Journal of Information Systems Education

Volume 32
Issue 4
Fall 2021

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Recommended Citation: Forst, R., Matta, V., & Kenyo, L. (2021). Teaching Tip: A System to Automate Scaffolding and Formative Assessment While Preventing Plagiarism: Enhancing Learning in IS and Analytics Courses That Use Excel. *Journal of Information Systems Education*, 32(4), 228-243.

Article Link: https://jise.org/Volume32/n4/JISE2021v32n4pp228-243.html

Initial Submission:	28 July 2020
Accepted:	4 January 2021
Published:	15 December 2021

ISSN: 2574-3872 (Online) 1055-3096 (Print)

Teaching Tip
A System to Automate Scaffolding and Formative Assessment While Preventing Plagiarism: Enhancing Learning in IS and Analytics Courses That Use Excel

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ABSTRACT

Student learning benefits from individual support and feedback. This type of support does not scale well especially in large classes. A system was built to automate the delivery of individual support and feedback on Excel assignments in information systems and analytics courses. The system embeds instructional scaffolding in the distributed assignments then grades and provides formative assessment for students' submitted assignments. Both the scaffolding and formative assessment help students advance in their understanding. To ensure that students do their own work, the system has highly visible controls to prevent plagiarism including the ability to generate and grade unique assignments for each student. The system promotes learning, prevents plagiarism, and eases faculty grading burdens. It has been fine-tuned over two years of continuous use with thousands of students. The software is freely available from the authors for academic use.

Keywords: Plagiarism, Excel, IS education, Instructional technology, Pedagogy

1. INTRODUCTION

Both scaffolding and formative assessment are processes designed to increase learners' understanding of concepts over time. Both are designed to close the gap between what a learner is able to do on their own and what they can do with support and feedback. Well-designed scaffolding supports learners by incrementally building in complexity toward the desired learning objective (Wood et al., 1976). Formative assessment, which explains why an answer is right or wrong, increases understanding, rather than simply providing a score. These strategies can be combined to improve learning, but this assumes learners are completing their own work. According to the International Center for Academic Integrity, 68% of undergraduate students admit to having plagiarized at least once (Danilyuk, 2019). For writing assignments, there are tools to check for plagiarism. These tools dissuade students from directly using others' work. The same tools, however, are almost impossible to use for Excel assignments because most students are working toward the same answer key.

The goal is to enhance student learning in courses using Excel-based assignments. This is done in an introductory analytics two-course sequence by providing students with instructional scaffolding and formative assessment on their assignments. Students can only learn if they do the work, so each student is given a workbook with slightly different problems to solve and a number of highly-visible controls to prevent plagiarism. This paper describes the system and how it is used. The rest of the paper is organized as follows: related work, system description, teaching suggestions, evidence of system effectiveness, future directions, and the conclusion.

There are two required, introductory analytics courses in the business core of a large midwestern university. These courses cover a number of traditional analytics concepts, and the assignments and assessments are implemented in Excel. The second course additionally serves as the required business statistics course for transfer credit to other universities. The first course has an enrollment of 110 students per section; the second has an enrollment of 45 students per section. Both courses use a flipped-classroom approach and teach business analytics using Excel as a tool. The topics covered in these classes are listed in the Appendix.

Both courses are taught with a similar pedagogy and are comprised of multiple modules. Each module has a theoretical lecture followed by three Excel-based assignments. The first is a prep assignment that students complete using the guidance of a step-by-step screencast. Preps are due before the first class of the module. The prep is followed by an in-class exercise and then a homework assignment. Each module's content is also tested using hands-on exams.

Faculty construct the assignments to align with learning outcomes and then process them through the system. The system creates a unique assignment file for each student. A learning management system (LMS) script delivers each assignment into the corresponding student's account. Students complete and submit their finished assignments. These are then downloaded, automatically graded, and reposted in batch.

This automated system supports student learning. One of the tenets of a flipped classroom is that faculty will be available in class to answer student questions. However, as class sizes increase, faculty are limited in their ability to help each student individually. Students need support beyond the classroom while they work on their assignments. That assistance is built into assignments through instructional scaffolding and formative assessment. Instructional scaffolding refers to help that the students receive while completing assignments (Boblett, 2012), and formative assessment refers to feedback on the graded assignments (Black & Wiliam, 2009). Instructional scaffolding and formative assessment both provide a support system that helps learners move from what they already know to what they are able to do next (Shepard, 2005).

2. RELATED WORK

Scaffolding was first defined in a study of adult-child interaction during problem-solving tutoring sessions, and subsequently went on to be incorporated into pedagogical practice. Scaffolding takes a learner through a carefully crafted process that builds in complexity toward a specific learning outcome, while ensuring that the learner is not overwhelmed (Wood et al., 1976). Professors may provide scaffolding in advance of an assignment or while students are completing the assignment (just in time scaffolding).

Formative assessment is often contrasted with summative assessment, which is just the grade. Formative assessment helps explain to students *why* their answers are wrong and how to avoid the same mistake next time. Because it contributes to student performance on the next assignment, formative assessment should be delivered as soon as possible after the assignment is submitted. Furthermore, this is an iterative process; today's formative assessment is tomorrow's scaffolding as professors learn which concepts need more support.

Scaffolding and formative assessment are only beneficial when students are doing their own work. As noted earlier (Danilyuk, 2019), over half of students admitted to plagiarizing at least once. Excel assignments are particularly susceptible to plagiarism. In subjects such as English, each student is expected to write an original paper. Programs such as Turnitin.com and SafeAssign are able to detect plagiarism in these assignments by looking for matches or near matches in blocks of text. They deter plagiarism by distributing a similarity report to both the instructor and student. However, in introductory courses using Excel, the assignments are usually highly structured such that each student is supposed to turn in the exact same "correct" answer. Turnitin and SafeAssign are not capable of detecting plagiarism on structured Excel assignments. To make matters worse, students can now get completed assignments online for many courses at any university. Websites such as CourseHero and Chegg are clearinghouses for publicly-shared assignments and exams.

There are two types of plagiarism from the Turnitin.com plagiarism spectrum that are relevant for Excel. (*The Plagiarism Spectrum*, 2015)

1. "**Clone**: An act of submitting another's work, word-for-word, as one's own." In Excel, the clone would be turning in another student's workbook as one's own.
2. "**Ctrl-C**: A written piece that contains significant portions of text from a single source without alterations." In Excel, Ctrl-C would be copying the formulas from another student's workbook.

Past research has focused primarily on detecting cheating after the fact rather than preventing cheating in the first place. There are multiple techniques to catch students, but they all revolve around hiding unique artifacts in the workbook tied to a student's identity (Singh et al., 2011). Turning in a workbook that contains another student's artifacts provides evidence of cheating. While unique artifacts help catch cloning, they do not stop Ctrl-C copying of formulas.

There are many dimensions that influence whether students will attempt to cheat on an assignment. Students cheat more when it is easier to do so, or they think the professor does not care. Given the opportunity and lack of deterrents, students will engage in plagiarism (Husain et al., 2017; Simkin & McLeod, 2010; Smith et al., 2002). Students have been shown to cheat more in online courses according to Arnold (2016), who added that students will even cheat during formative online tests that carry low points, thereby sacrificing the learning outcomes associated with them. Students may be attempting to make up for the negative effects of the online testing environment, greater ambient distractions, and differences in their confidence (Fask et al., 2014). Jones (2011) found that 92% of students knew someone who had cheated; she also added that students cheat on exams because they want to improve grades and because they procrastinate and have run out of time. Another study found that there are different understandings of what really constitutes plagiarism (Husain et al., 2017), especially when students from different cultures or countries are compared (Haswell et al., 1999).

On examining plagiarism, McCabe (2005) advised the development of behavioral and operational deterrents. Behavioral deterrents use educational and management techniques that are designed to bring a change in the inclination to plagiarize. Operational deterrents approach the problem in a different manner – by making it difficult to successfully conduct the plagiarism. Both deterrent types are discussed in detail and summarized in corresponding tables.

Behavioral deterrents include setting clear expectations, educating students about cheating, and establishing an honor code (Foss & Lathrop, 2000). One behavioral intervention is to assign judgment-free reflective essays to students who have cheated in the past (Dalal, 2016). Low stakes formative assessments are designed to improve student competence. Instructional scaffolding also builds student confidence by gradually reducing support, while often adding complexity to best prepare a student for the end goal. Together they provide an alternative to plagiarism (Sadler, 1989) by reducing the need to cheat, given that help is available to do it right. Table 1 summarizes these various behavioral deterrents: (i) clear communication of honor code and academic integrity standards, (ii) education of students about expectations and potential repercussions for their violation, (iii) use of reflective essays about plagiarizing, (iv) creating a culture of integrity and building trust and relationship with students, and finally (v) reducing the incentive to plagiarize by providing an easier path to completion of assignments and introducing formative tasks and making the summative assignments less formidable.

Although somewhat successful, behavioral interventions cannot guarantee the elimination of cheating (Novotney, 2011). For Excel-based assignments, behavioral, reflective (Dalal, 2016), or organizational (Born, 2003) interventions are less effective in light of the ease of copying and virtual undetectability (Atkinson et al., 2016).

Operational deterrents involve reducing opportunities to cheat (Bassendowski & Salgado, 2005; Foss & Lathrop, 2000; McCabe et al., 2012). Several features were found in the literature to detect and reduce plagiarism, such as using metadata (Brodie & Hellyer, 2012) or maintaining an audit trail of student changes to the spreadsheet (Singh et al., 2011).

	Assignment type	Communicate honor code/ integrity standards	Educate expectations/ repercussions	Use reflective dialogs (essays)	Culture of Integrity/trust building	Reduce incentive
Exploring Reflective Means to Handle Plagiarism (Dalal, 2016)	Hands-on SAP exercises	Inform students about importance	Provide learning materials about academic standards	Student discusses /writes about academic integrity	No information	No information
Plagiarism and Programming: A Survey of Student Attitudes (Aasheim et al., 2012)	Programming, math & writing	Students have different standards of plagiarism for assignment types	Hold classroom discussions on academic honesty	No information	Educate students that plagiarism standards are similar across assignments	No information
Student Cheating and Plagiarism in the Internet Era : A Wake-up Call (Foss & Lathrop, 2000)	Not specified	Establish academic integrity policy and publicize it well	Educators and parents must strengthen character education	Students should reflect on the learning process	Educators to take an active role and collaborate	Less cheating when security precautions are in place
Beat the Cheat (Novotney, 2011)	Not specified	Those who read the honor code were less likely to cheat	Explaining the purpose and relevance of learning	No information	Cheating is contagious	No information
How To Reduce Plagiarism (Born, 2003)	Essay and multiple choice	No information	Communicate meaning of plagiarism and why it will not be tolerated	No information	Forming a strong relationship discourages cheating	Discuss consequences
Ten Years in the Academic Integrity Trenches: Experiences and Issues (Atkinson et al., 2016)	Writing and data	Include information in the assessment requirements	Students to take greater responsibility for academic integrity	No information	Provide cultural transition courses	Improve processing of academic misconduct
Cheating among college and university students: A North American perspective (McCabe, 2005)	Writing, data & programming	Faculty should promote academic integrity	Make expectations on tests clear	No information	Target student perceptions of consequences to impact peer culture	Faculty should make an effort to prevent cheating
Academic Dishonesty in Graduate Business Programs: Prevalence, Causes, and Proposed Action (McCabe et al., 2012)	Writing	Faculty declare their interest in adopting honor code	Acceptance and understanding of academic policies deter plagiarism	No information	Ethical community building	Inversely related to certainty of being reported and penalty severity
Perceptions of and Attitudes toward Plagiarism and Factors Contributing to Plagiarism: A Review of Studies (Husain et al., 2017)	Writing	Uninformed students engaged more in plagiarism	Understanding of plagiarism is not consistent	No information	Acceptance of plagiarism of varies across cultural groups	Lack of penalty incentivizes plagiarism

Table 1. Comparison of Behavioral Interventions of Plagiarism Deterrents in Prior Research

Making deterrents visible rather than hidden was shown to be more effective (Husain et al., 2017; Rolfe, 2011; Simkin & McLeod, 2010; Tupe, 2018). According to Scott (2017), plagiarism is deterred by making assignments unique by changing numbers, values, or cases. Effective plagiarism deterrents are visible, tamper-resistant, and include personalization. While these can be accomplished manually (Wiedemeier, 2002), it is not scalable or easily sustainable even for small groups of students. Table 2 was developed to summarize operational deterrents that were found in the literature and those supported by the system under discussion (called XLGrader), shown in the first row for comparison. The dimensions of the operational deterrents found include: (i) visibility of the mechanism, (ii) its tamper resistance, (iii) creation of unique assignments, (iv) personalizing with the students' names, and finally, (v) using scaffolding to walk the student through the needed steps for completing an assignment. These are discussed at length in the next section.

Theme (Author, Date) / Plagiarism Assessment Detail	Assignment Type	Visibility of Deterrent	Detection Mechanism	Unique Assignment per Student	Personalization	Scaffolding
XLGrader (2020) Different data, different formulae, tamper proofing	**MS Excel**	**Shifted cells are colored to draw attention**	**Multiple layers of security, requires knowledge of coding**	**Each student gets unique start file**	**Personalization is displayed in bright colors**	**Hints and encouragement embedded**
Reducing Effects of Plagiarism in Programming Classes (Bowyer & Hall, 2001). MOSS™ software works compares submitted code/software works with many programming languages	Programming	Depends on faculty to declare use of tool	Depends on comparison of code composition	Students get the same assignment	None present	None present
Detecting Plagiarism in Microsoft Excel Assignments (Hellyer & Beadle, 2009). An Excel-Smash™ case study: Assessment based on comparison of file metadata, representation of text cells (commentary used, and formula cells.	Excel	Depends on faculty to declare use of tool	Depends on student awareness of file properties	Students get the same assignment	None present	None present
Can E-Cheating be Prevented? An Approach to Detect Plagiarism in Computer Skills Courses (Coakley & Tyran, 2001). This uses key detector approach and uses VBA to automate assessment	Excel & Access	Depends on faculty to declare use of tool	Multiple layers of data integrity checking	Each student gets unique data set	None present	None present
Plagiarism Detection for Group Assignments: Lessons from the Fraud Triangle (Farrell, 2018). Accounting & Finance application: Deterrent is based on using an assignment to make meeting minutes 3000 words. Reading/grading assignment increases grade load	Excel with written assignment	Instructor asks for process document	Evaluation of process document	Students get the same assignment	Based on differences in composition of process document	None present
From Plagiarism-Plagued to Plagiarism-Proof: Using Anonymized Case Assignments in Intermediate Accounting (Scott, 2017). Anonymized case studies by manually changing numbers	Case study (written assignment)	Depends on faculty to declare use of tool	Students are made to believe that assignments are unique	Students get mostly different assignments	None present	None present
Detecting Plagiarism in MS Access Assignments (Singh, 2013). Solution is based on macro to save all changes history of all changes to a table.	MS Access	Depends on faculty to declare use of tool	Uses hidden fields in MS Access database	Assignments do not contain unique data, carry unique identifiers	None present	None present
An Approach to Detecting Plagiarism in Spreadsheet Assignments: A digital answer to digital cheating (Singh et al., 2011). Technique: manually hide unique markers/formulae and use code to track metadata.	Excel	Depends on faculty to declare use of tool	Uses hidden fields in Excel and metadata markers	Assignments do not contain unique data, carry unique identifiers	None present	None present
Preventing Plagiarism in Computer Literacy Courses (Wiedemeier, 2002). Two-part assignment, with the second part customized. Many students admitted to cheating on first part, none on second part.	Operating System Theory	Depends on faculty to declare use of tool	Software to detect similarities between assignment content and metadata	Meta data is used to create uniqueness	Uses metadata to personalize assignments	None present

Table 2. Feature Comparison for Operational Interventions of Plagiarism Detection in Prior Research

3. DESCRIPTION OF THE SYSTEM

The authors developed a system that automates scaffolding and formative assessment while preventing plagiarism in Excel assignments. The tool was designed to be highly flexible and work with almost any Excel assignment—not just the ones created by the authors. The professor begins with a completed assignment—the answer key—and then the program removes the formulas and converts graphs and pivot tables to target images. Most Excel assignments are set up as scenarios with written directions with tables of data. Figure 1 shows an example tab in a workbook. The system hides the answer key and provides new sheets with the answers removed. Cells that students must complete are shaded in gray. Students complete those gray cells using appropriate formulas or functions that reference all necessary precedents. The cells with comments (those with red arrowheads) contain hints.

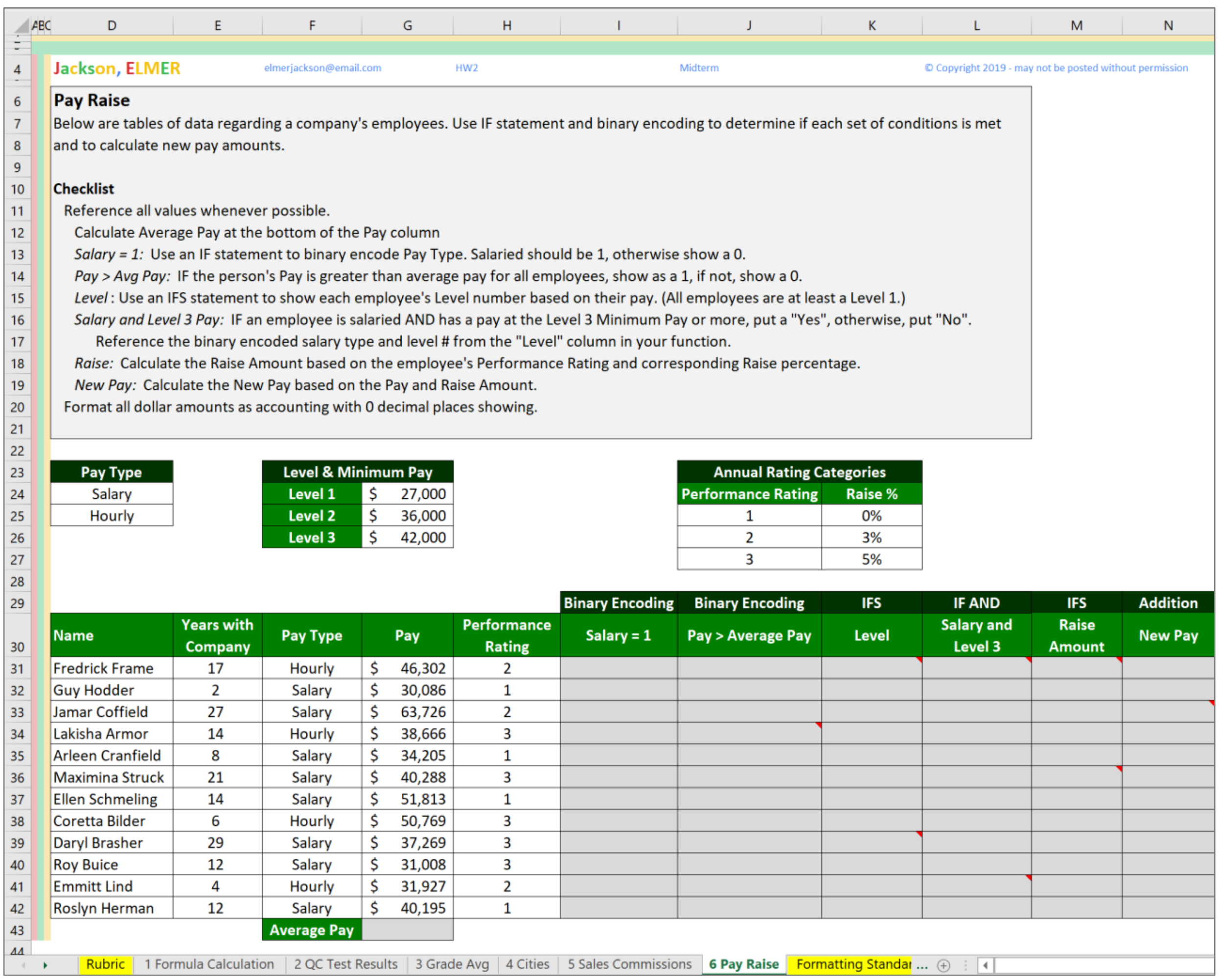
3.1 Automated Scaffolding

Just-in-time scaffolding includes hints, encouragement, and target images embedded throughout the assignment. The system scaffolds learning by revealing bits and pieces of the answer key. The professor can customize how many hints, if any, to give. The newer the concept, the more help students will need. As students master the concepts, the scaffolding can be scaled back, withdrawn, or moved to new concepts.

3.1.1 Hints. Scaffolding takes the form of hints for formulas. The hints appear as comments in the cell. Hints show the correct answer for that cell and the correct formatting. However, they do not reveal anything about which formula/function to use, which cells to reference, or whether to use an absolute or relative reference.

In Figure 2, hints are shown in the first and third cells of the column. The first hint allows students to check whether they calculated the correct answer and formatted it correctly. This exercise requires an absolute reference for the formula in order for it to copy correctly down the column. The second hint allows students to check if their formula copied correctly. If they have the right answer on the first hint, but the wrong answer on the second hint, then their absolute referencing is in error, and students would have to go back and troubleshoot their formula in order to get it to copy correctly.

Complex formulas are reasonable places to include hints, especially for newer concepts, but hints are not provided when the correct answer can be deduced logically. For example, if the task is to binary encode gender using an IF function (Male = 1, Female = 0), then hints are not given because students can logically deduce if the answers are correct or not.



Jackson, ELMER elmerjackson@email.com HW2 Midterm © Copyright 2019 - may not be posted without permission

Pay Raise

Below are tables of data regarding a company's employees. Use IF statement and binary encoding to determine if each set of conditions is met and to calculate new pay amounts.

Checklist

Reference all values whenever possible.

Calculate Average Pay at the bottom of the Pay column

Salary = 1: Use an IF statement to binary encode Pay Type. Salaried should be 1, otherwise show a 0.

Pay > Avg Pay: IF the person's Pay is greater than average pay for all employees, show as a 1, if not, show a 0.

Level : Use an IFS statement to show each employee's Level number based on their pay. (All employees are at least a Level 1.)

Salary and Level 3 Pay: IF an employee is salaried AND has a pay at the Level 3 Minimum Pay or more, put a "Yes", otherwise, put "No".

Reference the binary encoded salary type and level # from the "Level" column in your function.

Raise: Calculate the Raise Amount based on the employee's Performance Rating and corresponding Raise percentage.

New Pay: Calculate the New Pay based on the Pay and Raise Amount.

Format all dollar amounts as accounting with 0 decimal places showing.

Pay Type
Salary
Hourly

Level & Minimum Pay	
Level 1	$ 27,000
Level 2	$ 36,000
Level 3	$ 42,000

Annual Rating Categories	
Performance Rating	Raise %
1	0%
2	3%
3	5%

					Binary Encoding	Binary Encoding	IFS	IF AND	IFS	Addition
Name	Years with Company	Pay Type	Pay	Performance Rating	Salary = 1	Pay > Average Pay	Level	Salary and Level 3	Raise Amount	New Pay
Fredrick Frame	17	Hourly	$ 46,302	2						
Guy Hodder	2	Salary	$ 30,086	1						
Jamar Coffield	27	Salary	$ 63,726	2						
Lakisha Armor	14	Hourly	$ 38,666	3						
Arleen Cranfield	8	Salary	$ 34,205	1						
Maximina Struck	21	Salary	$ 40,288	3						
Ellen Schmeling	14	Salary	$ 51,813	1						
Coretta Bilder	6	Hourly	$ 50,769	3						
Daryl Brasher	29	Salary	$ 37,269	3						
Roy Buice	12	Salary	$ 31,008	3						
Emmitt Lind	4	Hourly	$ 31,927	2						
Roslyn Herman	12	Salary	$ 40,195	1						
		Average Pay								

Rubric | 1 Formula Calculation | 2 QC Test Results | 3 Grade Avg | 4 Cities | 5 Sales Commissions | 6 Pay Raise | Formatting Standar ...

Figure 1. Typical Formula-Based Sheet -- Directions, Values, Formulas/Cells to Complete, and Hints

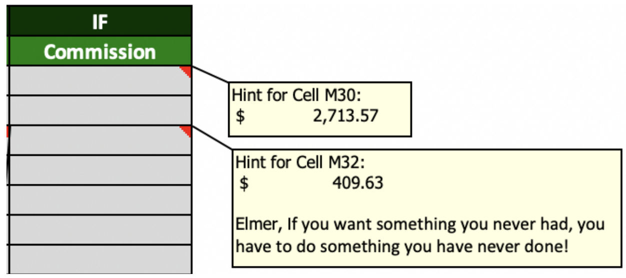


Figure 2. Hints and Encouragement -- Customizable Hints Used to Scaffold Learning

3.1.2 Personalized Encouragement. The second hint in Figure 2 also contains a personalized message of encouragement. Encouragement is a form of scaffolding. The encouragement message is randomly drawn from a list of over 70 messages and personalized by name. To avoid overusing encouragement, it only appears on about every fifth hint—though the frequency can be customized in code.

3.1.3 Target Images for Graphs and Tables. Whereas hints are used for cells, target images are used to provide scaffolding for pivot tables and charts. Students apply the concepts and techniques learned to recreate the example and check their work. Figure 3 shows a target image of a pivot table with most of the data blacked out. Details of how to create the table are not included, and blacked-out content keeps students from copy-pasting the example. Before target images were used, it was shocking to see how poorly students performed on pivot tables no matter how much practice they received. After using target images, however, students were able to master pivot tables.

Target images are also used to scaffold charts. Figure 4 shows a target image of a chart with a "Model" watermark. Details of how to create the chart are not included, and the watermark stops students from copy-pasting the example, but it gives them a target to compare against their work. Providing target images of charts improved student performance for developing charts.

3.2 Formative Assessment

Formative assessment explains why a student's answer is wrong and how to fix it. To grade well requires much more than matching the answer key. It is important to see if the student used a valid formula that matches best practice standards. When errors are found, detailed and helpful feedback will allow students to correct those errors.

3.2.1 Solution Flexibility. Even though the assignments are structured, students have the freedom to write a creative solution for each formula. There may be dozens of ways to develop complex formulas, and the answer key cannot anticipate all of them. For example:

- One student uses an IFS function while another uses nested IF functions
- One student finds a grand total by summing row totals, while another sums column totals
- One student uses an Average function while another constructs the average using Sum divided by Count

The system accepts all of the above variations as acceptable solutions as long as they reference the correct set of precedents.

3.2.2 System Feedback. Formative assessment should be a learning experience. Feedback given to students should be both particular and general. It should tell them exactly what errors they made and how to fix them but should also summarize the types of errors that they make consistently. XLGrader provides both. Here is the feedback on a graded assignment:

- Show the correct answer
- Show the correct formatting
- Explain the type of error(s) made. These could include any of the following:
    - Incorrect use of or missing absolute or relative references
    - Missing required precedents of a cell (usually because students hard code values in a formula)
    - Missing required elements in a graph, such as the title, axis labels, source, or legend
    - Missing, extra, or incomplete data series in a graph

Average Salary	Position	
Age	Associate	Management
39-43	$ 63,176	$ 63,742
44-48	$ 62,194	$ 61,619
49-53	[redacted]	
54-58		
59-63		
64-68		

Figure 3. A Pivot Table Target Image Provides Scaffolding for Students

Height	Shoe Size
63	6
56	8
57	10
59	6
59	5
60	11
60	6
60	5
60	5
60	7.5
60	7
60	6
60	6
60	6
60	6.5
60	7
60	8
60	7
60	8
60	5
60	7

Figure 4. Target Image of a Chart Provides Scaffolding for Students

- Missing values in a pivot table

XLGrader grades on instructor-chosen criteria and displays the correct answer, formatting, and other feedback for every cell that has an issue; these include cells that are blank, have incorrect answers, or formatting errors. Students who get the right answer but violate best practice may earn partial credit. Best practice includes writing a formula, referencing precedents within that formula, and using absolute references where appropriate. The feedback includes the type of error(s) in blue, the student's answer and formula in red, and the correct solution and formula in green. Students can see where they went wrong and how to correct for future assignments. In Figure 5, the first column shows feedback for cells that had manually-typed answers, and the second column shows feedback for cells that were left blank.

Figure 6 shows feedback for cells with incorrect answer values, incorrect number formats, and formulas with hard-coded values. Note that students lose points not just for incorrect answer values, but also for departures from best practice.

Formative assessment for charts is given directly in the chart. Figure 7 shows feedback for a chart that is missing three data points and an appropriate Y-axis title.

The system summarizes all of the particular feedback from formulas, charts, pivot tables, and so forth on a new tab in the graded workbook (see Figure 8). For convenience, each sheet in the workbook is numbered along with a one- or two-word description. Each row in Figure 8 shows the total number of errors per measure per sheet. For example, on sheet "3 Grade Avg" the student earned 10 out of a possible 16 points for number formatting. Summarized feedback allows students to see the types of errors that they consistently make. This tab is particularly useful for professors in consultations with individual students.

IF - Binary Encoding	IF AND - Binary Encoding
Vehicle Type New = 1	**Joelle Tanner AND New = 1**
missing formula -4, missing precedents -2, missing absolute reference -2 1 1 =IF(C32=F$25,1,0)	*missing formula -4, missing precedents -2, missing absolute reference -2, num format -1* 1 =IF(AND(B32=C$25,H32=1),1,0)
missing formula -4, missing precedents -2, missing absolute reference -2 1 1 =IF(C33=F$25,1,0)	*missing formula -4, missing precedents -2, missing absolute reference -2, num format -1* 0 =IF(AND(B33=C$25,H33=1),1,0)
missing formula -4, missing precedents -2, missing absolute reference -2 0 0 =IF(C34=F$25,1,0)	*missing formula -4, missing precedents -2, missing absolute reference -2, num format -1* 0 =IF(AND(B34=C$25,H34=1),1,0)
missing formula -4, missing precedents -2, missing absolute reference -2 1 1 =IF(C35=F$25,1,0)	*missing formula -4, missing precedents -2, missing absolute reference -2, num format -1* 0 =IF(AND(B35=C$25,H35=1),1,0)

Figure 5. Formative Assessment-- Deductions for Manually Typed Errors and Blank Cells

Total HW Points	Total Exam Points	Total Points	Grade Percentage	Min %
200	200	400	100.0%	70.0%
wrong answer -4 320 =SUM(C27:H27) 155 =SUM(C27:D27,F27:G27)	165	320	num format -1 0.80 =K27/K$25 80.0% =K27/K$25	missing precedents -2, missing absolute reference -2 Yes =IF(L27>=0.7, "Yes", "No") Yes =IF(L27>M$25,"Yes","No")
wrong answer -4 318 =SUM(C28:H28) 156 =SUM(C28:D28,F28:G28)	162	318	num format -1 0.80 =K28/K$25 79.5% =K28/K$25	missing precedents -2, missing absolute reference -2 Yes =IF(L28>=0.7, "Yes", "No") Yes =IF(L28>M$25,"Yes","No")
wrong answer -4 223 =SUM(C29:H29) 91 =SUM(C29:D29,F29:G29)	132	223	num format -1 0.56 =K29/K$25 55.8% =K29/K$25	missing precedents -2, missing absolute reference -2 No =IF(L29>=0.7, "Yes", "No") No =IF(L29>M$25,"Yes","No")
wrong answer -4 299 =SUM(C30:H30) 143 =SUM(C30:D30,F30:G30)	156	299	num format -1 0.75 =K30/K$25 74.8% =K30/K$25	missing precedents -2, missing absolute reference -2 Yes =IF(L30>=0.7, "Yes", "No") Yes =IF(L30>M$25,"Yes","No")

Figure 6. Formative Assessment -- Deductions for Errors

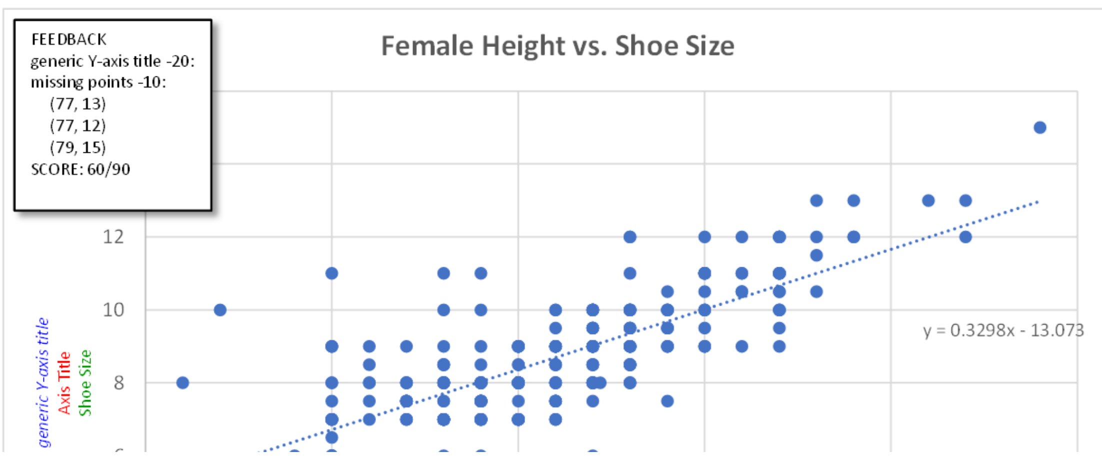


Figure 7. Formative Feedback--Missing Data Points and Y-Axis Title

Sheet	Measure	Earned	Possible	Percent
3 Grade Avg	Number Format	10.00	16.00	62.5%
4 Cities	Precedents	30.00	38.00	78.9%
3 Grade Avg	Answer	64.00	80.00	80.0%
3 Grade Avg	Precedents	32.00	40.00	80.0%
3 Grade Avg	Relative v Absolute	32.00	40.00	80.0%
4 Cities	Answer	72.00	76.00	94.7%
1 Formula Calculation	Answer	32.00	32.00	100.0%
1 Formula Calculation	Precedents	16.00	16.00	100.0%
1 Formula Calculation	Relative v Absolute	16.00	16.00	100.0%

Figure 8. A Rollup Report by Error Type for an Individual Student

3.3 Plagiarism Prevention

In order for the scaffolding and formative assessment to be effective, students must actually do the work, which means that there must be controls in place to prevent students from copying work from other students. The controls were designed to be visible, unique, personal, and tamper resistant. Visible controls should stand out—like a watermark on a currency bill. Unique controls should be different for each student; personalized controls should utilize the student's name, and tamper-resistant controls should be difficult to defeat.

3.3.1 Unique Values. Most spreadsheet assignments provide initial data values or assumptions. XLGrader randomly varies those values for each student, so if students compare assignments, they will see that files are unique, and the start values are different for each of them. Furthermore, different start values lead to different answers in the formulas downstream. This control is called value shifting. In Figure 9, the master spreadsheet on the left has values highlighted in purple that will be value shifted. The next two spreadsheets, for Elmer Jackson and Betty Smith, display values randomly varied from the key's values by up to 5%.

3.3.2 Unique Formulas. Structured spreadsheet assignments require students to create formulas that build upon one another to lead to a correct answer. Therefore, the formulas are virtually identical from one student to the next. By contrast, XLGrader is able to vary formulas by randomly shifting the position of all cells on the worksheet. If students compare formulas, they will see that the cell references of the formulas are different even though the formulas look similar. This is called formula shifting. The system randomly inserts rows and columns in the upper left corner of the worksheet. These new rows and columns drive the existing formulas and their precedents further down and to the right on the sheet. To draw attention to the deterrent, the inserted rows and columns receive random colors from a unique color palette. Formula shifting and value shifting work well in tandem to create unique assignments that cannot be copy-pasted from one sheet to another. In Figure 10, Elmer Jackson's cell F33 corresponds to cell H31 in Betty Smith's sheet. The difference is caused by varying numbers of colored rows inserted in the top left corner of each spreadsheet. Not only do the formulas appear in different cells but the precedent cells referenced in each of those formulas point to different cells, as shown in the formula bars at the top of each student's sheet.

3.3.3 Watermarks. The student's name is repeated at the top of every worksheet with each letter randomly colored. Figure 11 includes examples of watermarking in two different tabs of a workbook for Elmer Jackson. Note that the sequence of colors on each tab is different. Furthermore, the colors do not appear on a standard color palette, which makes it difficult to tamper with the watermark. Even if students are able to emulate the colors, the name will not match the name stored on a hidden sheet. That makes this control highly tamper resistant.

3.3.4 Personalized Filenames. The student's name is included in the name of the file as shown in Figure 12. The grading program automates the generation of individual files with every student's name in addition to their name and email shown on each tab.

3.3.5 Personalized Metadata. The student's name is also included in the properties metadata for the workbook. Figure 13 shows the Title and Author properties set in the metadata.

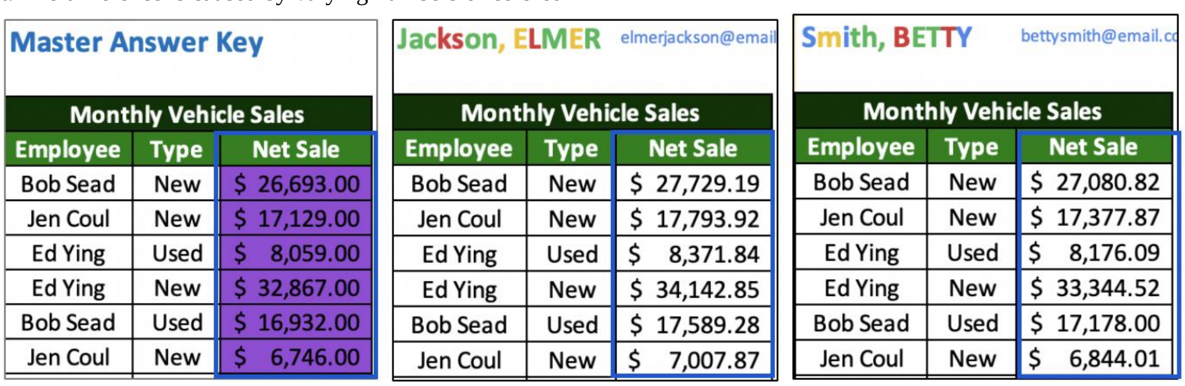


Figure 9. Value Shifting--Master (Left) and Two Student Versions of Purple Cells

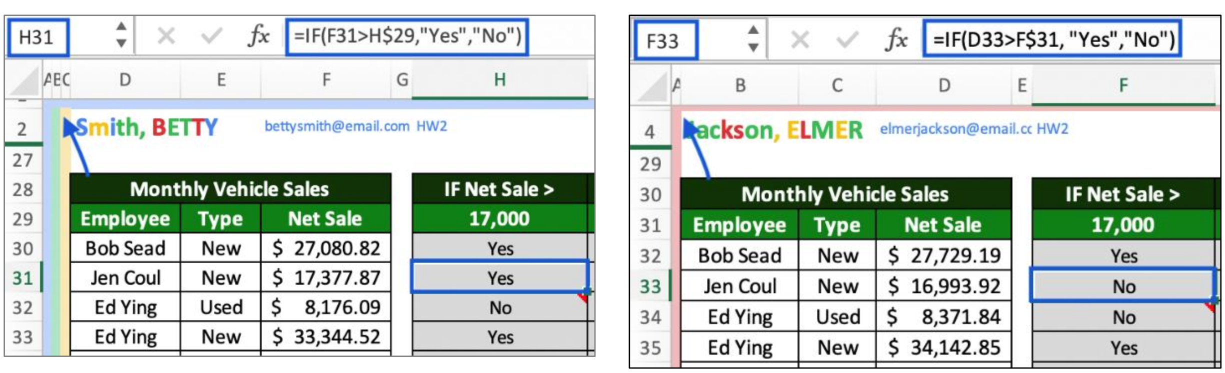


Figure 10. Formula and Value Shifting Together

Figure 11. Watermarking--Each Letter of Each Student Name is Colored Randomly

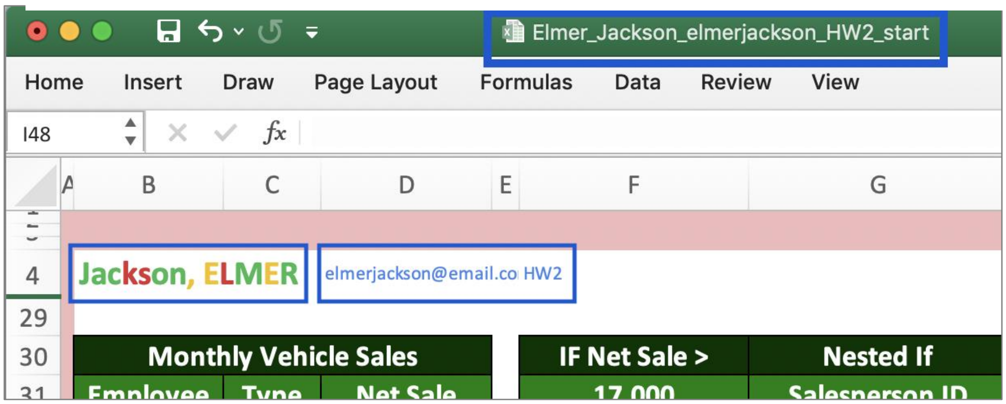


Figure 12. File Naming—The Student's Name is Included in the Filename

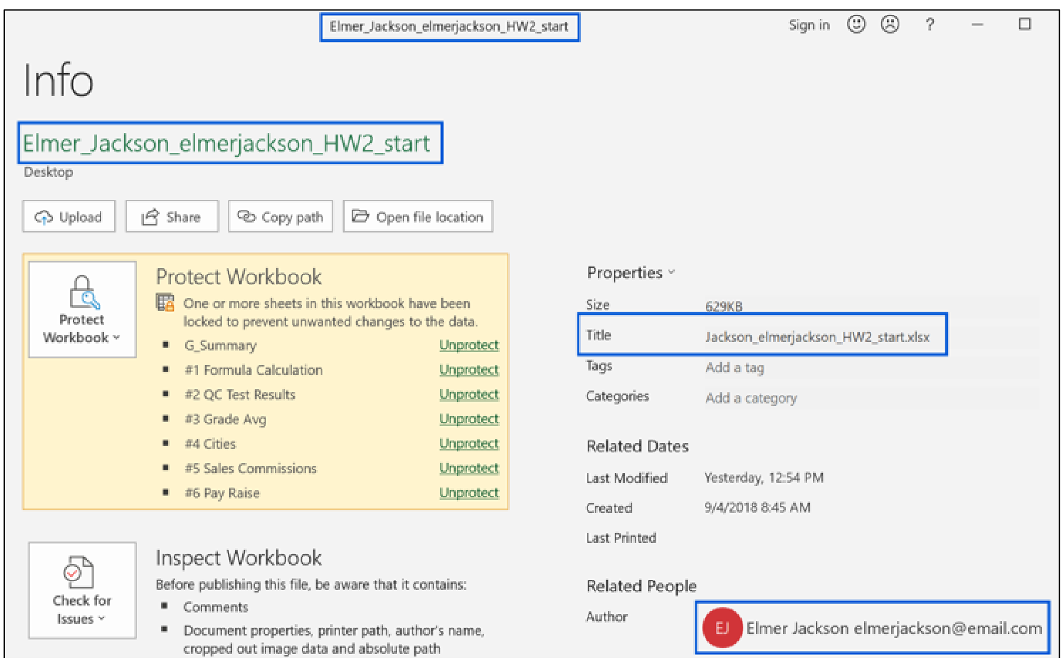


Figure 13. The Student Name is Included in Metadata

4. TEACHING SUGGESTIONS

There has been a lot of learning over two years about how to best use the system. Suggestions based on this fall into two broad categories: educate students about the system and tune the system to emphasize what is important.

4.1 System Instruction

Students need to be aware of the system's major features — scaffolding, formative assessment, and anti-plagiarism. It is worth spending part of a class period outlining each of these features early in the semester. For example, in-class exercises asking students to compare their values with students around them can help them see and realize the value shifting. This is a subtle way of making the point that copying would be difficult and a bad idea.

4.1.1 Excel Best Practice Education. The system was designed to enforce best practices. This means that for an answer to be completely correct all of the following need to be true:

- It is the right answer
- The formula references all of the correct root precedents. Root precedents are precedents of precedents and so forth until arriving at a set of constants
- The formatting is correct

Educating students about best practice and why it is important helps ward off questions like, “I got the same answer as the answer key, so why did I lose points?”. Usually, their mistake is hard coding part of the solution. Some students have a difficult time understanding why hard coding even part of the formula limits the ability to make changes to a worksheet.

4.1.2 Formative Feedback Instruction. It was surprising to learn that students did not intuitively understand the formative feedback generated by the system. This lack of understanding is easily remedied in 10 minutes by going over a graded assignment with the class. There is an added benefit in that students then realize the value of the formative feedback and will be more likely to view it.

4.1.3 Collaboration Allowances. Following constructivist learning theory, collaboration is promoted as a critical part of the learning process rather than discouraged (Hein, 1991). The type of collaboration permitted and the number of hints provided depend on the type of assignment. For assignments early in the module students may receive help from the professor and from each other for the prep, in-class, and homework assignments, but students may not receive help on the midterms.

For the prep and in-class assignments, a little bit of copying might well be viewed as a part of the scaffolding. “What *exact* formula did you put for cell G17?” might help a student advance through an in-class assignment. However, as they move to the homework, each student needs different values and formulas. That way the only question one student can ask another is, “What *type* of formula did you use?” This is more of a strategic question. Similarly, scaffolding hints are prevalent on early assignments but reduced as students progress through the module. The types of permitted collaboration and number of scaffolding hints provided are shown in Table 3.

Assignment	Permitted Collaboration	Scaffolding Hints
Prep	Formula sharing	All
In-class	Formula sharing	Many
Homework	Strategy sharing	Fewer
Midterm	None permitted	Fewest

Table 3. Permitted Collaboration and Number of Hints

4.2 System Customization

The professor has quite a bit of control over which items receive scaffolding, which items are graded, and point distributions. Fine-tuning those items leads to better learning outcomes.

4.2.1 Customizable Point Distributions. The professor selects the point distributions at the time of grading through the system’s user interface. After much experimentation, equal weights for getting the right answer and having all the correct precedents appeared to work the best. The rationale is that following best practice for spreadsheet design is as important as getting the correct answer. To further emphasize that point, formulas that do not reference *any* precedents receive zero credit. Additionally, to emphasize importance, individual cell values can be customized; cell values can be increased or given a value of 0.

4.2.2 Multiple Choice/Short Answer Questions. To test conceptual information, XLGrader also allows for multiple choice-questions, drop-down lists, and typed values, when appropriate. See Figure 14 for an example of how these types of conceptual questions can be assessed.

As an added benefit, the system helps maintain academic integrity in online courses that lack resources to proctor exams. It also helped during the COVID-19 pandemic when classes moved online.

5. EVIDENCE

The goal of this research was to show that instructional scaffolding and formative assessment could be automated to fit within the pedagogy of information systems and analytics courses. The constructivist research on learning clearly supports moving in this direction. However, going forward it would be appropriate to conduct an experimental study to gauge the system’s effectiveness. For now, the evidence accumulated for the system’s effectiveness is shared. Some of it is anecdotal and some quantitative.

Students in these two courses are performing at a higher level than ever before. By the end of the first course, students master skills such as pivot tables and regression. By the end of the second course, students master skills such as inferential statistics, predictive analytics, and prescriptive analytics. See the Appendix for a complete list of course topics.

When testing the second course for assurance of learning, the faculty examined the data using six components. The following percentage of students met or exceeded expectations (i.e., earned a C+ or better): interpretation (91.0%), representation (95.5%), calculation (73.1%), application/analysis (89.6%), assumptions (62.7%), and communication (73.1%). These scores are somewhat remarkable for a required core course.

Through the LMS, it is possible to see who has reviewed the feedback. Students viewed about 64% of the formative feedback provided for both homework assignments and exams. Anecdotal feedback also shows that the courses are well received. They consistently rank above average in overall course rating irrespective of professor.

The anti-plagiarism controls implemented by XLGrader have been robust. Nonetheless, 2,100 students were surveyed about the effectiveness of the anti-plagiarism efforts. Over a two-year period, 1,539 students completed a simple four-

Descriptive Statistics	
Manually type given population values, N/A, or ?, as appropriate. Calculate sample values. Format values as accounting with 2 decimal places except sample sizes.	
Previous Average Score	
Previous Standard Deviation	
Previous Sample Size	
Current Average Score	
Current Standard Deviation	
Current Sample Size	

Steps		
Step 1	Select the test	
Step 2	Select case	One-Sample Z-test One-Sample T-test
Step 3	H0	
	H1	
Step 4	Alpha (type as whole %)	
Step 5	Critical Value LOWER Limit	
	Critical Value UPPER Limit	
Step 6	Compute the Test Statistic	
Step 7	P-Value (% 2 decimal places)	
Step 8	Decision about the H0	

What is the correct conclusion?	Answer
A. There is not a significant difference between the current exam score and the previous exam score for students.	
B. The current exam score is significantly higher than the previous exam score for students.	
C. The current exam score is significantly lower than the previous exam score for students.	
D. There is a significant difference between the current exam score and the previous exam scoree for students. The data suggests the exam score has increased.	
E. There is a significant difference between the current exam score and the previous exam score for students. The data suggests the exam score has decreased.	

Figure 14. Mix of Cells Requiring Calculations, Selected Answers, and Multiple-Choice Questions

question survey. Responses were coded on a seven-point scale for each of the following questions:

a. Do you think other students are cheating in the course? (Anchors: No one is cheating to Cheating is widespread)
b. For most of the Excel assignments and tests in this course, each student received a personalized copy with differences in names, formulas, and values. From what you observed, how effective were these personalized copies in limiting cheating in the course? (Anchors: Extremely effective to Not at all effective)
a. While there are different versions of the exams, there is still the possibility that students are sharing their exams with other students. To what extent do you think students are collaborating on the exams? (Anchors: No one is collaborating to Collaboration is widespread)
b. What could be done to improve academic integrity even further?

The results of the survey are shown in Table 4.

Several students expressed appreciation of the plagiarism deterrence created by the system. One student stated that "as an honest person it was hard to see students receive better grades because of cheating [prior to the incorporation of the system]." Across the board, students' perceptions for all questions indicate that plagiarism is being effectively deterred, with the lowest level of agreement for any question over any semester being 88%. Students note that the system converts shameless plagiarism (e.g., "direct copying and resubmitting assignments") into collaboration (e.g., "getting help from a friend in explaining a concept or showing how a function works").

	Prevalence of Cheating 1-no one is cheating 7-cheating is widespread			Effectiveness of Personalization 1-extremely effective 7-not at all effective			Collaboration on Exams 1-no one is collaborating 7-collaboration is widespread		
	Agreement	Mean	Std. Dev.	Agreement	Mean	Std. Dev.	Agreement	Mean	Std. Dev.
Spr 2018	89%	2.25	1.39	88%	1.56	0.74	89%	2.02	1.16
Fall 2018	89%	2.12	1.11	91%	1.58	0.76	92%	1.95	1.02
Spr 2019	87%	2.06	1.13	90%	1.56	0.72	91%	1.96	1.15
Fall 2019	89%	2.08	1.14	88%	1.58	0.73	89%	2.07	1.23

Table 4. Descriptive Measures on Plagiarism Deterrence

However, collaboration is a gray area, and some students are not sure if it constitutes plagiarism. The confusion was apparent in responses to the fourth open-ended question. This may explain why the mean values on the survey items are not closer to one.

The exams were proctored and completed in the classroom using a laptop. The proctored environment made it difficult for a student to open another student's Excel file without drawing attention. In Spring 2018, a couple of comments noted that some students left the classroom early and uploaded the exam from outside the class after obtaining help from others. Another comment about exams suggested that students shared an exam with other sections of the same course that had not yet taken the exam. Since the appearance of these comments, instructors have begun to plug these leaks. Instructors confirm exam submissions as each student leaves the classroom and make variations in exams for different course sections.

Students find the scaffolded hints useful since those "checkpoints" help them know if they have chosen the correct techniques and are applying them correctly. On one homework assignment, a professor forgot to include any hints. Multiple students sent messages similar to this student's, which read, "I just wanted to make sure I was doing it correctly and if not wanted to make sure I understood how to do the problems. Any assistance just to make sure I'm on the right track would be appreciated." These types of comments show that students use the hints to not only check their answers but to make sure that they're understanding how to solve the problems correctly, which shows the usefulness of hints in the learning process. Regarding the same assignment, another student wrote, "I just wanted to know if you would be able to skim through my answers to see if I did the homework correctly. I think I did, but I am nervous because there isn't a lot of [hints] so if I did a majority of it wrong, I am not going to get a good grade. If you could check it, I would be really thankful." This type of comment reinforces the fact that hints help students learn and reduce student anxiety. Hints also build student confidence in their understanding when they get correct answers.

6. DISCUSSION

6.1 Limitations

This paper addresses a pedagogical solution to automate instructional scaffolding and formative assessment while combating plagiarism. While the system has been successful, it does have limitations.

The biggest limitation of the system is the lack of real-time monitoring of student performance. Professors place hints where they think that students may need help, but different students may need help in different places. An ideal system would monitor student performance in real time and provide assistance when needed—like a personal tutor.

The system is also limited to assignments in Excel. Nonetheless, some of the techniques described here could be adapted to other software platforms. In fact, a colleague is implementing similar anti-plagiarism features in Microsoft Access assignments.

6.2 Future Research

Work has begun on a new version of the system. The goal of this new version is to give students immediate feedback as they work, which offers several improvements over the existing system.

1. **Faster Feedback**: Students receive instantaneous feedback on each cell. The feedback is similar to the formative assessment currently provided but in real time.
2. **Fuzzy Feedback**: In trying to mimic a human tutor, the feedback is intentionally less precise, "You are high by about 10x" rather than, "the answer is $237.96."
3. **Real-Time Class Analytics**: Class averages per concept are calculated in real time as assignments are turned in.
4. **Easier Grading**: Since the grading takes place in real time as the student completes the assignment, the student only needs to turn in an encrypted string that contains their grade.

A working prototype has been developed that meets the above features and goals, though it has not yet been tested with students. In the new system, students receive instant feedback in every cell when they make a mistake. The feedback identifies the type of error and provides scaffolding hints on how to correct it, so students troubleshoot and learn in real time. To make grading easier for instructors, students turn in an encrypted string containing grading details to a web form rather than turning in their assignment. The encrypted string contains their grade as well as a summary of the types of errors that were made. The system generates class averages on the fly to diagnose which problems students are struggling with and what types of errors they are making. This allows the professor to deliver real-time addendums to the assignment for the rest of the class.

7. CONCLUSION

One of the goals of this teaching tip is to shift the conversation from grading students to helping students succeed. Instructional scaffolding, formative assessment, and plagiarism prevention help advance learning. The XLGrader system has made some headway in scaffolding with hints, target images, and messages of encouragement. Formative assessment has been advanced by validating root precedents, by checking for best practice formula creation and cell formatting, and by providing feedback on pivot tables and charts. Anti-plagiarism methods were improved, in particular stressing the visibility and tamper resistance of plagiarism controls. Of these three, anti-plagiarism is the most important place to start. If students are not doing their own work, then scaffolding and formative assessment may be futile.

Many of the ideas presented can be extended to other applications. In particular, the anti-plagiarism measures could port to other platforms. Note that the anti-plagiarism measures require distributing assignments personalized for each student. This is a radical departure from traditional homework assignments that allow students to begin with a blank canvas. We look forward to freely sharing our materials and working with others who can help advance the project even further.

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APPENDIX

Course Topics

The following lists show the topics from two introductory analytics courses. While both courses use this system, all of the examples in this paper are taken from the first course.

1st Course in Analytics

1. **Excel Basics**. Pattern Fill, Order of Operations, Basic Formulas, Formatting, Shortcut Keys
2. **Foundations of Excel**. More complex formulas, Relative vs. Absolute references, IF, IF AND, IF OR, Dates and Text Functions, Conditional Formatting
3. **Managing Data**. Match, Index (Match, Match), Index(Match) with single Match
4. **Descriptive Statistics**. Extreme Values, Measures of Central Tendency, Types of Distributions, Empirical Rule, Measures of Variability, DATP, Frequency Tables, Contingency Tables
5. **Conditional Descriptive Statistics**. Countifs, Sumifs, Averageifs, Pivot Tables
6. **Data Visualization**. Bar, Pie, Scatter, Line
7. **Inferential Statistics**. Probability Theory, Permutation and Combination, Central Limit Theorem, Sample Based Normal Distributions, Introduce One Sample Hypothesis Tests to level needed for Regression Module
8. **An Introduction to Predictive Analytics**. Correlation, Interpreting R, Simple Linear Regression, Prediction Intervals, R-Squared, Standard Error
9. **Data Lifecycle Management Project**

2nd Course in Analytics

1. **Excel Refresher**. Professional Formatting, Order of Operations, Shortcut Keys, Formula Manipulation, Cell Referencing, Dates and Text Functions, Index Match, IF Statements, Sumproduct, Recording/Editing Macros
2. **Descriptive Statistics**. Measurement Scales, Counting Functions, Summing Functions, Extreme Values, Measures of Central Tendency, Measure of Variability, Qualitative Data, Quantitative Data, Box and Whisker Plots, Pareto Charts
3. **Inferential Statistics I**. Probability Theory Review, Binomial Distributions, Hypergeometric Distributions, Poisson Distributions, Uniform Distributions, Normal Distributions
4. **Inferential Statistics II**. Central Limit Theorem, Sample Based Normal Distributions, Normal Probability Calculations, Confidence Intervals, Control Charts
5. **Inferential Statistics III**. Hypothesis Testing Theory, One Sample Tests, Two Sample Tests, ANOVA Tests
6. **Inferential Statistics IV**. Another week of Hypothesis Testing, One Sample Tests, Two Sample Tests, ANOVA Tests, Post Hoc tests
7. **Predictive Analytics I**. Correlation Analysis, Simple Regression, Missing Values, Multiple Regression with Binary Encoding, Non-linear Regression, Bivariate Data – scatter plots
8. **Predictive Analytics II**. Time Series Definitions and Moving Averages, Weighted Moving Averages, Exponential Smoothing, Auto Regression, Measures of Error
9. **Prescriptive Analytics I**. Optimization Overview, Production Type Optimization Models, Shipping Type Optimization Models, Inventory Type Optimization Models
10. **Prescriptive Analytics II** (Optional), Decision Theory, Decision Tree

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ISSN 2574-3872