Modeling Quarterback Passer Rating

Lesson Overview

One common use of modeling is the creation of a single numerical rating that incorporates multiple measures for the purposes of ranking products or people. This activity uses the measures commonly collected for football quarterbacks and provides an opportunity for students to create their own quarterback rating models. These can be compared to the formula in actual use by the National Football League (NFL) and to other formulas, such as that used by the National Collegiate Athletic Association (NCAA).

About the Lesson and Possible Course Connections:

The activity can be used with introductory algebra students, and lends itself to a group project assignment. There are nice connections to averages and ratios as a tool for analyzing information, in particular for accounting for the difference in the units associated with the data. The rating formula is a good example of a multivariable function, and its structure is easily analyzed. The activity could also be adapted for middle school students by using a smaller subset of the list of players.

Learning Goals

Students will be able to:

1. model a contextual situation mathematically and use the model to answer a question

2. represent data on two quantitative variables on a scatter plot, and describe how the variables are related.

3. find and interpret linear equations to model relationships between two quantitative variables;

4. use proportional relationships to solve real-world and mathematical problems.

CCSS Standards

Algebra Standards:
- A-SSE.B, A-SSE.B.1
- A-SSE.A, A-SSE.A.1
- A-CED.A, A-CED.A.2
- A-SSE.A.3

Interpreting Data Standards:
- S-ID.B, S-ID.B.6

Ratio and Proportional Relationships Standards:
- 7.RP.A, 7.RP.A.1

Mathematical Practice Standards
- SMP.4

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Lesson Materials

- Compatible TI Technologies:

    TI-84 Plus*; TI-84 Plus Silver Edition*; 🌈TI-84 Plus C Silver Edition; 🌈TI-84 Plus CE

    * with the latest operating system (2.55MP) featuring MathPrint ™ functionality.

    TI-Smartview CE software

- Modeling QB Passer Rating_Student.pdf

- Modeling QB Passer Rating_Student.doc

- Modeling QB Passer Rating.8xp

- Modeling QB Passer Rating_84CE.pdf

- Modeling QB Passer Rating_84CE.doc

Background

Who is the GOAT (greatest of all time) among past and current NFL quarterbacks? Many passing statistics are gathered for quarterbacks, including numbers of passing attempts, completed passes, yards gained, touchdown passes, and on the negative side, interceptions. How can all this information be combined in a way that allows us to give each quarterback a single numerical rating that could be used to compare and rank different quarterbacks? Students will use the data provided in the Appendix or in the calculator file, which can be provided directly to them containing the data.

> **Teacher Tip:** Students should run the QBSTATS program to store the data on their calculator. If they enter the data by hand, they are likely to make errors. Younger students might work with a subset, for example the current players. Students do not need a background in regression or multiple regression; they can think about different ways to combine the numbers in order to create a model for rating each quarterback based on the data. If they do have a background in regression, encourage them to think about other alternatives as well. Students do not really have to have a background in football (although it might make the task more interesting). Knowing that they are looking for a way to rank the players from best down, they can just play with the numbers. They may choose to use part or all of the information but should have some reason for their decision.

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👥 Facilitating the Lesson

Introduction: Present the class with the data – either projected or paper copies (See Appendix). Begin the discussion by having each student write down the answers to the following questions.

1. What do you notice? (Some made a lot of touchdowns and some not so many; Aaron Rodgers has very few interceptions; Tom Brady, Drew Brees, Brett Favre and Peyton Manning made more yards passing compared to all of the others; Favre had a lot of interceptions compared to the others, …)
2. What do you wonder about? (If the interceptions balance out the touchdowns, does that indicate a "mediocre" quarterback? Are the quarterbacks with the most touchdowns really the best?)
3. Which of the data do you think most important? Least important? Are the number of attempts important? Why or why not?

Discuss the answers with the class, recording the things students notice and wonder on the board or chart paper. I After the class has responded, if someone wonders who the best quarterback is, tell the class that is what you are going to investigate. If it does not occur in the wonderings, point out that sportswriters and others are wondering about who is best, so you are going to investigate. (Save the other wonderings as possible further investigations).

There are several ways this lesson can be implemented in the classroom:

1) Open-Ended Approach:

First**,** ask the students to think alone for a few minutes and then write down how they would start to rank the quarterbacks. Then, put them in pairs or threes for further discussion.

Student Instructions: In your groups,

- Exchange your ideas.
- Decide as a group how you will begin to analyze the data. Give each member of the group a job to do that will help you in the work.
- Decide whether your approach seems reasonable for the data. Explain why you think your model is good for rating the quarterbacks. What are the drawbacks, if any, to your model?

2) More-Structured Approach to Finding a Model:

Put students into groups to find a method to rate the players. Remind them that they will be expected to defend their process for rating the players. Pose the following questions to help push their thinking:

- Will a graph help?
- What relationships might you explore graphically to help determine a formula?
- Are all of the categories equally important? Why or why not?
- How can you account for a quarterback who played for many years as opposed to one who played for much less time.
- Can you create a formula?

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What to Expect: Example Student Solutions

EX 1: Graphing the Data

Some students might consider graphing the data. For example, if a scatter plot of (completions, touchdowns) is graphed, the relationship between completions and touchdowns seems to be linear (figure 1). Help them consider all of the data: for example, what happens with a quarterback who has high numbers of both completions and touchdowns, but also has a lot of interceptions (figure 2)?

Figure 1: Touchdowns vs. Yards Gained

Figure 2: Interceptions vs. Touchdowns

Students may investigate why it might be useful to divide by the number of attempts and should explain why the outcomes are different (Figures 3 and 4).
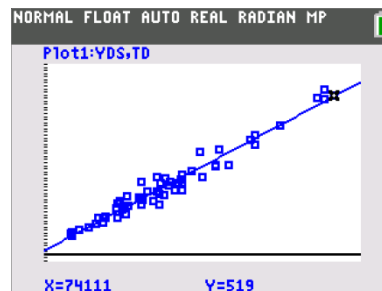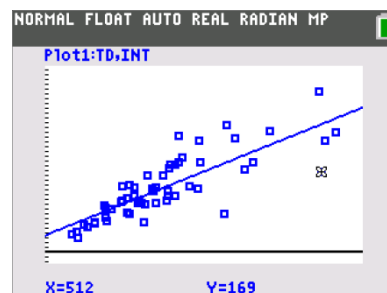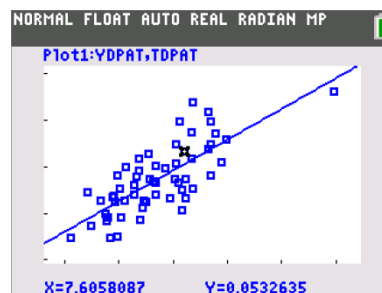

Figure 3: Touchdowns vs Yards Gained but now accounting for attempts
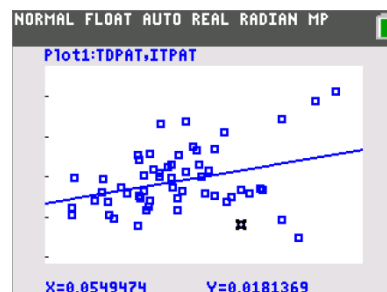
Figure 4: Interceptions vs. Yards Gained but now accounting for attempts

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EX #2: Creating a Formula

Some students might create a formula; they should recognize that using averages (rates) per attempt (for example, yards per attempt, completions per attempt, etc.) rather than counts might be useful for comparing two players with very different numbers of attempts – dividing by the number of attempts can accomplish this. One possible such model might be the following, where the interception rate is subtracted from the others.

$$\frac{C}{A} + \frac{T}{A} + \frac{Y}{A} - \frac{I}{A} = R$$

Notice that Y (measured in yards) is much larger than the other values, so this simple sum of averages makes the contribution of yards per attempt to the rating R much greater than any of the other averages.

To account for this, different coefficients (weights) for the terms could be introduced to adjust for the different sizes of these averages, as well reflecting some subjective judgment of their relative importance. For example, one such weighting might be:

$$5\frac{C}{A} + 10\frac{T}{A} + 2\frac{Y}{A} - 10\frac{I}{A} = R$$

Some students might look for a way to compare each player's performance "score" in a category (such as touchdowns per attempt) to the best "score" achieved among all the players. For example, Graham's touchdowns per attempt is the best of all players at 0.066, so each player's touchdowns per attempt could be divided by 0.066 to get a statistic relative to Graham's best performance, which would be 1.0 (from 0.066/0.066). Brees' touchdowns per attempt average of 0.053 would be converted to the value 0.053/0.066 = 0.80 or 80% of the best performance in the data. A similar benchmark for each data category could be computed, and the other players' scores converted to this new scale. These converted scores, now on the same scale could be combined to create an overall rating for each player.

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📌 Validating the Models

Students should validate their models either by asking whether the models make sense in different scenarios related to the context or by finding other information to reflect against the model. One strategy might be to have each group consider whether the models created by other groups make sense.

Some questions are suggested below that might be useful in helping students think about whether their model was reasonable:

- How do the rankings of the quarterbacks by different groups in class compare to each other? What might explain any big differences?
- Would different graphical representation generate different rankings that are reasonable? Why or why not?
- What is the highest rating someone could have from the model? The lowest? Do these extremes make sense?
- Popularly, several quarterbacks have been recognized as being "great" (e.g., Aaron Rodgers, Drew Brees, Tom Brady, …) Does the model place them appropriately? What might need to be changed in the model to take the statistics for these players into account?
- One of the "great" quarterbacks from many years ago was Johnny Unitas, who played with the Baltimore Colts from 1956 to 1973. He had 5186 attempts, made 2830 completions, 290 touchdowns and 253 interceptions. The total number of yards gained in passing was 39,768. Would the model place him in a rank that made sense? Why did he not earn a place in this set of top quarterbacks?
- One of the up and coming quarterbacks is Patrick Mahomes, of the Kansas City Chiefs with 724 completions, 1099 attempts, 9,412 yards gained, 76 touchdowns and 18 interceptions after the 2019 regular season. Would the model place him in a sense making rank?

🔍 Extension

Consider the actual formula* used by the NFL to rate quarterbacks described below, where :

A = attempts	T = touchdowns	Y = yards gained
C = completions	I = interceptions	

Method 1. The NFL quarterback rating R is given by this formula:

$$R = \frac{50 + 2{,}000\dfrac{C}{A} + 8{,}000\dfrac{T}{A} - 10{,}000\dfrac{I}{A} + 100\dfrac{Y}{A}}{24}$$

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Discussion Questions:

1. What are some interesting questions you might pose about this formula?
2. An alternate approach is described below as Method 2. How do the two approaches compare?
3. Find the ratings for the quarterbacks in the table using either the formula or the method 2, described below. How did your model compare to the one used by the NFL?

Method 2. Here is an alternative method of computing the NFL quarterback rating *R*:

Step 1: Complete passes divided by pass attempts. Subtract 0.3, then divide by 0.2

Step 2: Passing yards divided by pass attempts. Subtract 3, then divide by 4.

Step 3: Touchdown passes divided by pass attempts, then divide by .05.

Step 4: Start with .095, and subtract interceptions divided by attempts. Divide the product by .04.

The sum of each step cannot be greater than 2.375 or less than zero. Add the sum of Steps 1 through 4, multiply by 100, and divide by 6.

Discussion Question:

4. Are the two methods really equivalent? Why or why not?

* https://en.wikipedia.org/wiki/Passer_rating

5. College quarterbacks are rated using a different formula:

$$R_{NCAA} = \frac{8.4\, Y + 330\, TD \ + 100\, C - 220\, I}{A}$$

How would the ranking from this formula compare to your model? What about to the NFL method?

6. Choose a model (yours, the NFL or the College Ranking) to rate the quarterbacks in your school's league. How well do you think the ranking works?

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Appendix: Data Set for Lesson

The table below shows the results of using the NFL quarterback rating formula (either Method) for these quarterbacks. In the student handout there is a copy of this table without the rating column.

NFL **Ratings** based on the NFL Quarterback ranking formula (Method 1) given earlier:

	TDs	Pass completion	Yds gained	Attempts	Interceptions	Rating
Troy Aikman	165	2898	32942	4715	141	81.6
Kent Anderson	197	2654	32838	4475	160	81.9
*Tom Brady	512	5967	70138	9318	169	97.6
*Drew Brees	519	6559	74111	9744	233	97.8
*Sam Bradford	103	1855	19449	2967	61	84.5
Marc Bulger	122	1969	22814	3171	93	84.4
*Derek Carr	122	1716	18387	2741	87	89.2
Jay Cutler	227	3048	35133	4920	160	85.5
Kurt Cousins	125	1756	20119	2641	65	94.8
Dante Culpepper	149	2016	24153	3199	106	87.8
Randall Cunningham	207	2429	29979	4289	134	81.5
*Andy Dalton	188	2443	28100	3921	104	88.8
Len Dawson	239	2136	28711	3741	183	82.6
Boomer Esiason	247	2969	37920	5205	184	81.1
Brett Favre	508	6300	71838	10169	336	86.
*Joe Flacco	212	3499	38245	5670	136	84.1
Dan Fouts	254	3297	43040	5604	242	80.2
Rich Gannon	180	2533	28743	4206	104	84.7

Jeff Garcia	161	2264	25537	3676	83	87.5
Otto Graham	174	1464	23584	2626	135	86.6
Trent Green	162	2266	28475	3740	114	86
David Garrard	89	1406	16003	2281	54	85.8
Brian Griese	119	1752	19440	2794	99	82.7
Matt Hasselbeck	212	3222	36638	5330	104	82.4
Sonny Jurgensen	255	2433	32224	4262	189	82.6
Colin Kaepernick	72	1011	12271	1692	30	88.9
Dave Krieg	261	3105	38147	5311	199	81.5
*Casey Keenum	61	1090	12167	1759	39	85.5
Jim Kelly	237	2874	35467	4779	175	84.4
*Andrew Luck	166	1945	23029	3208	81	89.3
* Eli Manning	357	4755	55371	7898	237	84.2
Peyton Manning	539	6125	71940	9380	251	96.5
Dan Marino	420	4967	61361	8358	252	86.4
*Marcus Mariota	69	1005	11894	1592	42	89.5
Donovan McNabb	234	3170	37276	5374	117	85.6
Steve McNair	174	2733	31304	4544	119	82.8
Joe Montana	273	3409	40551	5391	139	92.3
Warren Moon	291	3988	49325	6823	233	80.9
*Cam Newton	182	2321	28469	3891	107	86.7
Carson Palmer	294	3941	46247	6307	187	87.9
Chad Pennington	102	1632	17823	2471	64	90.1
*Matt Ryan	290	4006	46103	6131	132	94.6

* Philip Rivers	373	4481	54299	6939	174	96
*Aaron Rodgers	336	3520	42476	5432	80	103.1
* Ben Roethlisberger	388	4552	55527	7073	189	94.1
Tony Romo	248	2829	34183	4335	117	97.1
*Matt Schaub	133	2098	24887	3281	90	89.1
*Alex Smith	193	3082	34068	4941	101	87.3
Roger Staubach	153	1685	22700	2958	109	83.4
*Matthew Stafford	235	3334	38144	5341	129	88.4
Bart Starr	152	1808	24718	3149	138	80.5
Ryan Tannehill	122	1796	20141	2858	72	87.8
Fran Tarkenton	342	3686	47003	6467	266	80.4
Kurt Warner	208	2666	32344	4070	128	93.7
*Russell Wilson	192	2065	25201	3211	62	100.3
*Jameis Winston	83	1127	13947	1839	57	87.3
Steve Young	232	2667	33124	4149	107	96.8

* Active in 2018

Resources

https://en.wikipedia.org/wiki/List_of_National_Football_League_career_passer_rating_leaders
career stats at nfl.com
Data can also be found by searching for each individual player's individual statistics.