

Spreadsheet check figures and guided errors for problem-solving instruction

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ABSTRACT

Functions and formulas in spreadsheets provide an instructional opportunity to help students build their skills in identifying errors in their own work and identifying a path to go about correcting the errors. This paper provides examples of functions and equations used to create two approaches to calculating the solution to one problem, such as a weighted average calculation or a loan payment calculation. Solving the problem two ways gives students the opportunity to see why both approaches work and to reconcile them if errors cause the results to differ. Using a guided errors pedagogy, instructors can also create an error in one computational approach so that students then work to reconcile the two. This method helps build problem-solving skills and confidence in a process for persisting to resolve errors. Learning from failure and correcting errors in one's work can contribute to perceptions of self-efficacy.

Keywords: spreadsheets, problem-solving skills, guided errors, learning from errors, self-efficacy

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INTRODUCTION AND LITERATURE

This paper demonstrates how exercises in spreadsheets can help students build their skills in identifying errors in their own work and identifying a path to go about correcting the errors. This method helps build problem-solving skills and confidence in a process for persisting to resolve errors. These objectives are supportive of a growth mindset by showing learners how to organize and direct their efforts in building skills. The next section reviews literature relevant to these skills and objectives. Example exercises are then presented and explained.

Problem-solving, Growth Mindset, and Self-efficacy

A premise of the growth mindset is that skills can be developed through one's effort (McGuire, 2015; Rege et al., 2021). Problem-solving skills are beneficial for both personal and professional development. Problem-solving has been associated with academic performance, motivation, and social adjustment, and employers identify problem-solving as important for succeeding in work environments (de la Fuente et al., 2022; Schefer-Wenzl & Miladinovic, 2019; Weaver & Kulesza, 2014). The metacognitive strategies of a growth mindset have been found to be related to performance in problem-solving (Akama, 2006). Practice in problem-solving can reinforce the growth mindset when repeated efforts drive progress in successfully finding a solution for a problem, thus demonstrating a payoff for effort.

Efforts to build problem-solving skills involve tackling problems and working to solve them. With such efforts, students both learn a process for problem-solving and increase their confidence in their ability to follow the process to a successful resolution. Confidence in one's ability is captured in the concept of self-efficacy. Perceived self-efficacy is defined as beliefs about one's own capabilities to achieve specified levels of performance (Bandura, 1994). This perception aligns with the foundations of growth mindset. People who are confident in their capabilities view difficult tasks as interesting challenges and opportunities rather than avoiding them, and an expectation of being effective in attempts supports intrinsic interest in activities (Bandura, 1994). Research has found a positive relationship between self-efficacy and academic performance (Brady-Amoon & Fuertes, 2011; Ramos Salazar & Hayward, 2018). Self-efficacy has been associated with student engagement and motivation (Panda, 2021; Ramos Salazar, 2018). Self-efficacy has also been related to behaviors and approaches such as goal-setting (Akama, 2006) and decision-making (Karpinski et al., 2020).

Self-efficacy expectancies were found to be the best predictor of persistence in subsequent attempts following a failed attempt on a task (Jacobs, Prentice-Dunn & Rogers, 1984). Persistence despite failure is necessary for improving over time and building skills. Bandura (1994) noted that individuals with self-efficacy attribute failure to missing or deficient skills which can be acquired through one's effort. Problem-solving often requires resolving and rectifying errors in order to reach the solution. These errors could be mistakes of one's own making or errors detected in work completed by others (such as work of teammates, team leaders, managers, or auditors). Kapur (2014) noted that learning from one's own failed problem-solving attempts or from those of other students was associated with improved performance for students learning math. The pedagogy of learning from failure has been suggested as a method for teaching problem-solving (Peschl, Deng & Larson, 2021), and classroom exercises illustrating how well-known individuals have overcome failures and setbacks (Thompson, 2020) has been found to promote student understanding of the growth

mindset. Highlighting errors rather than working to prevent them has been identified as an effective teaching approach. In that context, guided errors that direct students into and out of common mistakes were found to increase performance and self-efficacy (Lorenzet, Salas & Tannenbaum, 2005). This paper presents spreadsheet examples that help students learn to identify and correct errors in the math formulas and functions used in spreadsheet analyses. The next section explains the usefulness of spreadsheets for this purpose.

Spreadsheets for Problem-Solving

Spreadsheets are a tool for analyses in business. While Excel as a component program of Microsoft Office is widely used, other developers include spreadsheets with similar functionality such as Google Sheets and Numbers for Mac. The wide use and application of spreadsheets means that students who practice with them are building experience directly related to work or volunteer settings. Spreadsheet programs perform math and statistical calculations when the user enters formulas and functions. Research has demonstrated that math, programming and writing formulas, and relevant experience are associated with self-efficacy, motivation, and learning. In a study of students in computer programming, Kittur (2020) found that self-efficacy is associated with prior experience. In a study of student motivation in business statistics courses, Ramos Salazar (2018) found that math self-efficacy was positively associated with motivation in working on statistics. These findings suggest that experience and practice can increase students' self-efficacy and, further then, their motivation to engage with and persist with tasks such as programming and math. In a study of spreadsheet instruction for marketing students, Ganesh and Paswan (2010) noted that students' self-efficacy is associated with efforts by the instructors to increase the perception that the course is useful rather than to increase the difficulty. The common use of spreadsheets as a tool in business analysis makes them an advantageous setting for demonstrating relevancy between coursework and one's professional life.

In addition to the structured display and organization of data, spreadsheets will perform math and logic calculations. If the user enters a formula or function with the proper syntax, the spreadsheet will perform the command and return the result. However, the answer is correct only if the formula, function, or analysis is entered correctly. As long as the data will mathematically permit a calculation, the spreadsheet will generate a result. But the spreadsheet does not know if the formula was entered correctly and if the answer is correct for the analysis that the user is trying to perform. One way that students can reduce errors and increase correct answers for analyses when learning to use spreadsheets is to recognize that there will often be more than one way that a problem can be solved in a spreadsheet. These multiple approaches allow users to create check figures to troubleshoot their own work and allow instructors to construct exercises with guided errors for instructing students to solve problems in spreadsheets. If two approaches should produce the same result but those results do not match, then learners are alerted to an error and have a place to begin working to correct it.

A simple illustration of a problem being solved two ways in a spreadsheet is a basic addition problem. For example, summing the four numbers in cells A1 through A4 could be entered as the formula $=A1+A2+A3+A4$. Alternatively, this problem could be approached with the SUM function that would total the four cells with the entry $=SUM(A1:A4)$. If the two approaches produced different answers, troubleshooting might reveal, for instance, that the first formula was entered as $=A1+A3+A4$ with one of the numbers omitted in error. Or, the first formula might be discovered to be $=A1+A2+B3+A4$ with a wrong cell entered. Different errors

could cause the problem, but they could both be revealed using the two-method, check figure approach.

The following sections of this paper will provide examples of, first, basic analyses solved two ways in spreadsheet formulas and functions and, second, examples of basic errors for use as problem-solving illustrations.

Learning Objectives

The exercises and pedagogical approach presented in this article support the following learning objectives for students who are building skills with spreadsheets. Students working with these exercises will learn:

1. How check figures for identifying errors in calculations can be created in spreadsheets by using two different formulas, functions, or approaches
2. How approaching a problem with two different methods can help identify and correct errors
3. How the error identification process can help build problem-solving skills and confidence

EXERCISES WITH ANALYSES APPROACHED TWO WAYS

The following paragraphs explain three examples of check figures with two approaches for performing the same basic calculation. Because these analyses involve math calculations, the different approaches for the same problem should produce the same result or otherwise confirm the correct answer. Having two approaches to address an analysis provides a learner with a way to identify and correct errors.

Example 1: Weighted Average

The example in Table 1 (Appendix) illustrates the calculation of a weighted average using the common application of the calculation of a course grade. In the Table 1 example, the weights for the assignments are percentages totaling to 100%. However, the same formulas and functions will apply if the weights are points (i.e., 10 points for Homework 1, 15 points for Homework 2, etc.).

In this example, the weighted average is calculated using two approaches. In the first formula shown on row 9 of the table, the weight for each assignment is multiplied by its grade and then, that total is divided by the sum of the weights. The second approach is shown on row 12 using functions. The SUMPRODUCT function accomplishes the multiplication of each weight by each grade, and the SUM function totals up the weights to complete the calculation of the weighted average. Both approaches produce the same result of 85.35 for the weighted average grade. If the approaches produced two different answers, the student would be alerted to an error.

Example 2: Loan Payment and Amortization Table

The example in Table 2 (Appendix) illustrates a loan payment. The two approaches to the analysis include the calculation of a monthly payment for the loan and the amortization table that shows how the monthly payment fully repays the loan. In this case, rather than calculating

the payment amount two different ways, the payment amount is used in the amortization table. An error is indicated if the payment amount does not result in the loan principal being reduced to a \$0 balance at the end of the loan term. In this way, the learner can confirm that the calculation of the payment is correct.

Rows 1 through 4 in Table 2 show the inputs for and calculation of the payment function. Row 5 in the table shows the details of the function that students would enter to generate the payment shown in cell B4. The payment function (PMT) generates the periodic payment to repay a specified amount at a specified interest rate. The example here is using months as the periods. To generate this monthly payment, the annual interest rate shown in cell B2 must be converted to monthly (divided by 12) and the term years shown in cell B3 must be converted to months (multiplied by 12). The example shown in row 5 is making these conversions directly in the PMT function.

The amortization table for this loan is shown beginning in row 7. For efficiency of presentation, months 5 – 21 are omitted from Table 2. Beginning in row 34 of Table 2, the formulas are shown for computing the amount of interest paid, amount to principal, and remaining loan balance. If the monthly payment has been calculated correctly (from rows 1 – 4), then the loan balance will be zero at the end of the loan term. This result is shown in cell F32 which is the Principal Balance column for month 24 (the final month of the loan term).

Example 3: Sum of Squares and Concentration Index

The example in Table 3 (Appendix) presents a sum of squares calculation using companies' market shares in an industry. As shown in the example formula in row 16 or 17, the sum of squares can be calculated as a formula that squares each number and sums the squared figures. Alternatively, as shown in row 20, the function SUMSQ in Excel will perform the same calculation of squaring the numbers and summing the squares. If the two approaches do not produce the same result, the analyst is alerted to an error in one of them.

One application of a sum of squares in business analysis is as a concentration index. The United States Department of Justice (USDOJ) uses the sum of squares for analyzing industry concentration when analyzing requests to approve mergers and acquisitions between businesses. Used this way by the USDOJ, the sum of squares is identified as the Herfindahl-Hirschman Index (United States DOJ, 2018). The Table 3 example illustrates this industry concentration calculation with the index (as in cell B14 or cell B19) being the sum of the industry member companies' squared market shares. The companies shown in cells A5 through A11 are all members of the industry, and their market shares in column B total 100% as shown in cell B12 (accounting for all sales in the industry). The concentration index in cell B14 is calculated using the math equation that squares the shares and sums them. The same answer is obtained in cell B19 using the SUMSQ function. If two of the companies proposed to merge, the index before the merger would be compared with the estimated index calculated under the assumption of two companies combining in a merger. For example, the new market share for combined Company D&E could be estimated at 28% post-merger and the index recalculated.

The concept of a measure for concentration can be applied to other real-world analyses such as concentration of revenues for one corporation having multiple subsidiaries. The sum of squares would be calculated using the percentage that each subsidiary's revenues are of the corporation's total revenues. That index could be compared with percentages in another year to examine changes in concentration over time or compared with other corporations to analyze

dependence on few or balance across several revenue streams. A concentration index could also examine the concentration of product development projects in a business' portfolio. Using the numbers of products in a particular innovation category such as an industrial classification code or a science field and determining the percentage that each category is of the total number of products under development, a concentration index can be calculated for the product development portfolio.

EXAMPLES OF GUIDED ERRORS

Training that guides learners to work through common errors has been associated with higher performance and self-efficacy compared with training focused on preventing errors (Lorenzet et al., 2005). The following examples illustrate errors that can be created in these spreadsheet exercises for students to identify and solve. As presented above, there are two approaches for the calculations in the examples. In the following guided errors, both calculations are already completed, but there will be an error in one so that the two answers do not match. The students' assignment would be to figure out which formula is wrong, why it is wrong, and the change that will correct it. This method gives students the opportunity to learn both why the errors are errors and why the correct formulas are correct. Further, they gain experience with common errors and how they occur.

Errors Example 1: Weighted Average

Table 4 (Appendix) repeats the weighted average example shown above but includes calculations that produce different answers because they contain errors. There are two error examples to illustrate different ways that errors can be created. For learners who are new to spreadsheets, the instructor could opt to use only one of the errors so that learners have only to compare two calculations to identify one with an error and one that is correct. The formula details that are written in cells D9, D12, and D15 of Table 4 are shown here for convenience, but these would not be written for the students. The students would examine the contents of the cells C8, C11, and C14 to find the formulas and functions being used to generate the results.

Comparing Error 1 (shown in cell C8 in Table 4) to the Correct Answer (cell C14) reveals that one contains an error because the results differ. Students would need to investigate both to determine which is correct and which is erroneous. For convenience here, the erroneous formula is identified. The formula for Error 1 contains an incorrect math symbol. Because the weighted average calculation involves multiplying the weights by the grades and summing those results, the numerator of the formula as shown in row 9 (detailing the contents of cell C8) contains both multiplication and addition symbols. One of the symbols that should be multiplication is, instead, addition. Specifically, at the end of the expression in the first set of parentheses, B6 should be multiplied by C6 instead of added. This error offers the opportunity to show discuss with students how care is necessary when entering formulas, for example, that contain several mathematical signs.

Comparing Error 2 (shown in cell C11) to the Correct Answer shows that parentheses were not used in the entry containing an error. The math expressions both preceding and following the division sign (/) should be enclosed in parentheses. With the parentheses omitted, the order of operations is incorrect. This error offers an opportunity to discuss with students the

importance of the order of operations and how to ensure the order is followed in spreadsheet entries.

Another error that could be used would be omitting a cell reference (such as B6 of the denominator) from the formula. If a term is missing from the denominator, the full total of the weights is not included in the weighted average calculation. Such an error highlights how omissions can occur when entering formulas and that the spreadsheet will perform the calculation and produce an answer anyway.

Errors Example 2: Loan Payment and Amortization

Table 5 (Appendix) repeats the loan payment example from above, but it reflects an error. The fact that an error exists is revealed by the amortization table which shows the loan principal balance at approximately zero in month 13 and then becoming negative over the remaining months of the loan term. Since the amortization table does not reach zero in month 24 as it should, one problem-solving approach would be to check the formulas in the amortization table to make sure they are working properly. Upon determining that the formulas in the table are set up correctly, the learner could then turn to checking the payment (PMT) calculation. The formula in row 5 is labeled here as an error, but the label would be omitted for students. The error in this entry is that the interest rate is not divided by 12 to convert to a monthly rate to correspond to the monthly time period for the payment. The correct entry, as shown earlier in Table 2, is $=\text{PMT}(\text{B}2/12, \text{B}3*12, \text{B}1)$. This example illustrates a common error of not having the period of the interest rate (here, months) match the period of the loan terms (months). The class discussion could center on the nature of the PMT function that specifies “periodic” payments and requires that the user entering the function understand what “period” of time is the basis for the calculation (whether annually, quarterly, monthly, etc.).

Alternatively, rather than having an error in the payment calculation, an error could be introduced into the amortization table. For example, if the formula for the amount applied to interest is $=\text{B}2*\text{F}9$ instead of the correct formula, then the amount to interest each month will be greater than the amount to principal (assuming the PMT calculation is correct as shown earlier in Table 2). This amortization table error can lead to a discussion of interest rates as percentages.

Errors Example 3: Sum of Squares and Concentration

Table 6 (Appendix) presents the sum of squares example from above but with an error. In this case, the error is in the cell that uses the function SUMSQ (cell B19). Instead of covering the correct range of the data to be analyzed, the function has added a cell. While the function should be $=\text{SUMSQ}(\text{B}5:\text{B}11)$, it is entered as $=\text{SUMSQ}(\text{B}5:\text{B}12)$ which erroneously includes the cell for the total of the market shares (B12). This error illustrates the need for caution when selecting a range of cells for a spreadsheet function to ensure that the necessary set of cells is included rather than too many or too few.

CONCLUSION

Learning and a growth mindset are supported by the ability to identify errors in one’s work and persist in correcting the errors. Developing the skills to correct and learn from errors is

associated with self-efficacy. This paper has presented analyses and problems in spreadsheets as a setting for students to gain experience with a problem-solving process and confidence in math operations in business analyses. By learning to approach one problem with two formulas, students can create check figures to investigate the accuracy of a solution and to identify the source of an error.

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APPENDIX

Table 1
Example 1: Weighted Average

	A	B	C	D
1	Assignment	Weight	Grade	
2	Homework 1	10%	92	
3	Homework 2	15%	87	
4	Project	20%	84	
5	Exam 1	25%	76	
6	Final Exam	30%	91	
7		100%		
8			85.35	= Weighted Average Grade calculated with formula
9				$= (B2 * C2 + B3 * C3 + B4 * C4 + B5 * C5 + B6 * C6) / (B2 + B3 + B4 + B5 + B6)$
10				
11			85.35	= Weighted Average Grade calculated with functions
12				$= \text{SUMPRODUCT}(B2:B6, C2:C6) / \text{SUM}(B2:B6)$
13				

Table 2
Example 2: Loan Payment and Amortization

	A	B	C	D	E	F
1	Amount borrowed	\$16,500				
2	Annual interest rate	6.0%				
3	Years length of loan	2				
4	Monthly payment	(\$731.29)	= Monthly payment calculated with function			
5			=PMT(B2/12,B3*12,B1)			
6						
7				Amount for	Amount to	Principal
8	Amortization Table:	Month	Payment	Interest	Principal	Balance
9		Start				\$16,500.00
10		1	\$731.29	\$82.50	\$648.79	\$15,851.21
11		2	\$731.29	\$79.26	\$652.03	\$15,199.18
12		3	\$731.29	\$76.00	\$655.29	\$14,543.88
13		4	\$731.29	\$72.72	\$658.57	\$13,885.31
...	
31		22	\$731.29	\$10.86	\$720.43	\$1,451.69
32		23	\$731.29	\$7.26	\$724.03	\$727.65
33		24	\$731.29	\$3.64	\$727.65	\$0.00
34						
35	Formula for Amount for Interest (in cell D10) = \$B\$2/12*F9					
36						
37	Formula for Amount to Principal (in cell E10) = C10-D10					
38						
39	Formula for Principal Balance (in cell F10) = F9-E10					
40						

Table 3
Example 3: Sum of Squares and Concentration Index

	A	B	C
1	Herfindahl-Hirschman Index (a concentration index) for Example Industry		
2	Market Shares (%) of Companies in Example Industry		
3			
4	Company Name	Market Share (%)	
5	Company A	23	
6	Company B	22	
7	Company C	19	
8	Company D	19	
9	Company E	9	
10	Company F	5	
11	Company G	3	
12	Total Market	100	
13			
14		1850	= Concentration index calculated with formula
15			(calculated as sum of the squared shares)
16			=B5^2+B6^2+B7^2+B8^2+B9^2+B10^2+B11^2
17			Or
18			=B5*B5+B6*B6+B7*B7+B8*B8+B9*B9+B10*B10+B11*B11
19		1850	= Concentration index calculated with function
20			=SUMSQ(B5:B11)

Table 4
Errors Example 1: Weighted Average with Error

	A	B	C	D
1	Assignment	Weight	Grade	
2	Homework 1	10%	92	
3	Homework 2	15%	87	
4	Project	20%	84	
5	Exam 1	25%	76	
6	Final Exam	30%	91	
7		100%		
8	ERROR		149.35	= Weighted Average Grade calculated with formula
9	EXAMPLE 1			=(B2*C2+B3*C3+B4*C4+B5*C5+B6*C6)/(B2+B3+B4+B5+B6)
10				
11	ERROR		331.95	= Weighted Average Grade calculated with formula
12	EXAMPLE 2			=B2*C2+B3*C3+B4*C4+B5*C5+B6*C6/B2+B3+B4+B5+B6
13				
14	CORRECT		85.35	= Weighted Average Grade calculated with formula
15	ANSWER=>			=(B2*C2+B3*C3+B4*C4+B5*C5+B6*C6)/(B2+B3+B4+B5+B6)
16				Or with functions =SUMPRODUCT(B2:B6,C2:C6)/SUM(B2:B6)

Table 5
Errors Example 2: Loan Payment and Amortization with Error

	A	B	C	D	E	F
1	Amount borrowed	\$16,500				
2	Annual interest rate	6.0%				
3	Years length of loan	2				
4	Monthly payment	(\$1,314.70)	= Monthly payment calculated with function			
5	ERROR EXAMPLE =>		=PMT(B2,B3*12,B1)			
6	Error in PMT function causes errors in table below =>					
7				Amount for	Amount to	Principal
8	Amortization Table:	Month	Payment	Interest	Principal	Balance
9		Start				\$16,500.00
10		1	\$1,314.70	\$82.50	\$1,232.20	\$15,267.80
11		2	\$1,314.70	\$76.34	\$1,238.36	\$14,029.44
12		3	\$1,314.70	\$70.15	\$1,244.55	\$12,784.89
13		4	\$1,314.70	\$63.92	\$1,250.78	\$11,534.11
...	
21		12	\$1,314.70	\$13.01	\$1,301.69	\$1,300.12
22		13	\$1,314.70	\$6.50	\$1,308.20	(\$8.08)
23		14	\$1,314.70	(\$0.04)	\$1,314.74	(\$1,322.82)
24		15	\$1,314.70	(\$6.61)	\$1,321.31	(\$2,644.13)
25		16	\$1,314.70	(\$13.22)	\$1,327.92	(\$3,972.05)
26		17	\$1,314.70	(\$19.86)	\$1,334.56	(\$5,306.61)
27		18	\$1,314.70	(\$26.53)	\$1,341.23	(\$6,647.85)
28		19	\$1,314.70	(\$33.24)	\$1,347.94	(\$7,995.79)
29		20	\$1,314.70	(\$39.98)	\$1,354.68	(\$9,350.47)
30		21	\$1,314.70	(\$46.75)	\$1,361.45	(\$10,711.92)
31		22	\$1,314.70	(\$53.56)	\$1,368.26	(\$12,080.18)
32		23	\$1,314.70	(\$60.40)	\$1,375.10	(\$13,455.28)
33		24	\$1,314.70	(\$67.28)	\$1,381.98	(\$14,837.26)
34						
35	Formula for Amount for Interest (in cell D10) = $BS2/12 * F9$					
36						
37	Formula for Amount to Principal (in cell E10) = $C10 - D10$					
38						
39	Formula for Principal Balance (in cell F10) = $F9 - E10$					
40						

Table 6
Errors Example 3: Sum of Squares and Concentration with Error

	A	B	C
1	Herfindahl-Hirschman Index (a concentration index) for Example Industry		
2	Market Shares (%) of Companies in Example Industry		
3			
4	Company Name	Market Share (%)	
5	Company AA	23	
6	Company BB	22	
7	Company CC	19	
8	Company DD	19	
9	Company EE	9	
10	Company FF	5	
11	Company GG	3	
12	Total Market	100	
13			
14	CORRECT	1850	= Concentration index calculated with formula
15	ANSWER=>		(calculated as sum of the squared shares)
16			=B5^2+B6^2+B7^2+B8^2+B9^2+B10^2+B11^2
17			
18	ERROR	11850	= Concentration index calculated with function
19	EXAMPLE		=SUMSQ(B5:B12)