Assessing Essential Skills in Math 140 Unit Assessment for Mathematics

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(Picture by Ranjith Siji via Pixabay)

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Introduction

For the purpose of choosing an optimal concept to assess in this course, we opted for the Student Learning Outcome: "Solving Polynomial Equations and Inequalities." The Math 140 assessment consists of four components: solving a quadratic equation and a quadratic inequality algebraically, along with solving an equation and an inequality graphically. The pilot for this assessment was administered during the Spring term of 2019. Its original sample tallied 121 responses. After eliminating duplicates as well as removing invalid or missing ID responses from the sample, we ended up with a data set of 95 unique student responses. The analysis of this first sample showed that students performed better than we expected in solving polynomial equations algebraically and graphically; however, we also found that students had more difficulty with solving polynomial inequalities. Subsequently, for the Fall term of 2019, we revised the pilot and we had seven mathematics full-time faculty members collaborate in finalizing our innovative assessment and administering it by the end of the semester. We successfully collected 137 unique student responses. This sample was analyzed and the report from our research analyst was completed at the time the college switched to remote learning due to the Covid-19 crisis. There was at that point no opportunity for deeper examination of the results nor for drawing conclusions. At the end of this past Spring 2020 term, the assessment for Math 140 (the same as was given in the Fall of 2019) was administered again.

Department buy-in and outcome definition

"Math 140 – College Algebra" is an essential prerequisite for college level mathematically dependent courses such as business, accounting, science and engineering. The Mathematics Department has been consistently interested in finding out more about students learning in this course in order to help them succeed not only in Math 140 but also in the following courses such as Calculus and Differential Equations. Moreover, the number of Math 140 sections offered has been increased over the past two semesters compared to all the other mathematics courses because of its pivotal role in preparing students for higher level mathematics. In conjunction with the sections at HWC, we offer Math 140 in collaboration with DePaul University and CPS High Schools.

During the Spring 2019 semester, nine out of the thirteen full time faculty members of the Mathematics Department worked collaboratively on the project: "Assessing Essential Skills in Math 140". At first, we revised the SLOs for the course and we selected three concepts that were interesting to be investigated. We subsequently voted for two of the SLO's, as a compromise between a majority of votes that deemed the two topics equally important and therefore not mutually exclusive. Since we ended up with a close tie between two learning outcomes, we decided to assess both under the title "Solving polynomial equations and inequalities." This is a particularly important outcome that students need to master prior to starting Calculus.

Assessment research and design

After we completed a research survey of existing assessment tools and processes most widely used in higher education, we decided to start from scratch and create our own

innovative tool to more accurately address the needs of our student population. We planned to create a short online survey consisting of questions properly aligned with the SLO assessed. Initially, we discussed the errors that students would typically make while solving problems addressing this particular topic, which arises in not only Math 140 but in Calculus as well. We were unanimously familiar with common mistakes such as incorrect simplification or incorrect use of Zero Factor Property, but we discovered new frequent errors students make for which we couldn't identify the origin. We made a decision to address all these commonly recurrent mistakes in our assessment.

During the Spring term of 2019, the mathematics faculty designed a short online survey on Google Forms containing four exercises: solve a quadratic equation and a quadratic inequality algebraically, as well as solve an equation and an inequality graphically. The details of these exercises are presented in **Appendix A**.

As in our previous assessment, we have used Google Forms because it is browser independent and especially mobile friendly, a significant advantage for our students. Another benefit in using Google forms is the facility to export the responses into an Excel document that helps perform all appropriate analyses on the collected data.

There are, however, a few setbacks with using Google Forms that we strived to overcome. We therefore created the pilot questions on a Word document to make use of the Math editing tool available in that platform and not as efficiently offered in Google forms. In addition, the Google form interface did not allow for any mathematical editing to properly display symbols and expressions present in the question. We addressed that setback by reiterating the expressions in a correct mathematical format and including them as images in the answer options from which the student would select with no possible confusion about notation.

By midterm of Spring 2019, our pilot assessment was completed. For the first two questions, we provided different possibilities of solving the exercises, saved as images and presented as different options, and further asked students to select only the correct procedure. For the last two visual questions, a graph of two functions was given, and students were supposed to identify the correct solution out of multiple answers by getting information from the graph. We wanted to include in the answers the common mistakes students make when solving these types of exercises along with the correct procedure/ answer (Appendix A).

Pilot assessment tools and processes

At the start of the Spring 2019 semester, we invited all faculty, including our adjunct colleagues, to be part of this project. All were introduced to the project via e-mail and in one-on-one discussions to emphasize the importance of their participation and encourage everyone to volunteer. Encouraging their students to take the assessment survey was emphasized and left to their discretion as to how they prefer to implement the survey in their classes. This pilot assessment was administered during the last three weeks of the semester.

Administer specific assessment

During the Fall 2019 semester in order to achieve a larger sample and involve more students in providing responses to the assessment, several new faculty members joined in the effort and participated in finalizing the Math 140 assessment. The population of students participating at this stage mirrored a wider range of our student body, including online and face to face classes.

First the summarized Math 140 pilot assessment findings were discussed with my colleagues in the mathematics department. We analyzed the results of the pilot assessment, revised the questions of the survey and made adjustments by integrating our findings into the final assessment tool.

For the first question involving solving quadratic equations, we reformulated the instructions to avoid any possible misunderstanding of the terms used to clarify the exercise. We took out one step from the solution to Option 3 to make it shorter, and we modified the last option (Appendix B). We discussed all these changes with one of our AC Research Analysts to ensure that the data obtained after these modifications would still be comparable to our previous measurements and could therefore be aggregated accurately with our prior analyses. The details of these modifications and their impact are presented in **Appendix B**.

For the second question, and after an extensive discussion about how we can construct the sign chart for solving a quadratic inequality, we decided to keep it unchanged since the majority of instructors are using the chart in this format.

For the last two questions, solving an equation and inequality graphically, the answers were modified. As a result, for these last two questions, it would not be accurate to compare the results between the pilot and the results of the Fall 2019 assessment. Our goal was to identify whether students were struggling with the concepts or with the way the answers were formulated. These changes are illustrated in **Appendix C**.

The amended final assessment was administered during the Fall of 2019 and Spring of 2020 semesters in order to gather a more significant amount of data and to subsequently compare the results from one semester to the next with better accuracy.

Data analysis

During the Fall of 2019, we analyzed the results of the pilot assessment administered in the previous Spring term. Students typically performed better than we expected in the topic of solving polynomial equations algebraically and graphically; however, we found that they struggled with solving polynomial inequalities. This was not too surprising since this topic is challenging and students tend to solve inequalities the same way they solve equations, without accounting for the different meaning of the two concepts and the different methodology in solving them.

For the first question, which covers solving a quadratic equation, more than half of students selected the correct solution (about 60% in Spring 2019 and about 55% in Fall

2019). The positive outcome was the fact that less than 5% of students selected the newly added pitfalls that students would possibly make in solving these equations. These results are presented in **Appendix D**.

The questions about solving an inequality algebraically and graphically were the topics students struggled with the most. For solving an inequality algebraically, the second question, merely 25% of students identified the correct solution in the Spring 2019 pilot assessment. This figure (to almost 30%) in the Fall of 2019. The correct answer for Question 2 is Option 2, illustrated in the first bar chart of Appendix E. It is obvious that we need to address this issue and find a way to help students improve this SLO. For solving an inequality graphically, the fourth and last question, about 35% of students answered the question correctly in both semesters. The correct results are represented by the orange column of the bar charts. These detailed results can be found in **Appendix E**.

One positively surprising result was how students responded to solving an equation graphically, which was question number 3 in the assessment. The originally posed question in the pilot had solution options comprising the correct answer, which is the values of x only where the two graphs intersect, and an intermediate step which states *both* coordinates (x and y) of the points of intersection. It is important for students to discern that when asked to solve an equation, what they are supposed to find is the specific value of the variable x, not the full coordinate location (x *and* y) in 2D space. These values of x are found graphically by identifying the points of intersections (that is, both x and y) and then isolate the x values. Most students, namely 56% were able to identify the intersection points, but they didn't make the mathematical distinction between "coordinates" and "equation solution", and therefore a pair (x, y) was not the final answer. In effect, 33% of students picked the values of x, (the correct answer) in the Spring of 2019. To more effectively assess and also help students while addressing the tricky nature of multiple choice questions, we eliminated the option of (x, y) answer for the points of intersection as an answer for the final assessment. As a consequence 72% of students chose the correct answer for the Fall 2019 assessment. The students' results are depicted in quantitative bar charts in **Appendix F**.

Supporting evidence-based change

It is clear to us that students struggle particularly with solving inequalities algebraically and from reading graphs, as opposed to solving equations algebraically and graphically. We recommend that more focus should be paid to the former topics in Math 140 since this is a paramount concept not only for College Algebra but for ensuing Calculus courses that rely heavily on the concepts learned in this crucial prerequisite course.

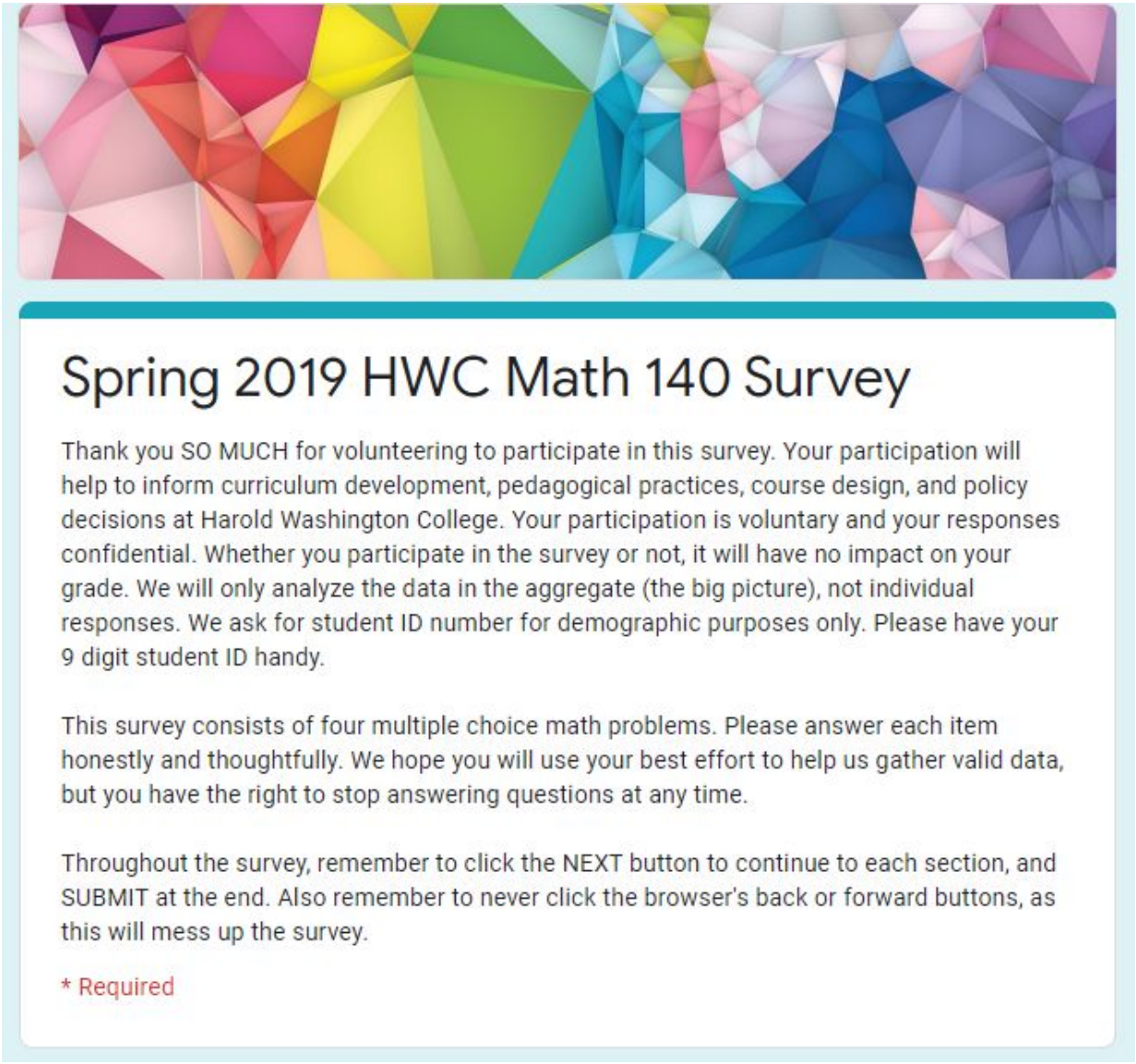
In the optimal and much hoped for likelihood of all us returning to school in the Fall of 2020, the continuing goal is to analyze the reports from the Fall 2019 and the Spring 2020 assessments results within the mathematics department. Ultimately, we will strive to use these findings to draw conclusions and to write recommendations for improving this specific SLO and optimize this very important course.

Conclusion

Throughout the Math 140 assessment process, the majority of full time faculty at the HWC Mathematics Department have worked jointly and successfully collaborated towards the same goal. We were able to get most part-time instructors teaching this course as well as online instructors from other colleges to also get involved in this process. It is encouraging that the number of responses gathered for the Math 140 assessment was so substantial, in spite of the unfortunate circumstances of this memorable Spring 2020 semester, thus providing an adequate and reliable sample size, and a continuing and unbroken collaboration between faculty at CCC.

Appendix

Appendix A



Spring 2019 HWC Math 140 Survey

Thank you SO MUCH for volunteering to participate in this survey. Your participation will help to inform curriculum development, pedagogical practices, course design, and policy decisions at Harold Washington College. Your participation is voluntary and your responses confidential. 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. We ask for student ID number for demographic purposes only. Please have your 9 digit student ID handy.

This survey consists of four multiple choice math problems. Please answer each item honestly and thoughtfully. 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.

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

* Required

Indicate your student ID# *

Note: Enter your 9 digit student ID (no dashes). This information is anonymous and is not linked to individual student performance in class.

Your answer

Next

Note: Each Option Button appears below its solution.

1) The following quadratic equation is solved 3t^2−12t−15=0. Which of the following is the correct procedure and solution? *

$3t^2 - 12t - 15 = 0$

$3t^2 - 12t = 15$

$3t(t - 4) = 15$

$3t = 0 \quad t - 4 = 0$

$t = 0 \quad t = 4$

Option 1

$3t^2 - 12t - 15 = 0$

$3t^2 - 12t = 15$

$3t(t - 4) = 15$

$3t = 15 \quad t - 4 = 15$

$t = 5 \quad t = 19$

Option 2

$3t^2 - 12t - 15 = 0$

$3(t^2 - 4t - 5) = 0$

$3(t - 5)(t + 1) = 0$

$t = 3 \quad t = 5 \quad t = -1$

Option 3

$3t^2 - 12t - 15 = 0$

$t = \frac{12 \pm \sqrt{(-12)^2 - 4 \cdot 3(-15)}}{2(3)}$

$t = \frac{12 \pm \sqrt{324}}{6}$

$t = 2 \pm 18$

$t = 20 \quad t = -16$

Option 4

$$3t^2 - 12t - 15 = 0$$

$$\frac{3t^2 - 12t - 15}{3} = \frac{0}{3}$$

$$t^2 - 4t - 5 = 0$$

$$t = \frac{4 \pm \sqrt{(-4)^2 - 4 \cdot 1(-5)}}{2(1)}$$

$$t = \frac{4 \pm \sqrt{36}}{2}$$

$$t = \frac{4+6}{2} \qquad t = \frac{4-6}{2}$$

$$t = 5 \qquad t = -1$$

◯ Option 5

2) The solution for the inequality x^2 − 4 ≥ 0 in interval notation is (-∞, -2] ∪ [2, ∞). Which of the following is the correct way of solving the inequality? *

$$x^2 - 4 \geq 0$$

Step 1: $x^2 \geq 4$

Step 2: $x \geq \pm 2$

◯ Option 1

$$x^2 - 4 \geq 0$$

Step 1: $x^2 - 4 = 0 \quad x = \pm 2$

Step 2:

x		-2		2	
$x^2 - 4$	+ + +	0	- - -	0	+ + +

◯ Option 2

$$x^2 - 4 \geq 0$$

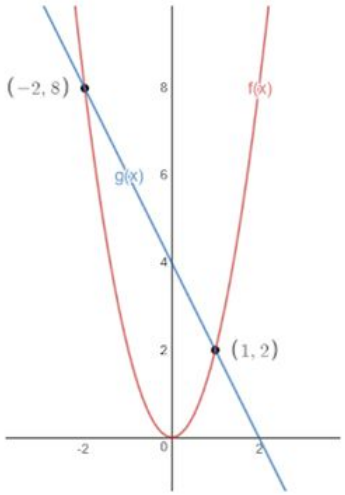
Step 1: $(x-2)(x+2) \geq 0$

Step 2: $x - 2 \geq 0 \qquad x + 2 \geq 0$

$$x \geq 2 \qquad x \geq -2$$

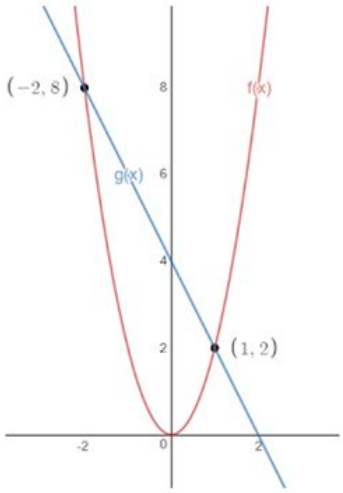
◯ Option 3

3) Use the graph below to answer the following question. What is the solution of the equation f(x) = g(x)? *



- (-2, 8) and (1, 2)
- x = -2 and x = 1
- y = 2 and y = 8

4) Use the graph below to answer the following question. What is the solution of the inequality f(x) < g(x)? *



- (-2, 1)
- (-2, 2)
- (-∞, -2) ∪ (1, ∞)

Appendix B

Fall 2019 Assessment

1) The quadratic equation, $3t^2 - 12t - 15 = 0$, is solved below. Which of the following is the correct procedure and solution?

Option 1

$3t^2 - 12t - 15 = 0$

$3(t^2 - 4t - 5) = 0$

$3(t - 5)(t + 1) = 0$

$t = 3 \quad t = 5 \quad t = -1$

Option 2

$3t^2 - 12t - 15 = 0$

$$t = \frac{12 \pm \sqrt{(-12)^2 - 4 \cdot 3(-15)}}{2(3)}$$

$$t = \frac{12 \pm \sqrt{324}}{6}$$

$t = 2 \pm 18$

$t = 20 \quad t = -16$

Option 3= Correct

Fall 2019 Assessment

$3t^2 - 12t - 15 = 0$

$t^2 - 4t - 5 = 0$

$$t = \frac{4 \pm \sqrt{(-4)^2 - 4 \cdot 1(-5)}}{2(1)}$$

$$t = \frac{4 \pm \sqrt{36}}{2}$$

$$t = \frac{4 + 6}{2} \qquad t = \frac{4 - 6}{2}$$

$t = 5 \qquad t = -1$

Spring 2019 Pilot Assessment

The following quadratic equation is solved $3t^2 - 12t - 15 = 0$. Which of the following is the correct procedure and solution?

$3t^2 - 12t - 15 = 0$

$$\frac{3t^2 - 12t - 15}{3} = \frac{0}{3}$$

$t^2 - 4t - 5 = 0$

$$t = \frac{4 \pm \sqrt{(-4)^2 - 4 \cdot 1(-5)}}{2(1)}$$

$$t = \frac{4 \pm \sqrt{36}}{2}$$

$$t = \frac{4 + 6}{2} \qquad t = \frac{4 - 6}{2}$$

$t = 5 \qquad t = -1$

Option 4

$3t^2 - 12t - 15 = 0$

$3t^2 - 12t = 15$

$3t(t - 4) = 15$

$3t = 0$ $\quad$ $t - 4 = 0$

$t = 0$ $\quad$ $t = 4$

Option 5

Fall 2019 Assessment

$3t^2 - 12t - 15 = 0$

$3t^2 - 12t = 15$

$3t(t - 4) = 15$

$3t = 3$ $\quad$ $t - 4 = 5$

$t = 1$ $\quad$ $t = 9$

Spring 2019 Pilot Assessment

$3t^2 - 12t - 15 = 0$

$3t^2 - 12t = 15$

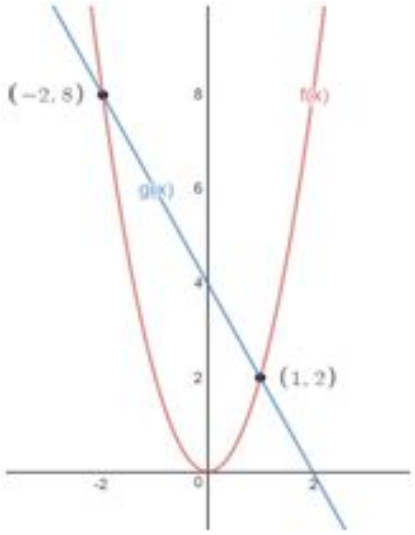
$3t(t - 4) = 15$

$3t = 15$ $\quad$ $t - 4 = 15$

$t = 5$ $\quad$ $t = 19$

Appendix C

Use the graph below to answer the following questions.



3) What is the solution of the equation f(x) = g(x)?

Fall 2019 Assessment

1) $x = 0$ and $x = 2$
2) $x = -2$ and $x = 1$ Correct
3) $y = 2$ and $y = 8$

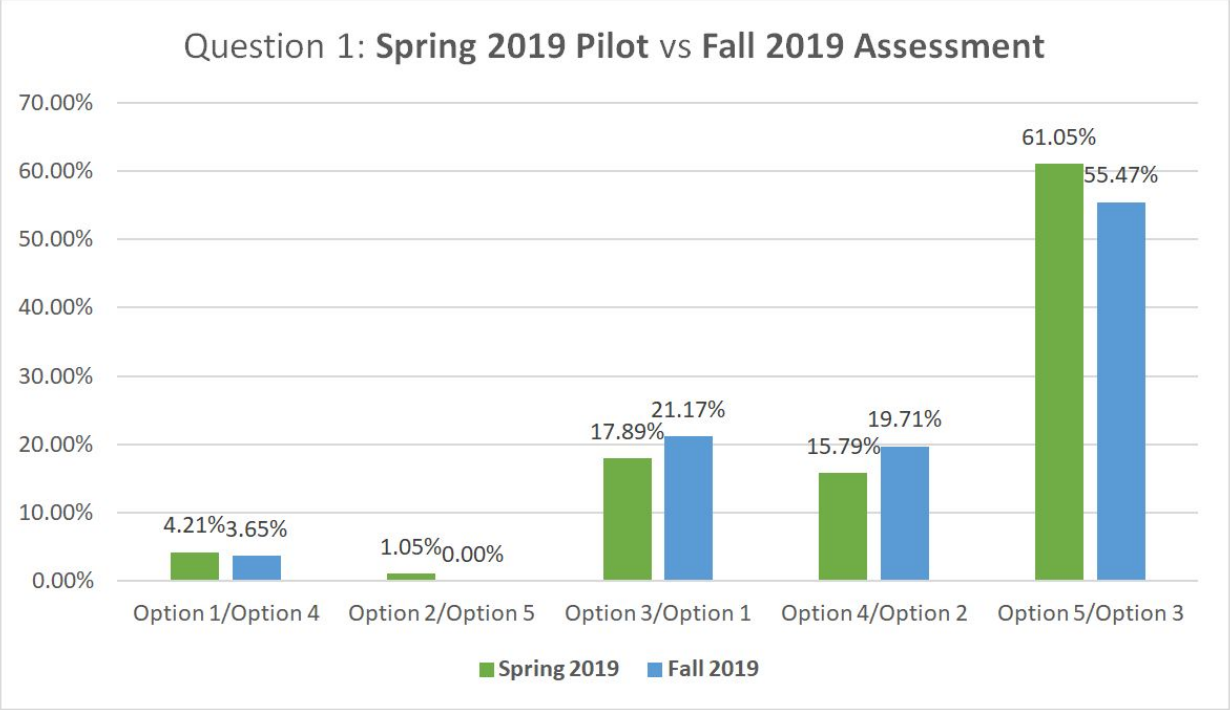
Spring 2019 Pilot Assessment

1) (-2, 8) and (1, 2)
2) $x = -2$ and $x = 1$
3) $y = 2$ and $y = 8$

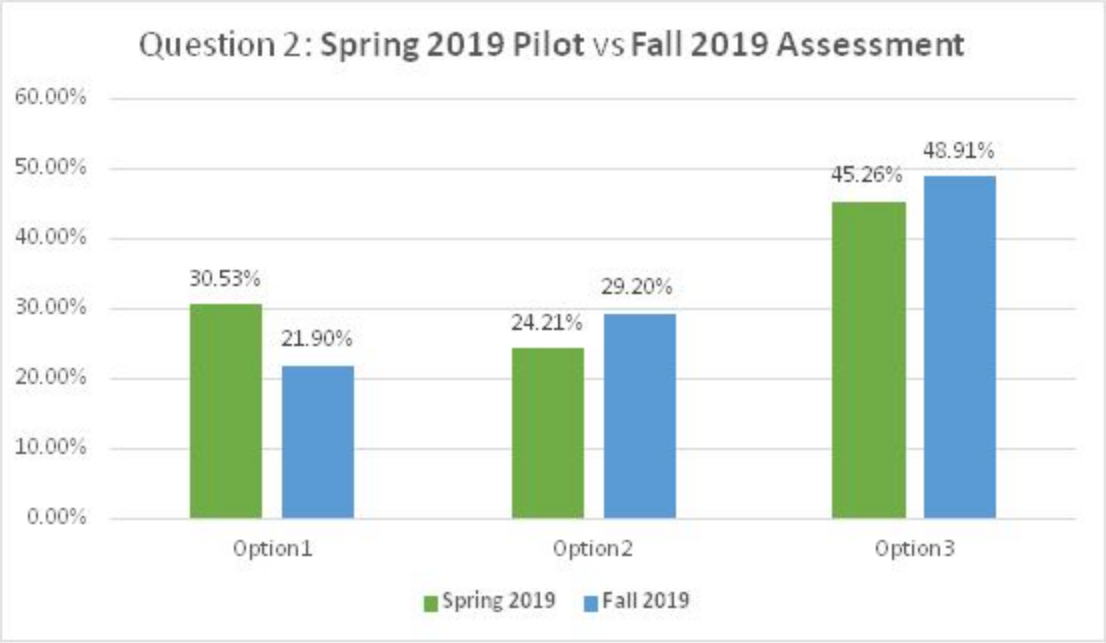
4) What is the solution of the inequality f(x) < g(x)?

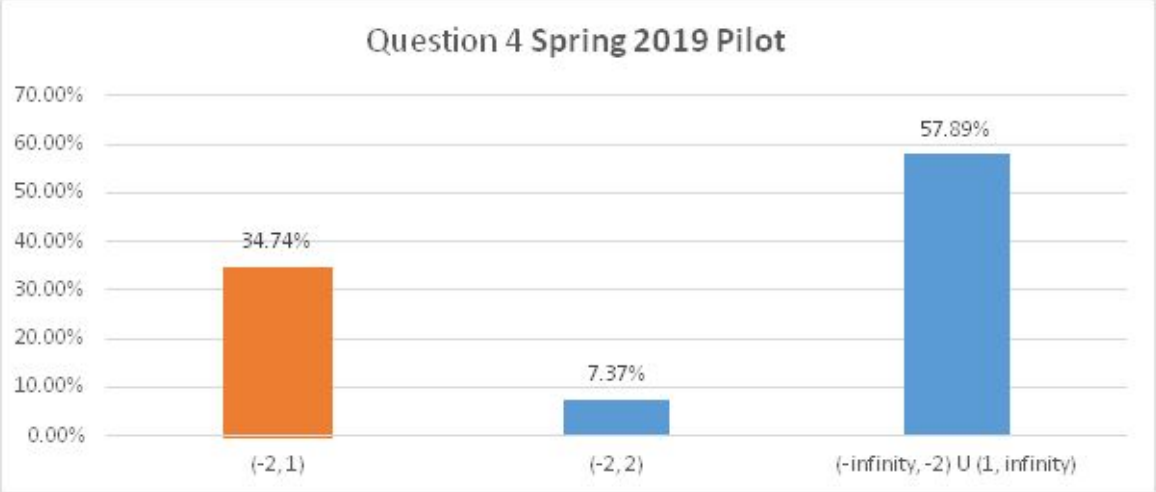
Fall 2019 Assessment	Spring 2019 Pilot Assessment
1) (-2, 1) Correct	1) (-2, 1)
2) (-∞, 0) ∪ (2, ∞)	2) (-2, 2)
3) (-∞, -2) ∪ (1, ∞)	3) (-∞, -2) ∪ (1, ∞)

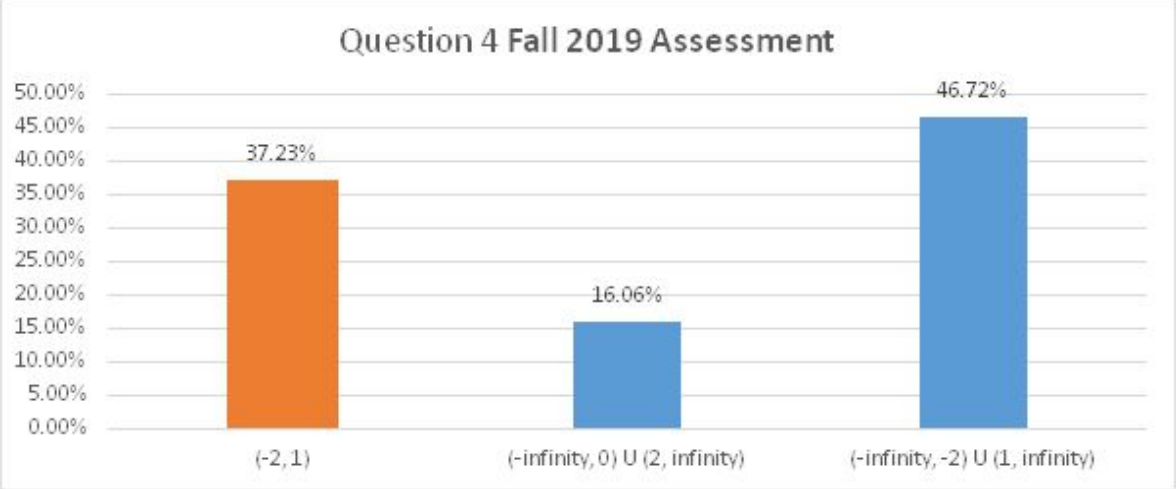
Appendix D



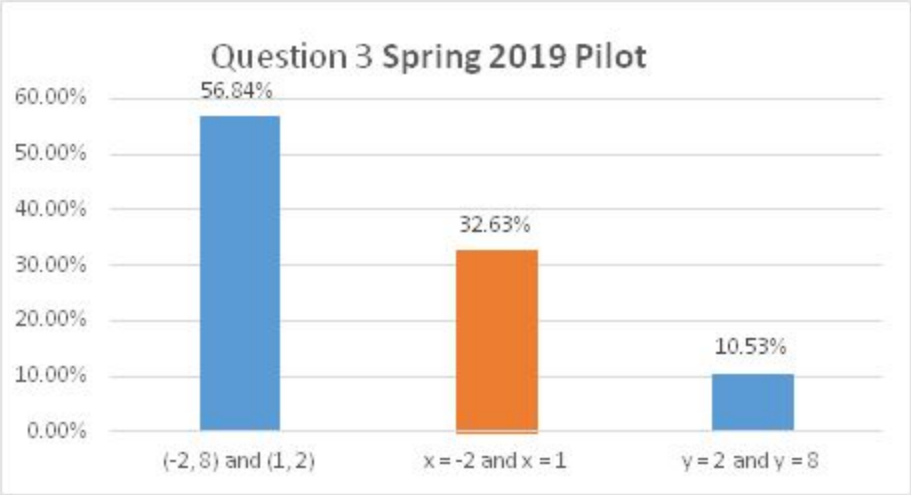
Appendix E

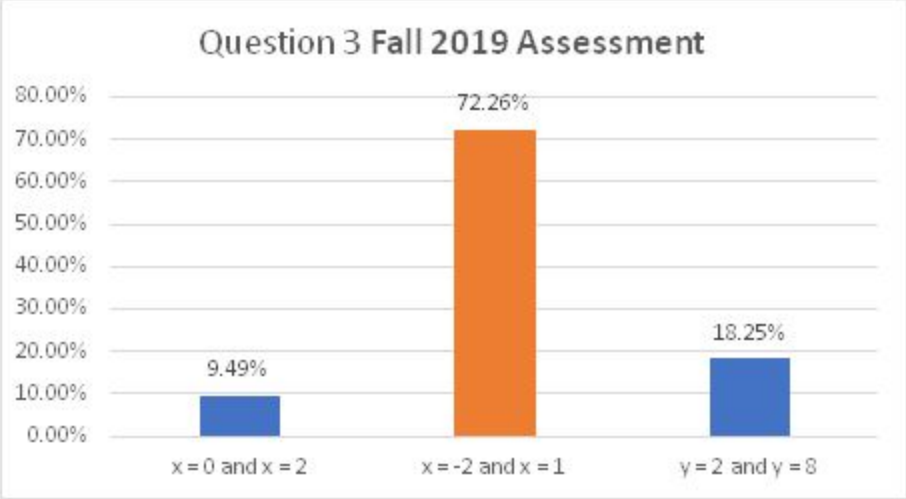

Question 2: Spring 2019 Pilot vs Fall 2019 Assessment
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
30.53%
21.90%
24.21%
29.20%
45.26%
48.91%
Option1
Option2
Option3
Spring 2019
Fall 2019


Question 4 Spring 2019 Pilot
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
34.74%
7.37%
57.89%
(-2,1)
(-2,2)
(-infinity,-2) U (1, infinity)


Question 4 Fall 2019 Assessment
50.00%
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
37.23%
16.06%
46.72%
(-2,1)
(-infinity,0) U (2, infinity)
(-infinity,-2) U (1, infinity)

Appendix F


Question 3 Spring 2019 Pilot
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
56.84%
32.63%
10.53%
(-2, 8) and (1, 2)
x = -2 and x = 1
y = 2 and y = 8


Question 3 Fall 2019 Assessment
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
9.49%
72.26%
18.25%
x = 0 and x = 2
x = -2 and x = 1
y = 2 and y = 8