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# Secure Answer Book and Automatic Grading

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**Abstract**—In response to the growing need to perform assessments online, we have developed a secure answer book, as well as a tool for automatically grading it for our course on spreadsheet modeling. We applied these techniques to a cohort of about 160 students who took the course last term. In this paper, we describe the design, implementation and the techniques employed to enhance both the security of the answer book and the ease, accuracy and consistency of grading. In addition, we summarize the experience and takeaways, both from the instructor and the student perspectives. Although the answer book and grading tool described may be specific to the course for which they were developed, many of their design principles may be extended to other courses and electronically submitted assignments.

**Keywords**—*e-learning, summative assessment, automatic grading, academic integrity, online assignments*

## I. INTRODUCTION

In the spring term of 2020, COVID-19 spread throughout the world with alarming speed as a deadly pandemic. It forced almost all schools and universities to shut down in order to minimize the physical proximity and consequent contagion among and through students. It also necessitated cancellations or online administration of classes. In addition, many of us had to set up and administer online examinations as well, which came with the need to ensure academic integrity among our students. It also may have forced us to rethink how we approach grading because the answer books submitted were electronic files. Thinking of these challenges as an opportunity to innovate, we created a secure Answer Book, and a Grader tool to perform its valuation automatically.

Although most e-learning platforms have features to manage basic quizzes and assignment submissions, along with the ability to automatically grade objective type questions, such tools may not be sufficient or practical for certain courses. In our university, we have a course on spreadsheet modeling and analytics, similar to the ones described in articles by Leong [1] and LeBlac [2]. Aiming to equip our undergraduate students with employable skills in the business world, this course teaches techniques in business modeling and decision support using Microsoft Excel, including simulation of queues [3] and processes.

The final exam for this course consists of two business modeling scenarios and shows screenshots of the model template. It then asks the students to complete the models on their computer and write down the answers (such as the formulas and/or values in various specified cells). The students would return the question paper with the answers written down, and the grading would be based on their handwritten responses. In order to minimize cheating, the invigilators would ensure that the students do not have network access during the exam.

The COVID situation necessitated a complete revision of the final exam. The question paper had to be distributed

through our e-learning platform, and the answers had to be uploaded as Excel files. With this decision to move to electronic answer books came some challenges: How do we prevent the students from cheating by sharing their answer books? Although monitoring through video-conferencing software may help, in practice, it becomes cumbersome to implement and comes with privacy concerns. Lockdown browsers are applicable only for closed-book exams administered solely through a web browser. In order to address these challenges, we developed a highly secure answer book template, which were distributed to the students just before the examination.

The availability of the student answer books as computer files gave us the opportunity to grade them automatically. While a manual verification is always recommended, automation brings about consistency and efficiency in grading. The system we developed has the ability to build a valuation rubric iteratively to account for answer variants, and grade answer books in batch, tabulating the marks as a grade book. The implementation of the answer book and its automated grading form the subject matter of this article.

The rest of the article is organized as follows: We first take a look at the related work, both in online examinations and the available security measures as well as approaches to automatically grading Excel files. We will then describe our Answer Book, highlighting the security features. In the following section, we will describe the automatic Grader. Finally, after touching upon our experience with the approach and plans for the future, we will conclude by summarizing how these tools may be extended to other courses.

## II. RELATED WORK

Traditional strategy for ensuring academic integrity in examinations is strict invigilation, which was rendered ineffective by the global pandemic of this year. Although some studies [4] indicate that the instances of academic dishonesty are no more prevalent online than in traditional settings, the onus is still on the instructors to ensure integrity and fairness. One study [5], from the perspective of minimizing proctoring costs, came up with eight control procedures for online examinations. These tips were, however, not directly applicable to our final assessment based on spreadsheet modeling. Another article [6] recommends creating an awareness and a general culture of academic integrity.

Staying with the traditional monitoring strategy, but transporting it to the online world, there has been some research into the use of video monitoring [7]. Although not commonly found in the literature, lockdown browsers and monitoring tools such as Respondus (<https://web.respondus.com>) and ProctorU (<https://www.proctoru.com>) make some online assessments (typically quizzes) secure, but were not appropriate for our open-book examination because we needed the students to be able to access other applications on their computers.

On the topic of secure answer books using spreadsheets, the literature is generally silent. The only references we could find were in the finance field, with a view to minimizing operational risks associated with unmanaged spreadsheets [8], [9]. General methods for “cracking” the spreadsheet password are readily available on the Internet, as described in two recent articles [10], [11]. Our secure answer book is immune to such attacks because it employs encryption through a public password protection, which cannot be removed.

Automatic grading of spreadsheets has been, however, a more popular theme. In one relatively recent work [12], grading was performed using another piece of software (Matlab), using ActiveX Com controls (limiting its use to the Windows operating system). It has the ability to email a feedback message to the students, making it appropriate for formative assessment. Another article [13] describes a framework for specific accounting/business contexts, where an instructor proficient in Excel and VBA can develop automatic graders. It does not, however, describe a mechanism for improving the valuation rubric iteratively, or the ability to run in batch mode.

A slightly older work [14] describes how VBA can be used in grading objective type tests (with possible alternative answers pre-encoded). Although objective type questions are not sufficient to test the learning outcomes of our course, their article has an excellent survey of related work as of that time. In particular, they discuss the MEAGER framework [15], [16] for automatic grading using an Access database. Another approach [17] is based on a program that simply reads the student's Excel data and extracts the data for the items that need to be graded, which can handle two variants of each answer.

All these approaches concede that formula evaluation is difficult, and address the issue by limiting the choices available to the students. Another limitation of such systems is the considerable effort needed to hard-code the possible answers. As we will describe later, our system gets around this problem by allowing dynamic and iterative updating of the valuation rubric with unlimited number of alternative answers.

### III. SECURE ANSWER BOOK

In our implementation, we used a macro-enabled Excel file as a secure Answer Book. This file contained the skeleton models from which the questions were designed and prepared. Since the Answer Book was based on the workflow of preparing the final exam questions, very little extra work was needed to build it. Immediately before the final examination, the Answer Book was released to the students using our e-learning platform. Students were invited to use it in order to benefit from the skeleton models. In our last examination, all 163 students who were offered the Answer Book used it.

The security features of the Answer Book and the rationale behind implementing them are listed in Table I. Note that the features include an Audit Trail (an immutable log of some of the actions on the Answer Book). The student workflow in using the Answer Book, along with the implementation of some of the security features in Table I, is shown in the flowchart in Fig. 1. The ability to run VBA macros is critical to ensure security. Therefore, upon opening of the Answer Book, if macros are disabled, the students will see only a warning screen, as indicated by the first decision diamond in the flowchart in Fig. 1. Once the Answer Book is opened with macros are enabled, the Audit Trail is updated with the student

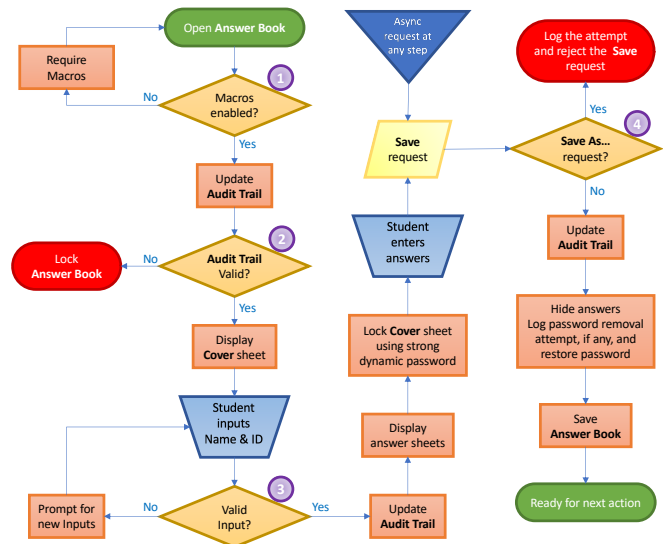


Fig. 1. Student workflow and the associated processing in the secure AnswerBook

information. If the Audit Trail shows a mismatch, the Answer Book is locked with an error screen. This Audit Trail check is pictured in Fig. 1, in the second decision diamond with the badge 2. If the audit check succeeds, the students will see the Cover sheet of the Answer Book where they can enter their identification details. They do not get to see the skeleton models (hidden in the individual answer sheets) yet.

TABLE I. SECURITY FEATURES OF THE ANSWER BOOK AND THEIR RATIONALE

No	Feature	Rationale
1	Each Answer Book should be uniquely tied to a student's identity	Prevent copying by file sharing
2	Students should not be able to view/edit model skeletons before identifying themselves	Prevent collaborative effort and submission as individual work
3	They should not be able to modify the identity after entering it	Prevent submission of the work of other students as their own
4	They should not be able to alter the Answer Book structure by adding, deleting, copying or moving sheets	Prevent copying from the work of other students by sheet
5	Copying and pasting from or to the Answer Book should be disabled	Prevent copying at the cell level
6	The code (VBA project) implementing the security features should be protected behind a password	Prevent hacking attempts
7	The Answer Book should be locked by a simple public password and it should be impossible to save it with a different (or without any) password	Ensure encryption and foil hacking by binary editing of the contents
8	“Save as...” should not be allowed	Prevent saving without the macros to get around the security
9	Audit Trail with student name and time stamp logging activities like file opening, saving, attempt to remove password, attempt to save as a different document etc.	Detection of inauthenticity and hacking attempts

The Cover sheet is protected by a relatively strong password, but its security is not critical before the students enter their details. Once the students enter them, however, the Cover is relocked with a strong, dynamic password generated with the hash of their identity details, the current timestamp and a cryptographic salt [18]. It will be impossible to unlock the Cover sheet to modify the student details without knowing the hashing algorithm and the salt, implementing the first three feature requirements in Table I.

Note that the students will not be able to get around this security feature by “unhiding” the answer sheets on their own because they are set to the “very hidden” state of visibility in Excel, necessitating the access to the VBA project and the password to modify the structure. The VBA project itself is protected and hidden under another strong password. The password-protection of the structure of the Answer Book and its project implements the fourth feature in Table I.

Feature 5 is implemented by clearing the clipboard (the copy/paste buffer) when the Answer Book gains or loses the input focus, when the student activates or deactivates it. This feature makes cheating difficult by ensuring that the student is not able to copy and paste values from other sources. Note that this mechanism does not limit the student's ability to copy and paste to/from other parts of the same Answer Book, which would have made it prohibitively onerous.

Feature 6 is aimed at foiling attempts to get around the security features by viewing and modifying the VBA code. It ensures that the students cannot view the logic behind the strong dynamic password, along with the cryptographic salt used in generating it. VBA project passwords are, however, notoriously easy to crack [10], [11]. We therefore ensure that the Excel file itself is encrypted with the help of the next feature.

Feature 7 ensures that the project password is not visible through editing the Excel file in the binary mode. When an Excel file is protected by a password (even a weak or publicly known password), the whole file is encrypted, and editing it in binary mode does not reveal any sensitive information. In addition, by intercepting their save requests, the students are prevented from modifying or removing the password. If they modify the password, for instance, the Answer Book will silently reinstate the original public password. If they remove it altogether, the save attempt will be canceled, after displaying a message box warning, “Password Required: Please do not remove the password! Saving with the original password.”

The students are also not allowed to save the file in a different format (without macros/security, for instance), which is the eighth feature in Table I. If they try, they will see a message box stating, “Save As! Disabled: Make a copy of the file instead!”

Finally, we have implemented an immutable audit trail system which logs the timestamp, author name and activities (such as file opening, saving, attempt to remove password, attempt to save as a different document etc.). The audit trail is a “Threaded Comment,” a feature of the Office 365 version of Excel. It records the name of the owner of the software license, which the student cannot modify. The audit trail is checked for consistent names right after opening the file and before any other action can take place, which ensures that file sharing among students cannot be used for cheating. The audit trails and their checks can be turned off in the VBA code if needed. The full trails can be viewed and compared against the student

identification (provided on the Cover sheet) when the Answer Book is graded.

#### *Limitations*

1. The Office 365 version of Excel (which has “Threaded Comments”) is needed for the audit trail implementation.
2. While copy/paste actions are intercepted and prevented when working with the Answer Book, copying by typing in information shared through other mechanisms (e.g., formula shared through email or chat application) cannot be prevented.
3. The audit trails logging operations can, in principle, make the Answer Book unresponsive while saving, although we have not seen it happen.

#### IV. AUTOMATIC GRADING

While the focus of the Answer Book design was on its security, the Grader (the tool for automatic grading) is conceived to closely follow the final examination and grading workflow of the instructors teaching our spreadsheet modeling course. With this requirement in mind, we will describe the features of the Grader, and the workflow it attempts to emulate and facilitate.

During the question design phase of the final examination of our course in the current workflow, the faculty members come up with a business scenario to be modeled and implemented. We then solve the modeling problem ourselves in Excel, and draft the question paper using the screenshots of the model, with the output cells cleared. The question paper will also have boxes for answers. This exam preparation work becomes a part of the new workflow as well, both in building the Answer Book as well as the Grader. The Answer Book is, in fact, built from the worksheets of the Excel workbook which produce the screenshots, with the security features described in the previous section added in.

The Grader is also built from the same worksheets of the question design workflow, with extra functionality added in for grading. The only difference is that in copying the model worksheets to the Grader, we do not clear the output formulas and values, which become the reference answers. The extra features and functionality in the Answer Book and Grader are independent of the actual examination questions, making the new tools extremely reusable.

The following requirements were kept in mind while designing the Grader:

1. Ability to generate the Grader (and indeed the Answer Book) from the question designs for the exam.
2. Ease of building and validating the answer keys from question designs with very little additional work.
3. Robust mechanism to build a comprehensive rubric by iteratively adding possible alternative formulas from student answers, optionally with partial grades.
4. Ability to flag candidate formulas (by comparing their numeric values to the reference ones) while grading and testing the students, even when the formulas contain random functions.
5. Facility to run the Grader in batch mode, grading a folder of student Answer Books, generating a grade book.

The use case workflow of the Grader is depicted in Fig. 2, which shows how these requirements are used in practice.

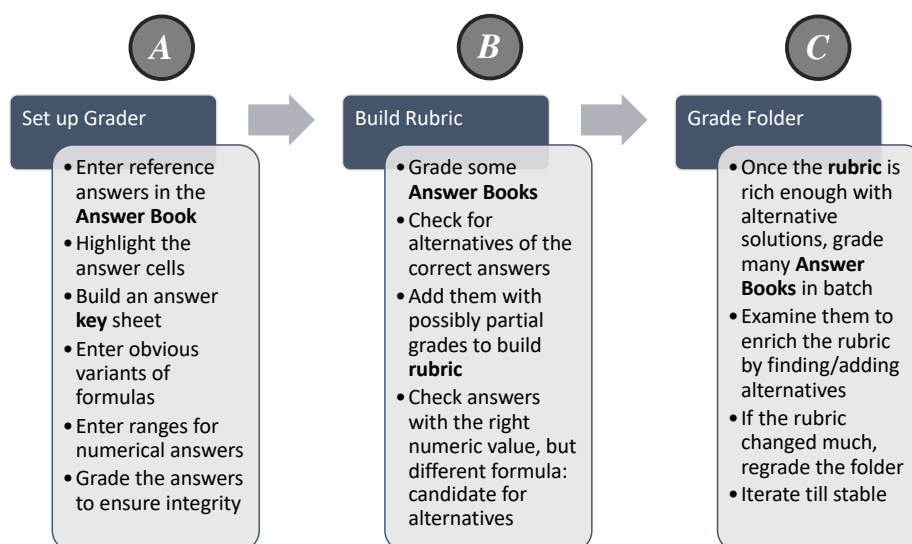


Fig. 2. The main stages of the Grade workflow

### A. Setting up the Grader

In building the Grader, the first step is to set it up by inserting the answer sheets. For the spring term of 2020, when this automated grading tool was first deployed, we had two questions, with the first one having two parts. Each question part corresponds to its own solution worksheet in the answer book, named **Q1-1**, **Q1-2** and **Q2**, which are the models and reference solutions as designed by the faculty. These sheets form the starting point of the Grader workflow.

We then programmatically create the answer “key” sheets, such as **Q1-1-key**, by running the `buildKeySheet()` macro, after highlighting all the cells that contain an answer (either formula or value) in the sheet **Q1-1**. The macro makes a preliminary attempt at standardizing the formula text by converting it to uppercase and stripping white spaces. It also replaces random functions (`RAND()` and `RANDBETWEEN()`) by sensible constant values so that the student's numeric answers can be compared to the reference ones. Note that the same code in the macro `buildKeySheet()` is reused to extract formulas and values from the student Answer Books while grading, thereby ensuring consistency.

One special case that we need to consider is when a different model, based on the same problem statement, may fit into the same answer skeleton. For instance, in the last examination we had a question that asked the students to compute the loan

amount needed to finance a business scenario, where the repayments were done at the beginning of the period. One could compute the amount needed considering that the first payment should or should not be financed by the loan, which would make the loan quantum different. Such alternative models can be incorporated in the **Q\*-key** sheets by merging the two separate answers, using the `mergeAltKeySheet()` macro.

Once the key sheet is built, we enter the marks and value ranges. This is a one-time setup activity. We are then ready to validate the Grader, using the interface shown in Fig. 3. We validate the key sheets generated and the marks entered by grading the answer sheets (**Q1-1**, **Q1-2** and **Q2**) against the answer keys (in the **Q\*-key** sheets). This is done by clicking on the “Grade AnswerBook” button (see Fig. 3) and grading the Grader file itself. The grading process creates a **Q\*-grade** sheet for each answer sheet and computes the total marks on the Cover sheet. We expect to see full marks for the Grader file, which will validate the mark allocations.

### B. Building the Rubric

Once the Grader is set up, we can use it to grade a student's Answer Book. We open the Answer Book and click on the “Grade AnswerBook” button (See Fig. 3) to grade it. The Grader will use the **Q\*-key** sheets, build the corresponding **Q\*-grade** sheets in the Answer Book, compute the total in each sheet and aggregate it on the Cover sheet. See Fig. 4 for a sample **Q\*-grade** sheet. Notice the blue triangles at the top-right corner of some of the student answers in the Formula column, which indicate the presence of a comment explaining how the grading is done. The color code used is described in the Legends table below, and next to it are some action buttons.

Although we start with the reference solution (and possibly a few variants), we have to be able to update our valuation rubric because Excel is a highly flexible tool. Every calculation can be done using several different formulas. For instance, a value lookup may be performed using `LOOKUP()`, `XLOOKUP()` or `INDEX() & MATCH()` functions. Besides, in many of the computations (such as summation, multiplication etc.), the arguments may be permuted without affecting the value, operators (+, \* etc.) or functions (`SUM()`, `PRODUCT()`)

The cover sheet of the Grader includes the SMU logo and a table showing the total marks and out of marks. Below this is a table of action buttons with their descriptions.

Total Marks	Out Of
25	25

*Validating the answer key*

Grade AnswerBook	<b>Grade AnswerBook:</b> Grade an open AnswerBook. Will let you select one.
Grade a Folder	<b>Grade a Folder:</b> Select a folder & grade it. Will create a <b>new</b> <i>GradeBook.csv</i> file.
Redo Totals	<b>Redo Totals:</b> Select a folder to recompute marks, overwriting the <i>GradeBook.csv</i> file.

Fig. 3. The cover sheet of the Grader, showing various action buttons



Ref	Cell	Formula (Ref)	Formula	Out of	Marks	Value (Ref)	Value	Range	Out of	Marks
B10	B10	B9*12+B7	B9*12	0.5	0	\$391,353.68	\$261,353.68	0.005		
B11	B11	\$G\$6*\$F\$6*12-B10	(\$F\$6*\$G\$6*12)-B10	0.5	0.5	\$218,751.58	\$348,751.58	0.005		
B26	B26	G25	G25	0.2	0.2	\$59,969.71	\$64,913.35	0.005		
B40	B40	VLOOKUP(\$A\$40,\$A\$25:\$G\$36,6,FALSE)	INDEX(\$B\$25:\$G\$36,MATCH(\$A\$40,\$A\$25:\$A\$36,0),MATCH(B\$39,\$B\$23:\$G\$23,0))	1	1	\$58,039.33	\$71,051.57	0.005		
B41	B41	INDEX(F25:F36,MATCH(\$A\$40,\$A\$25:\$A\$36,0))	LOOKUP(A40,A25:A36,F25:F36)	1	0	\$58,039.33	\$0.00	0.005		
B43	B43	LOOKUP(A43,G25:G35,A26:A36)	LOOKUP(\$A\$43,\$G\$25:\$G\$36,\$A\$25:\$A\$36)	1	0	Apr	Feb			
B9	B9	B3+B4*B5+B6*\$F\$6*\$G\$6	B3+(B4*B5)+B6*(\$F\$6*\$G\$6)	0.5	0	\$21,779.47	\$21,779.47	0.005		
C25	C25	\$F\$6*\$G\$6	F6*G6	0.2	0.1	\$50,842.11	\$50,842.11	0.005		
D25	D25	\$C\$9	C9	0.2	0.1	\$21,800.00	\$21,800.00	0.005		
E21	E21	-PMT(B20/12,B21,F24,0,1)	-PMT(\$B\$20/12,\$B\$21,F24,0,1)	0.2	0.1	\$29,080.00	\$24,182.81	0.005		
E25	E25	IF(MATCH(A25,\$A\$25:\$A\$36,0)<=\$B\$21,\$E\$21,0)	IF(F24>=\$E\$21,\$E\$21,F24)	1	0	\$29,080.00	\$24,182.81	0.005		
F24	F24	C7+2*C9+E21	C7+C9*2			\$172,680.00	\$143,600.00	0.005	0.2	0.2
F25	F25	(F24-E25)*(1+\$E\$20/12)	F24-E25	1	0	\$144,198.33	\$119,417.19	0.005		
G1	G1	SLOPE(B15:B17,A15:A17)	SLOPE(\$B\$15:\$B\$17,\$A\$15:\$A\$17)	0.1	0.1	-78.95	-78.95	0.01		
G2	G2	INTERCEPT(B15:B17,A15:A17)	INTERCEPT(\$B\$15:\$B\$17,\$A\$15:\$A\$17)	0.1	0.1	4215.79	4215.79	0.01		
G25	G25	(B25-D25-E25)*(1+\$E\$20/12)+C25	(B25-(D25+E25)+C25)*(1+\$E\$20/12)	1	0	\$59,969.71	\$64,913.35	0.005		
G3	G3	RSQ(B15:B17,A15:A17)	RSQ(\$B\$15:\$B\$17,\$A\$15:\$A\$17)			0.9868	0.987	0.0001	0.2	0.2
G6	G6	TREND(B15:B17,A15:A17,F6)	G1*F6+G2			\$1,452.63	1453	0.005	0.1	0.1

Legends	
Reference Formulas & Values from the Answer Keys	Test Selected Formula on the Grader
<b>[Bold]</b> Value with Randomization removed	Insert Selected Formula as an Alternative
Right (reference or alternative) Answer, Full marks	Grade this sheet again
Partial/alternative Answer, Partial marks	Grade this AnswerBook again
Ref (5) Mismatch with ref/alt Formula: 50% marks	Recompute Total (after Manual Adjustments)
Wrong Answer, Zero marks	
Invalid cells (Col B ↔ C), No Auto-grading	
Error in the student formula/value. Review Manually	
Right Formula with wrong value. Investigate	
Same value, different Formula. Alt Formula candidate	

Total Marks	Out Of
2.7	9

Fig. 4. The cover sheet of the Grader, showing various action buttons

etc.) may be mixed and matched to obtain the same right results. All this flexibility leads to students answering correctly, but in many different ways. Therefore, the Grader tool has the ability to spot potential alternative formulas while grading the student Answer Books to enhance the valuation rubric.

For enhancing the rubric, the most important cells in the Formula column in Fig. 4 are the ones that give the right numerical answer, without matching our reference formula (in the Formula (Ref) column). Such formulas are detected and highlighted in amber. They are potentially alternative solutions that should go into our rubric. But they need to be tested against our reference solution. We can click on the “Test Selected Formula on the Grader” button to paste the student formula in the corresponding question sheet. If the value generated by the formula is right, it will be highlighted green, otherwise red. Once a candidate student formula tests correctly, we can review it and add it to the rubric by clicking on “Insert Selected Formula as an Alternative” button. It will add the formula as a threaded comment (with optionally different/partial marks), which will be used in future valuations.

One of the learning objectives of our course is to be able to apply relative, mixed or absolute referencing in Excel, implemented by the use of a \$ sign in cell references. The ability to use the correct referencing is typically tested in our exam. In order to give partial credit to wrong referencing, the Grader automatically detects missing or misplaced \$ signs and awards 50% of the credit of the right version of the formula. It then highlights such cells in a specific color and embeds a comment to inform the instructor of the partial credits being awarded, as shown in Fig. 4.

### C. Grading Answer Books in Batch

Once a few Answer Books are graded with the rubric updated with possible alternatives/partial formulas, we can grade a folder (containing several, or all, student Answer Books) by clicking on the “Grade a Folder” button in the Grader (Fig. 3). The Grader will loop over the Excel files in the folder in batch

(automation) mode, grading each one. When the batch valuation is completed, we have to go through the graded Answer Books again, review and test formulas and insert the right ones in the Grader. We iterate this process (multiple times) to get to the final grades.

The automation part of the Grader does the following:

- Go through each Answer Book in the specified folder.
- Unlock the Answer Book, validate the audit trail.
- Grade it, iterating through each answer sheet within the Answer Book.
- Recover the answer sheets from potentially corrupt files if the grading fails.
- Tabulate student name, total marks, recovery status, audit status etc. in a Grade Book.

### Limitations

As designed, the Grader works extremely well in a wide variety of situations, successfully grading all possible variants of the answers and helping the instructors save significant amount of time and effort. It has, however, some limitations.

1. The Grader requires Microsoft Office 365 because it makes use of the “Threaded Comments” to implement alternative formulas and values. Unlike the Answer Book, where the need for threaded comments could be avoided by turning off the audit trails, the Grader cannot function without them.
2. When an alternative model is merged into the answer key of a question, it creates a corresponding set of alternative formulas and values. They are not grouped together as one consistent solution set, making it possible to have a formula from one model for one cell, and from the alternative model for a different cell. Such answers could be wrong but cannot be detected by the Grader. Although theoretically possible, we did not encounter such cases in our last term.

- When the Grader tries to standardize formulas, it converts them to uppercase and strips off white spaces. This process modifies the output of formulas containing strings within, although we do not expect it to affect the grading.

## V. EXPERIENCE

We ran our online final examination with the secure Answer Book for our cohort of 163 students in the spring term of 2020. We encountered no problems with the exam administration. The Answer Books were provided to the students as a skeleton solution. Among the 163 students who used the secure Answer Book, we detected no attempts at cheating.

We further challenged some students and teaching assistants to attempt to “crack” the security features of the Answer Book. Although they could unmask the Cover sheet password using binary editing, they could not get any farther. Indeed, with the cryptographic salt [18] and hashing, a brute-force attack to unlock it would be in vain. The protection of the VBA project is also made robust by ensuring file level encryption using a weak public password. The potential hackers will find it impossible to save the file without the original public password.

From the grading perspective, once the Grader was set up, and the valuation rubric built, it took about 26 minutes to grade all 163 students. While it sounds impressive, the actual work of interactively building and enhancing the valuation rubric was indeed much longer. However, compared to the previous years of manual grading, the automated Grader reduced the time required to grade by a factor of two to three, in our estimate. Where the automated Grader tool really helps is in being consistent in applying the rubrics. As all instructors know, when the grading process runs over multiple days, it becomes exceedingly difficult to maintain consistency in grading similar or equivalent answers. The Grader never forgets the partial credits for a particular answer variant. Even if we reconsider and change the rubric, it takes only about 10 seconds to regrade each Answer Book.

## VI. CONCLUSION

In this article, we described a secure Answer Book in Microsoft Excel that we used for the final assessment for our course on spreadsheet modeling. We presented the details of how the security features were implemented, along with our experience of using it in a cohort of 163 students.

Once the student Answer Books were standardized, we were in a position to automate the grading process. We developed our Grader tool for this purpose. The automation of the grading process helped reduce the time spent on grading by about a factor of at least two, even when we include the time taken to iteratively build the valuation rubric from student answers. Furthermore, the use of the Grader ensures a very high level of consistency in grading.

Future plans for the project include deploying it to a larger cohort of about 800 students of the same course in Fall 2020. We will also explore the use of these tools for formative assessments such as assignments.

While the Answer Book and Grader are developed for our course on spreadsheet modeling, they can be used for other

courses where the answer book could be cast in Excel form, which also we plan to explore in Fall 2020.

The Secure Answer Book and Grader described in this article are available from the authors, along with instructions on how to use it. The concepts behind securitizing the Answer Book may be employed in other types of files, such as Microsoft Word, where it may be possible to lock some sections using a strong dynamic password. Taking advantage of automated grading techniques for short answer type objective questions [19], the Grader may be extended to other types of online summative or formative assessments.

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