9.42	4.71	13.61

Appendix G: Various Graphical Summaries

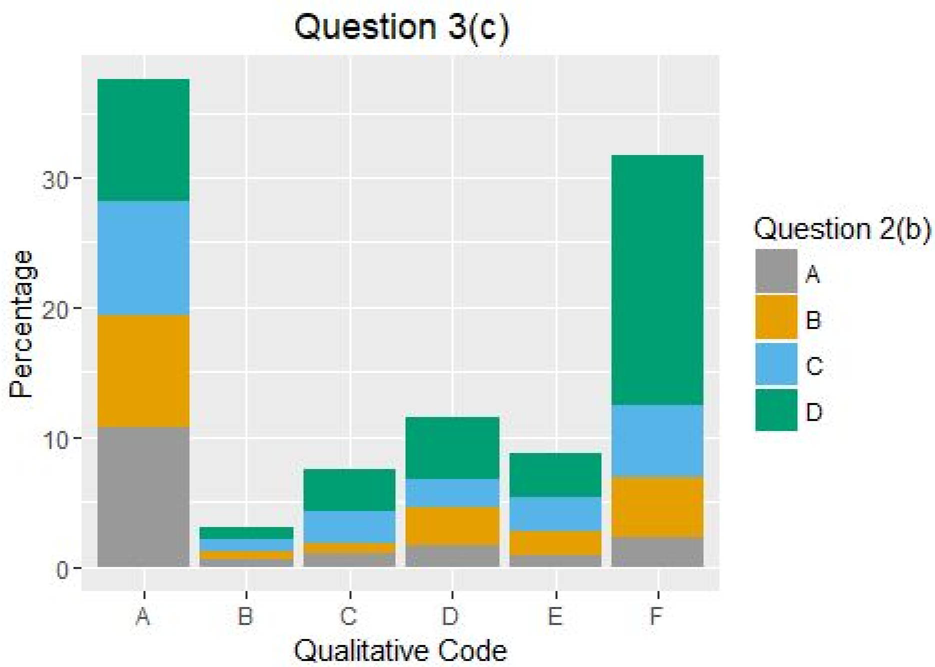
This appendix presents several graphical summaries relevant to our analysis. These visual displays are based on the tables presented before, in Appendix F.

Graphs with several embedded colors present the distribution of responses for questions 2(b) and 3(c) as shown before in two-way tables. Also, the performance on these two questions for each student profile is visualized in two colors. Finally, monocolor graphs, present the conditional performance in 2(b) and 3(c), as well as the summary statistics of successfully completed courses.

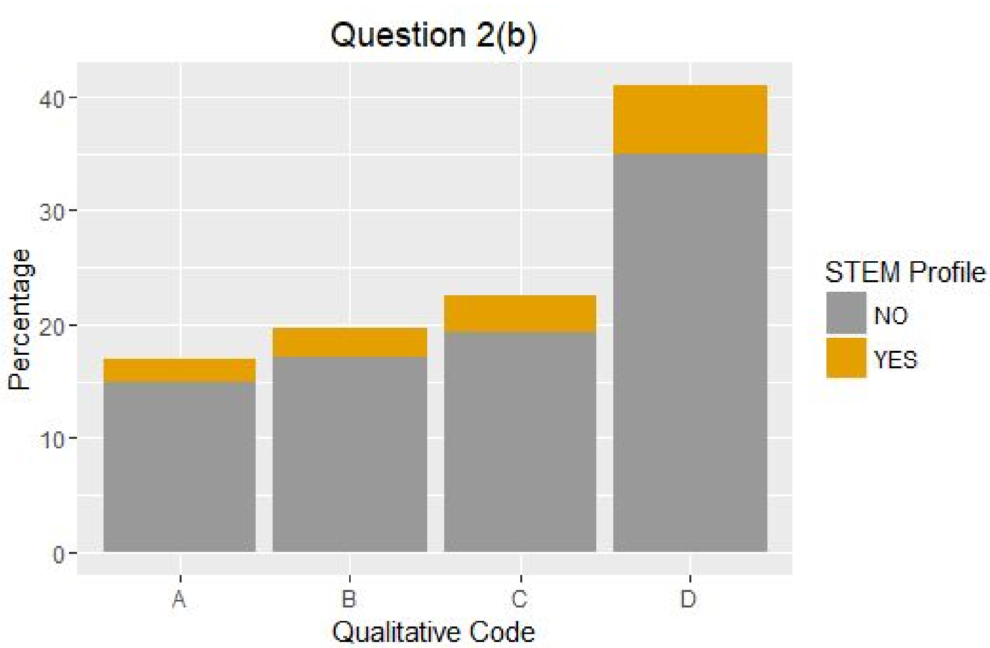
Performance on Question 2(b) with Question 3(c) Proportions Embedded



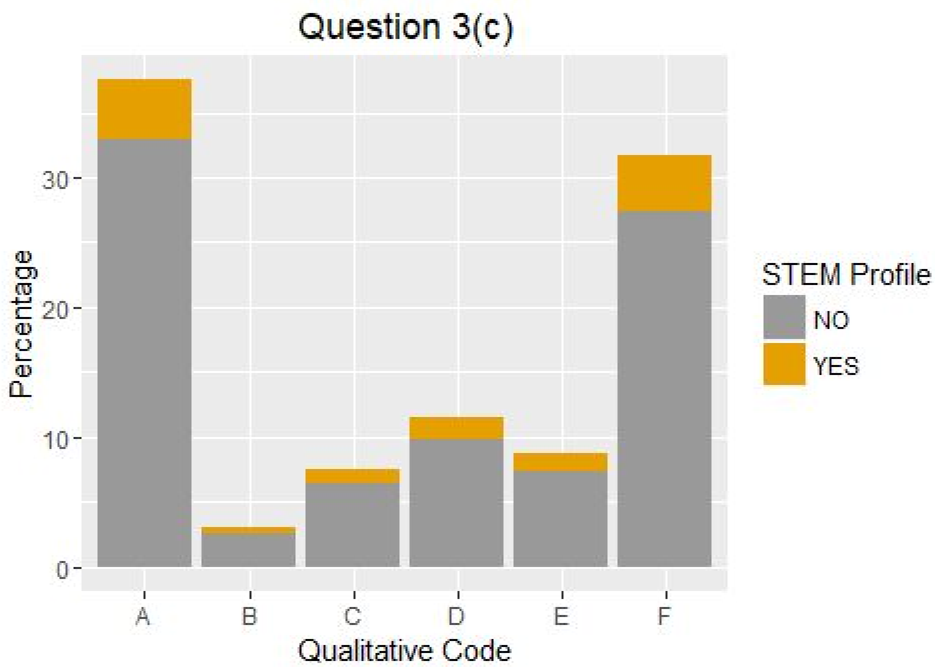
Performance on Question 3(c) if Qualitative Code in Question 2(b) was A



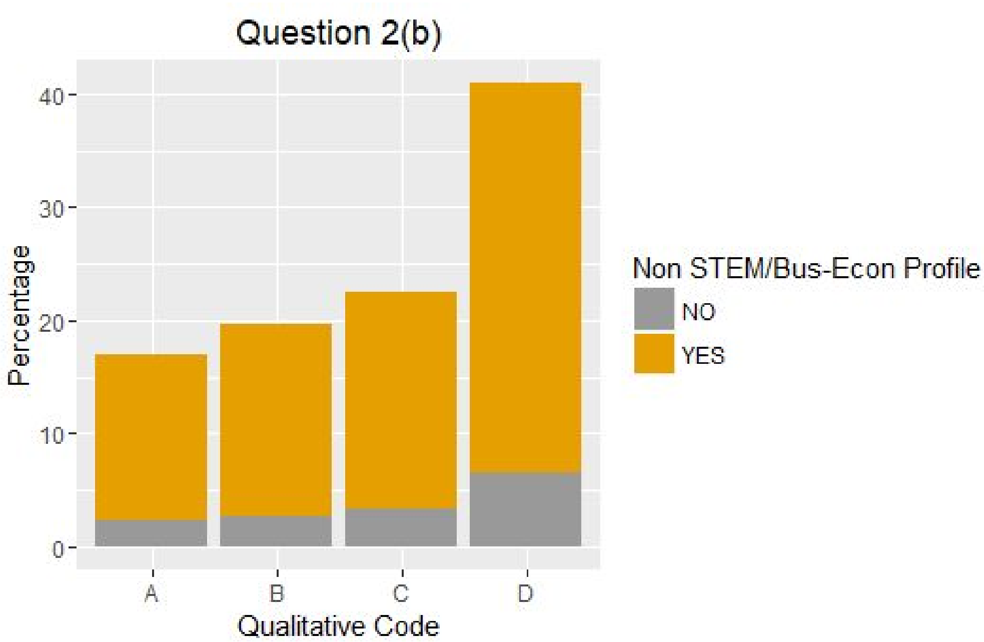
Performance on Question 2(b) with Proportion of STEM Profile Students Embedded



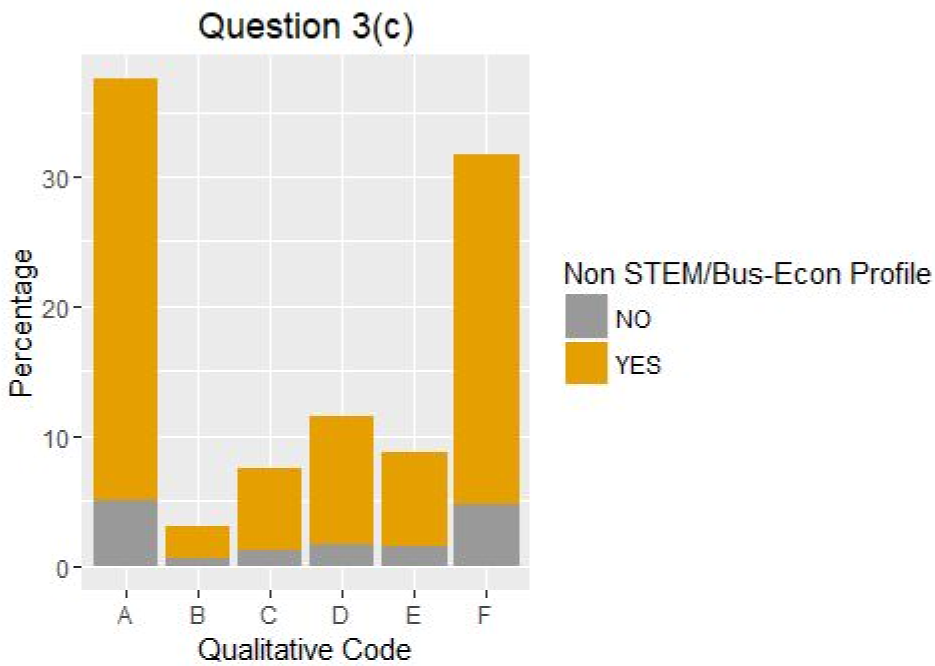
Performance on Question 3(c) with Proportion of STEM Profile Students Embedded



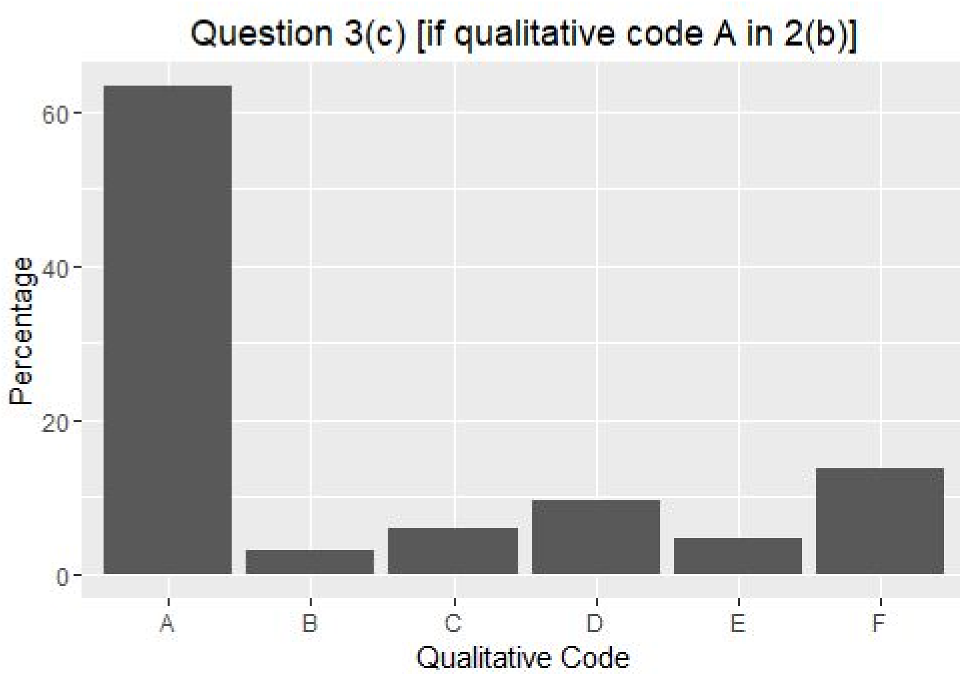
Performance on Question 2(b) with Proportion of Neither Profile Students Embedded



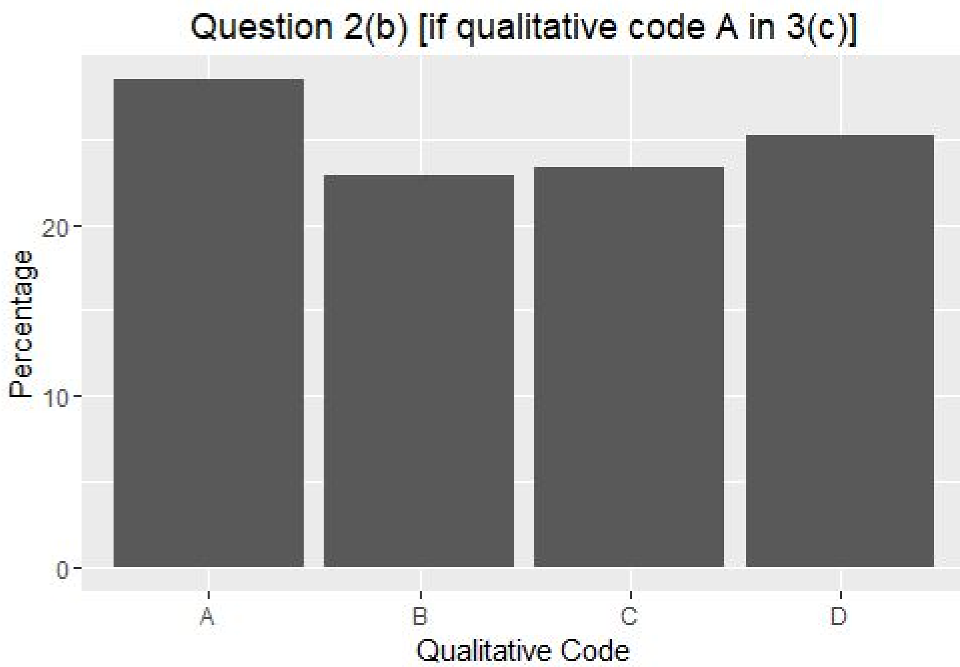
Performance on Question 3(c) with Proportion of Neither Profile Students Embedded



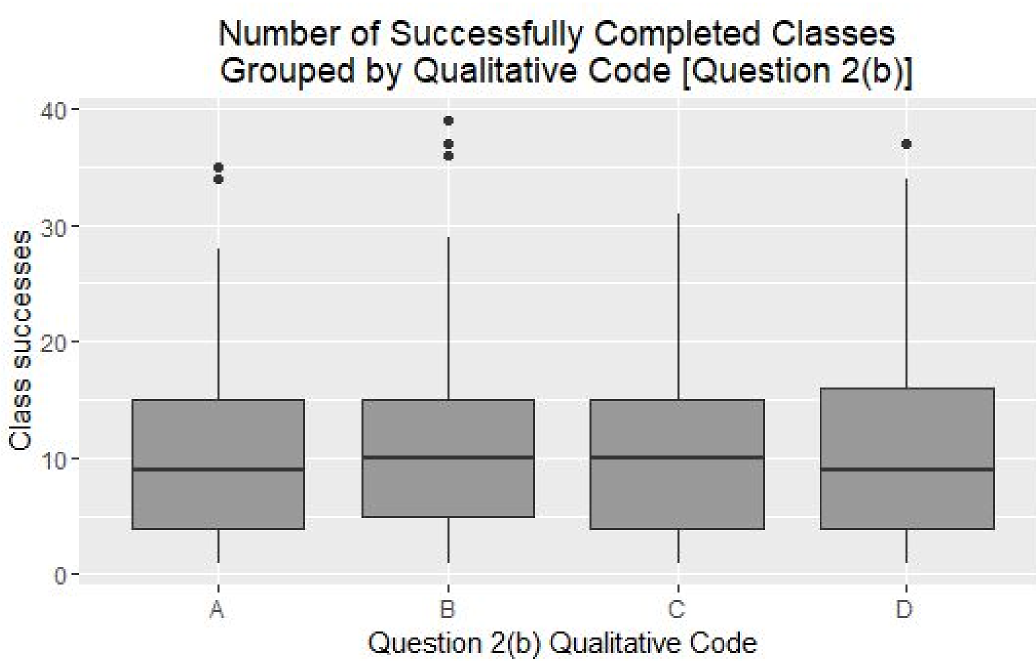
Student Performance on Question 3(c) if Code in 2(b) was A



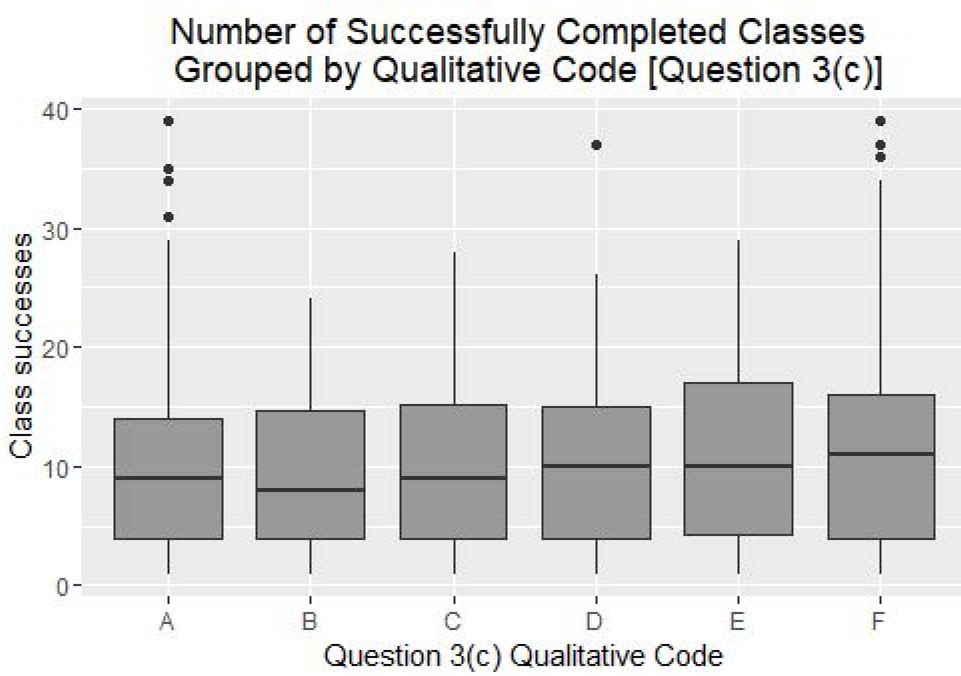
Student Performance on Question 2(b) if Code in 3(c) was A



Number of Successfully Completed Classes Grouped by Qualitative Code from 2(b)



Number of Successfully Completed Classes Grouped by Qualitative Code from 3(c)



Appendix H: Exploratory Analysis

Some Other Results

1. The most frequent response for Question 2(b) corresponded to qualitative code D ("blank, or no intelligible reason given, or no reason at all given") with 41.05% of responses.
2. The most frequent response for Question 3(c) corresponded to the "best answer" qualitative code A ("answers U-3, mentions lower unemployment looking better for re-election") with 37.59% of responses. The second most frequent response corresponded to qualitative code F ("blank, or not clearly specifying U-3 or U-5") with 31.74%.
3. Students whose Question 2(b) answer corresponded to code A had a high chance of giving a code A response in Question 3(c) with 63.35% probability.
4. Students whose Question 3(c) answer corresponded to code A had a, roughly, equal chance of giving a code A, B, C, or D response in Question 2(b).

Significance Tests of Independence

Several tests of independence were performed to look for possible associations between variables. Here is a summary of the tests and their results:

1. A Pearson's Chi-squared test of independence (see "Notes on Methodology" at the end for more) was performed to see if there was any association between Question 2(b) and Question 3(c) responses. The results of the test (Chi-squared statistic = 144.28, df = 15, P-value < 2.2e-16) indicate a statistically significant association between these two variables. However, the strength of this association is weak (see the correlations below for more) and predictions based on responses do not appear to be appropriate.
2. Fisher's Exact Tests (see "Notes on Methodology" at the end for more) were performed to see if there were any associations between Question 2(b) and each profile described before ("STEM," "Business-Economics," or "Neither"). No significant associations were found (the smallest P-value for the test between Question 2(b) and the Business-Economics profile, was 0.07751, getting close to the "edge of significance" (See https://xkcd.com/1478/ for a helpful and humorous take on this issue.).

Strength of Associations

The significant association between Question 2(b) and 3(c) responses reported above does not measure strength of the association. A measure of effect size (i.e. strength of an association) is the Goodman and Kruskal's tau measure (see "Notes on Methodology" at the end for more). The Goodman and Kruskal's tau corresponding to the significance tests above are:

	Question 2(b)	Question 3(c)
Question 2(b)		0.054
Question 3(c)	0.050	
STEM Profile	0.000	0.000
Business-Economics Profile	0.001	0.001
Non-STEM/Bus-Econ Profile	0.000	0.000

(Note: each entry represents the association measure *τ(x,y)* from the variable *x* (predictor) indicated in the row name to the variable *y* (response) indicated in the column name)

As illustrated in the table above, the statistically significant association between Question 2(b) and 3(c) responses is very weak. Hence, it will be very difficult to predict one variable's responses from another.

Significance Tests of Difference based on Classes Taken

To determine whether the total number of classes taken had any impact on student performance, Welch's One-way ANOVA tests (see "Notes on Methodology" at the end for more) were performed. The results of these tests (Question 2(b): F-statistic = 0.59796, P-value = 0.6166; Question 3(c): F-statistic = 1.0656, P-value = 0.3805) did not indicate any significant difference in performance. Hence, the number of courses taken did not appear to have an influence on student performance.

Appendix I: Notes on Methodology

Here is a list of statistical tests used in the analysis outlined before, along with links to examples of their use.

Pearson's Chi-squared Test of Independence

This is a standard test of independence between two categorical variables. See this resource for more:

- "Chi-Square Test for Independence." Available at https://onlinecourses.science.psu.edu/stat500/lesson/8

Fisher's Exact Test

This is a statistical test used to determine if there are associations between two categorical variables. It is appropriate when sample sizes are small. Also, it is more accurate than the chi-square test of independence when the expected numbers are small. See these resources for more:

- "Fisher's exact test of independence." Available athttp://www.biostathandbook.com/fishers.html
- "Fisher's Exact Test." Available athttp://mathworld.wolfram.com/FishersExactTest.html

Goodman and Kruskal's Tau Measure

This is a measure of association between two categorical variables. This measure is analogous to the standard (Pearson's) correlation coefficient, with strong associations indicated by values close to 1 and weak or no associations indicated by values close to 0. See these resources for more:

- "The GoodmanKruskal package: Measuring association between categorical variables." Available at https://cran.r-project.org/web/packages/GoodmanKruskal/vignettes/GoodmanKruskal.html

Welch's One-Way ANOVA Test

This test compares two or more means to see if they are all equal or at least one is different. It is an alternative to the standard one-way ANOVA test and can be used even if the data does not have equal variances. See these resources for more:

- “One-Way Analysis of Variance.” Available athttps://ncss-wpengine.netdna-ssl.com/wp-content/themes/ncss/pdf/Procedures/NCSS/One-Way_Analysis_of_Variance.pdf
- “Welch’s ANOVA: Definition, Assumptions.” Available at http://www.statisticshowto.com/welchs-anova/
- “Benefits of Welch’s ANOVA Compared to the Classic One-Way ANOVA.” Available athttp://statisticsbyjim.com/anova/welchs-anova-compared-to-classic-one-way-anova/