Measuring spreadsheet skills: Engaging students through personalized formative and summative assessments

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Abstract

While today's undergraduate students are digital natives, their ubiquitous use of electronic devices does not necessarily align well with having the computing and/or programming skills of past generations. Specifically, spreadsheet skills are transferable across science and engineering topics, especially lab courses, as well as for financial and budgeting activities in personal or professional applications. Spreadsheets conveniently use simple functions and formulas to calculate sums, averages, and other statistics quickly in desktop, web, and mobile formats, including Microsoft Excel and Google Sheets. Traditionally, spreadsheet skills were taught by demonstration by an expert in person, but now, dozens of spreadsheet influencers have significant followings on video platforms like YouTube. However, the acquiring of spreadsheet skills is sped up by educational best practices, such as formative and summative assessments. In this paper, a unique set of activities provides students opportunities to demonstrate basic and more advanced spreadsheet skills. Spreadsheet activities include in-class exercises, auto-graded exercises in an interactive textbook, and personalized spreadsheet quizzes. In-class activities incorporate a personalized or randomized component, so each student works to complete their task while the instructor serves as an in-person coach. Outside-of-class activities leverage tools in an interactive textbook from zyBooks – a Wiley brand. Students practice spreadsheet formula writing and outputs using unlimited attempts on auto-graded, randomized problems in the interactive textbook. Finally, individualized, in-person, and proctored assessments are demonstrated. Each student selects their name from a drop down to generate their unique spreadsheet for the quiz. Leveraging Microsoft's OneDrive, Excel, and Teams, students work can be captured in real time. The grading of the assessments is done quickly using formulas with tolerances. Overall, spreadsheet skills are commonly used to solve problems from creating the latest products and processes to tracking finances. The tools detailed here provide an opportunity to encourage learning and document skills development.

Introduction

Spreadsheets are pervasive in engineering education and engineering practice. Engineers and engineering students use spreadsheets daily to organize data, perform calculations, and visualize results. Those calculations can involve simple arithmetic, pre-loaded spreadsheet functions, and even Python codes for machine learning and other complex numerical analyses. Spreadsheets are used across platforms and device types, such as Microsoft Excel, Google Sheets, and Apple Numbers. Thus, learning spreadsheet skills is essential for engineering students. Recent surveys confirm that spreadsheets remain central to the undergraduate chemical engineering curriculum, with usage increasing compared to earlier decades [1]. Despite their importance, effective assessment of spreadsheet skills at scale remains challenging for instructors, especially in the age of generative artificial intelligence (genAI).

Traditional approaches to spreadsheet education follow a master-student demonstration framework, where an instructor shows students how to use specific features through screenshots and live demonstrations [2, 3]. Recently, YouTube and other similar web platforms provide abundant (and nominally free by watching ads) resources for learning spreadsheets [4, 5]. Videos provide knowledge dissemination but generally lack a mechanism for the learner to engage or interact. However, educational best practices, such as deliberate practice, require formative exercises and individualized feedback for students to master new skills [6-8]. Moreover, many videos focus on specific versions of proprietary software rather than transferable spreadsheet concepts that apply across platforms and versions.

The challenges of assessing spreadsheet skills are numerous and have been discussed for many years [9-11]. First, manual grading of spreadsheet assignments is time-consuming for instructors, often requiring examination of both formulas and calculated results across multiple cells [12, 13]. Second, delayed feedback limits students' ability to iterate and improve their skills through deliberate practice [14, 15]. Thus, multiple choice tests were employed to evaluate spreadsheet skills, but this type of assessment indirectly measured spreadsheet knowledge and skills [16]. Assessing both formulas and the outputs of spreadsheet formulas, sometimes called stored and displayed content, is analogous to grading code as well as the output of the code [17].

Recent advances in automated grading and simulator systems have begun to address these challenges [18-20]. One system can grade both cell formulas and styles while providing feedback through cell comments [12]. Similarly, PySheetGrader embeds grading specifications directly into reference spreadsheets, reporting a statistically significant 4% improvement in student performance on take-home assignments [21]. Other recent papers addressing spreadsheet skills are disciplinary and specific, including structural engineering [22], statics [23], and advanced chemical engineering courses [24].

Interactive textbooks are a technology that combines student-centered content delivery, embedded assessment, immediate feedback, and learning analytics. These platforms apply established learning theories including cognitive load theory, scaffolding, and deliberate practice [6-8]. Previous work found reading participation rates of 90% or higher for spreadsheet content in an interactive textbook, compared to typical higher education reading rates of 20-50% [13, 25-27]. Auto-graded problems with randomized numbers and cell locations allow unlimited attempts without penalty, enabling students to engage in deliberate practice with immediate feedback on correctness [13, 26, 27]. These studies documents student reading engagement and success on auto-graded problems across multiple cohorts involving hundreds of students as well as capturing secondary metrics like attempts before correct. In addition, these studies examined different types of spreadsheet skills, including general skills, functions, and advanced topics.

Here, student-centered activities and assessments will be summarized to address the need for options beyond the master-student demonstration framework. The main question of interest is how can individual spreadsheet tasks be structured to both develop and assess a range of spreadsheet skills and competencies. Three separate contexts will be discussed: 1. In-class formative exercises, 2. Outside of class auto-graded exercises, and 3. In-class assessments. By examining these activities through the lens of educational theories, including deliberate practice, this work captures some practical insights for spreadsheet instruction and how students develop spreadsheet skills.

Materials and Methods

While data from specific courses and cohorts are outside of the scope here, several course environments have used these assessments. To date, students in several courses, including Material and Energy Balances, Introduction to Chemical Engineering, and Chemical Engineering Calculations. These courses fit into the curriculum from Fall and Spring of the 1st (freshman) year to Spring of the 2nd (sophomore) year. While completed as part of traditional, in-person courses here, the activities should be transferable to laboratory course requiring the application of spreadsheet skills. Spreadsheet content has been both a primary course objective as well as integrated into core chemical engineering concepts. For example, interpolation using a spreadsheet has been integrate with learning steam tables in Material and Energy Balances.

Throughout the paper, screenshot examples are provided while video demonstration is planned for the talk. Student names are fictitious and randomly created by genAI.

Implementation and Examples

This section highlights in-class activities, out-of-class auto-graded exercises, and in-class, individualized assessments. Since spreadsheets serve many purposes in engineering courses and projects, specific examples will help document both content and pedagogical technique.

In-class spreadsheet activities

Teaching spreadsheets to undergraduate students implies that a professor demonstrates actions in the application and the students mimic on their own devices in real time. While this type of lecture may be effective for some content, many options are possible when students are learning spreadsheet skills. In **Table 1**, three scenarios range from the professor/instructor and students all completing to the exact same exercise to prompts with personalized information.

Table 1. Several types and examples of in-class spreadsheet activities.

In-class activity type	Example
Cell locations and values are all the same	Material balance problem using a stream table containing numbered streams, flow rates, and different chemical species
Cell values randomized	After giving the same 10 x-values for making a plot, student use the RAND() function to create a set of y-values. Then students create a scatter plot (chart rubric discussed later).
Cell values personalized	Find your age in years to 5 significant figures using a spreadsheet and the date and time functions from your reading. Complete this task at least 2 different ways. (A reformulation of [28])

Moving beyond mimicking the exact same calculations and cell locations empowers students in at least two ways. First, students can work with neighboring students about how successful students calculated their answer. Moving from what is the right answer to how to calculate the right answer is a start toward conceptual understanding as well as moving from school world where right answers are valued to engineering world where varying inputs value adaptability [29, 30]. Second, giving students agency via personalization provides benefits as discussed in the literature e.g., [31, 32].

Out-of-class, auto-graded spreadsheet exercises

An interactive book authored to develop spreadsheet skills without any prior experience includes interactive reading participation elements and randomized, auto-graded exercises. Specifically, *Spreadsheet Essentials* from zyBooks is available as a standalone title containing 16 sections of content as of January 2026; this content is also available as one of the chapters in the *Material and Energy Balances* zyBook [33, 34]. Using any HTML5-compliant browser, students acquire knowledge and demonstrate spreadsheet skills across three categories: general skills, function types, and advanced skills. Details on the topics and skills were detailed in a recent paper [27]. In addition, previous publications provided example images from animations and auto-graded problems [25, 26, 35]. Faculty can obtain free evaluation copies from the publisher [34].

A summary of the previous research and data types will help frame the new auto-graded problems being introduced here. On one hand, students completing the reading participation for all 16 sections will click over 360 times, the effort of clicking correctly is one reading metric. On the other hand, spreadsheet skills are measured by fraction correct on over 140 auto-graded questions, which are called challenge activities. Students have unlimited attempts for these formative, randomized exercises that require writing formulas, finding the output of formulas using different spreadsheet functions, or both. Across 5 cohorts and hundreds of students, first quartile and median reading participation were generally 95-100%, which is much larger than other reported reading rates in higher education [36]. Finally, median correct on auto-graded problems ranged from 94 to 99% across the 5 cohorts.

While previous work focused on scaffolded, auto-graded problems that appear in each section, new, more difficult problems are being introduced. The existing, scaffolded problems generally ask students to demonstrate a single skill aligned with the current section. However, the new, end of chapter exercises normally ask for both formulas and their output, which are called stored and displayed content. In addition, all numbers randomized for each student and attempt. While the scaffolded exercises commonly contain less than 10 numbers/filled cells, these data sets are now much larger and as many as 63 filled cells. Thus, some of the scaffolded exercises could be done on a calculator, which bypasses the goal of developing spreadsheet skills. For example, a problem related to using the math function SUM contains between 35 and 63 filled cells depending on the randomized attempt (**Figure 1**). The formula is entered below the spreadsheet/table, and the numeric value is entered into the cell. Both answers are auto graded; Numbers with tolerances and formulas as string with all common variations included as correct answers.

The rationale for new, larger, and likely more difficult problems is two-fold. First, zyBooks introduced an assessment platform where instructors could assign specific problems with restrictions including time and number of attempts. Second, both deliberate practice and cognitive load theory encourage learners to push themselves beyond the basics to become a master [14, 37]. Thus, these problems are designed to minimize the opportunities for using short-term or working memory. The combination of shorter, scaffolded problems with longer, more summative problems provide opportunities for spaced repetition, which should favor deeper learning. We hope to present learning analytics from these new problems in a future publication.

Sum the numbers in the filled cells. Place the displayed content in Cell C10 and the stored content below the spreadsheet.

	A	B	C	D	E	F	G
1	34.5	-98.1	-16.8	67.7	53.7	-93.4	84.7
2	-84.9	-49.7	25.3	-65.6	38.7	32.9	71.5
3	55.3	81.1	15.6	28.8	-76.3	17.5	89.9
4	-42.9	-66.2	-66.3	-88.1	88.8	57.8	32.6
5	-37.1	-31.8	92.9	52.6	96.4	-83.8	38.8
6	-23.2	66.1	13.2	-36.9	-37.6	62.2	26.9
7	83.8	-92.1	-24.8	41.8	91.4	-13.3	-11.8
8	92.5	32.1	42.6	-19.1	89.7	-97.5	99.3
9	-78.5	49.2	-59.1	-92.7	36.9	-36.8	-86.1
10				Ex: 111			

Copy sheet   Stored content: Ex: =FUNC(B1:E2)

Sum the numbers in the filled cells. Place the displayed content in Cell C10 and the stored content below the spreadsheet.

	A	B	C	D	E	F	G
1		-38.1	-77.3	-95.7	51.9	44.3	
2		83.5	-67.7	58.1	32.7	-49.2	
3		-79.1	-39.7	81.7	-68.9	68.8	
4		83.8	-49.9	59.2	-61.7	-69.4	
5		-64.7	-24.8	84.5	-54.9	96.1	
6		-23.4	-41.8	-97.8	-95.9	-16.8	
7		-86.4	11.4	73.7	-98.3	-35.8	
8							
9							
10				Ex: 111			

Copy sheet   Stored content: Ex: =FUNC(B1:E2)

Figure 1. Top. One example of a more difficult spreadsheet challenge activities with 63 numbers to sum. Bottom. Another example of the same challenge activity level with 35 filled cells.

In-class, individualized spreadsheet assessments

The formative exercises completed in class as well as outside of class via the interactive textbooks precede in-person spreadsheet assessments. First, the need for summative assessments using spreadsheets applies sound learning science related to stress, which can be thought of as desirable difficulties that leads to improved retention and learning [38, 39]. The features and context first set up a detailed demonstration of some of the unique features of these assessments. Both setting and features of the spreadsheet assessments (Table 2) will be demonstrated through screenshots and additional discussion. The university context will also be interwoven as many of the features are easily transferrable to almost any course.

Table 2. Details about spreadsheet assessments.

Setting		Features
In-person		Same problem statement with randomized numbers unique to each student
Timed		Rubric provided with problem statement in spreadsheet. Scores earned for both displayed content (answers) and stored content (formulas)
Proctored		Partial auto-grading of numeric responses uses tolerances. Done asynchronously by instructor.
In computer lab – either personal laptop or university machine allowed		Help menu within Microsoft Excel allowed, but genAI and web searches were prohibited.
		Real-time autosaving of Microsoft Excel files if using Microsoft Teams for assessment

These spreadsheet assessments take place in person with a single proctor in a computer laboratory/classroom at Trine University. The assessments last 50 minutes or less to accommodate the normal class day and time. The class size was around 20 students, so one proctor was sufficient. The small class size and single proctor may be considered a limitation with large class sizes that cannot fit into a single university computer lab. These spreadsheet quizzes have been given over multiple semesters in courses for 1^{st} and 2^{nd} year students. One course is Introduction to Chemical Engineering for first semester students where spreadsheet assessments cover basic spreadsheet skills and non-reacting, relatively simple, material balance problems. A second-year course called Chemical Engineering Calculations applies more advanced spreadsheet skills to solve problems from the material and energy balances and first thermodynamics courses that are prerequisite.

Students are allowed to use the university's computers or their own laptop, which accommodates personal preferences as well as Mac and Windows users. Microsoft Teams is used as the course's learning management system [40], and Microsoft Excel as an application is strongly encouraged as the testing platform. Using Excel as an application compared to web-based spreadsheets is preferred due to the much simpler methods to create scatter charts, which will be discussed later. The quiz begins when the spreadsheet is released in Teams, usually within a minute or two of the class's start time. Students then open the spreadsheet inside Excel, which can use the cloud and

SharePoint/OneDrive to auto-save each keystroke like web-based office tools. Before reading the problem statement, the students select their name from a dropdown menu, which presents them with several unique numbers needed to solve the problem.

When the spreadsheet assessment begins, the students open the same xlsx file. Generally, one sheet with the problem statement is visible (labeled Problem in **Figure 2**). However, a second locked and hidden sheet contains the roster and any randomized numbers assigned to each student. The worked solution may also be included in the locked and hidden sheet but should be removed before distribution. Hidden sheets can be unhidden without the passcode, so locking the sheet does not keep students from seeing this sheet. Additionally, a third sheet may be included with physical property data. Including a set of data removes the need to use a digital book's appendix, reference title, the Internet, or genAI to find needed properties.

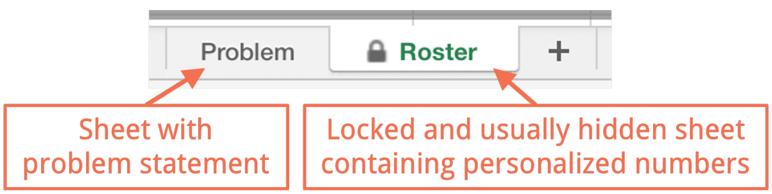


Figure 2. Sheets used for a randomized spreadsheet assessment. Left is the sheet containing the problem statement and place for students to work, and right is a roster sheet that is normally locked and hidden to students.

Students begin their assessment by selecting their name from a dropdown box in a cell near the top of the sheet (**Figure 3**). This selection auto fills one or more numbers unique to their quiz. For the example quiz being detailed here, the topic of the quiz is basic spreadsheet skills, i.e., writing formulas and functions for a set of numbers. Specifically, quiz grades on five quizzes for over 20 students identified only by student number create a modest size data set for students to respond to the question prompts.

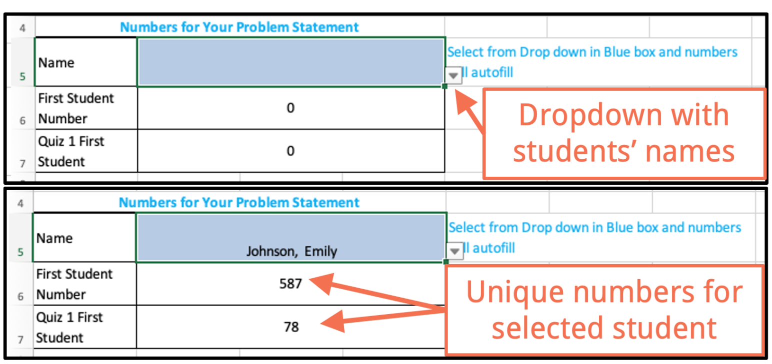
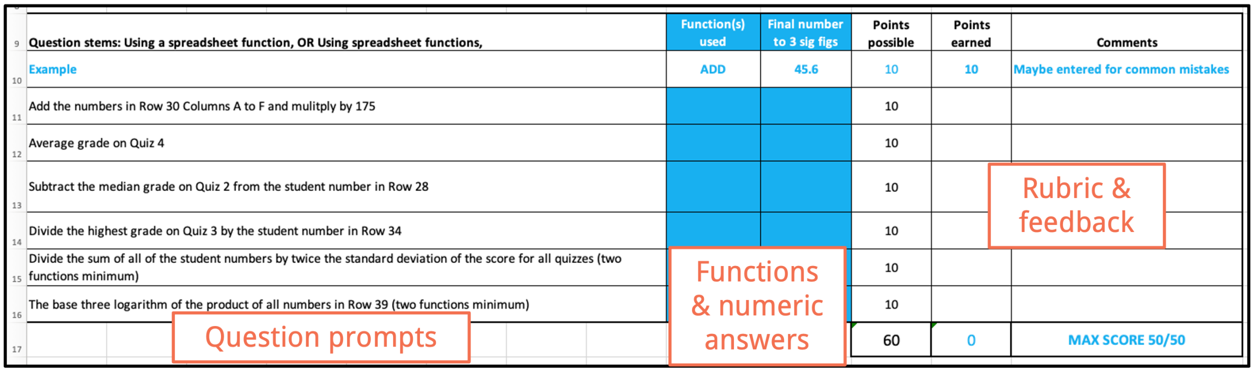


Figure 3. Top. Dropdown cell including all students' names in the course. Bottom. Student's name selected (Emily Johnson) and two numeric values auto-fill.

Next, a set of question prompts and cells to enter answers are designated (**Figure 4**). In most cases, both stored content and displayed content are entered by the students. The necessity of writing acceptable formulas as well as getting the correct value is a consistent expectation of the course and aligns with the challenge activities discussed earlier. Finally, the points possible is given for each question along with cells for score entry and feedback cells.



	Question stems: Using a spreadsheet function, OR Using spreadsheet functions,	Function(s) used	Final number to 3 sig figs	Points possible	Points earned	Comments
10	Example	ADD	45.6	10	10	Maybe entered for common mistakes
11	Add the numbers in Row 30 Columns A to F and mulitply by 175			10		
12	Average grade on Quiz 4			10		
13	Subtract the median grade on Quiz 2 from the student number in Row 28			10		
14	Divide the highest grade on Quiz 3 by the student number in Row 34			10		
15	Divide the sum of all of the student numbers by twice the standard deviation of the score for all quizzes (two functions minimum)			10		
16	The base three logarithm of the product of all numbers in Row 39 (two functions minimum)			10		
17				60	0	MAX SCORE 50/50

Figure 4. Question prompts, place to enter both functions (or formulas) and numeric answers, cells for scoring and feedback.

After students submit their spreadsheet via Microsoft Teams, the instructor downloads the files and initiates the grading process. In this example assessing basic spreadsheet skills, four new columns with grading formulas are pasted into each student's sheet to the right of the comments column and executes partial auto-grading (**Figure 5**). The first two new columns examine the functions listed by the students. Using nested COUNTIF and IF functions, the student's text can be auto scored most of the time. Some limitations are noted in the figure, namely the student's answers in rows 15 and 16 should be marked true. The numeric responses, called displayed content in the zyBook, are auto-graded correctly within a tolerance. Row 8 shows a 2% tolerance was used for comparing the student's answers and the instructor's key. The numeric grading within a tolerance seems very reliable over the 3 semesters of use to date.

Finally, a column labeled Comments allows the instructor to provide constructive feedback. In **Figure 5**, three numeric answers are incorrect. In row 14, the student visually inspected the group of data to find the largest number, which does not utilize the MAX spreadsheet function. Most recently, 100 random numbers were provided with the question prompts, which was not enough as some students chose inspection over a spreadsheet function. A larger data set may be provided in future semesters to overcome this limitation. Rows 15 and 16 include a common mistake, i.e., using a correct spreadsheet function with an incorrect argument or argument order. Overall, the partial auto-grading method is efficient and still allows the instructor agency on valuing both process (function use in spreadsheets) and product (final numeric answers).

Student responses

These columns are for grading and not given to students

							Tolerance=	0.02
Function(s) used	Final number to 3 sig figs	Points possible	Points earned	Comments	Criteria	Goal = TRUE	Criteria	Goal = TRUE
ADD	45.6	10	10	Maybe entered for common mistakes				
SUM	2.01E+05	10	10		SUM	TRUE	201075	TRUE
AVERAGE	77.0	10	10		AVERAGE	TRUE	77.0	TRUE
median	6.88E+02	10	10		MEDIAN	TRUE	688.0	TRUE
D29/A34	0.111	10	7	MAX function should be used	MAX	FALSE	0.111	TRUE
SUM, STDEV	1.45E+03	10	5	denominator incorrect. Wrong cells for SUM.	STDEV and SUM	FALSE	788.88	FALSE
PRODUCT, LOG	3.90E-02	10	7	LOG function cell addresses reversed.	PRODUCT and LOG	FALSE	25.51	FALSE
		60	49	MAX SCORE 50/50				

Scores & feedback

Partial auto-grading

Figure 5. Student responses (left columns), scores and feedback manually entered by instructor (middle columns), and pasted in formulas for auto-grading numbers with tolerance and text.

Conclusion

Three methods for student-centered spreadsheet instruction were presented. Unique features from in-class activities, out-of-class auto-graded exercises, and in-class, individualized assessments provided a multi-tiered approach to students demonstrating their competence with spreadsheets. First, three types of in-class exercises were presented that move from demonstration to personalized problem solving. Next, a set of new auto-graded problems available in an interactive textbook provided a mechanism for students to complete randomized, repeatable formative practice outside of class. The learning analytics from similar auto-graded spreadsheet activities show both high student engagement and fraction correct on this type of homework [13, 26, 27]. Finally, a unique in-person and personalized assessment was detailed. With each student getting their own data set, these activities lessen the chances of cheating in a crowded computer lab as well as have a method for partial auto-grading.

While some limitations were noted for these activities, the advantages for both student and instructor are greater in the author's opinion. Finally, the in-person assessments have been applied beyond basic spreadsheet skills for chemical engineering specific problems including material balance stream tables, fitting data to non-trivial models, and creating high quality plots. We hope this contribution can be applied broadly for science, technology, engineering, or math (STEM) students from middle and high school to graduate students.

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