Investigating Automated Grading Techniques in Effectively Teaching Advanced Excel to Large Groups Of Accounting Students

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Abstract. The global student population is growing while faculty size remains constant. Lecturers shoulder an increasingly heavy teaching burden with concomitant pressure to increase their research outputs. Automated marking can alleviate the teaching load on lecturers, especially when the automated marking setup does not demand additional programming skills. This case study is an in-depth description of a course in advanced Excel for accounting students, and how it changed from paper-based assessment to fully online assessment. The move to automated assessment was motivated by large and increasing student numbers and limited lecturing resources, a phenomenon particularly salient in developing countries, where the case study is situated. An online assessment structure was developed by the lecturing team since the university does not have additional funds for costly automated grading tools. It used existing resources such as the university's learning management system and implemented simple string matching as opposed to more complex semantic similarity approaches. We found the success of the automatic grading depended on two aspects: the students adhering to a clearly defined process during assessments, and the Learning Management System's (LMS's) offerings in terms of grading functionality. The LMS used in the automating grading system described here, offered only basic matching functions for grading but no text manipulation functions required to build more robust and general-purpose grading solutions. This highlights a possible gap for LMS providers to address. In this case study we also touch on lessons learned in automated marking, improving marking efficiency, and managing the constraints of the available tools.

Keywords: Automated marking, Automated grading, Excel, Online Assessment, Pattern matching.

1 Introduction

Stress and multitasking often blindside lecturers. Obuh [1] lists several reasons for the lack of work-life balance, including high teaching loads, tight marking deadlines, and growing student numbers, without the equivalent of additional lectures appointed to ease the load. Fuelling the problem further is a growing focus on research outputs to fund public universities [2]. Reporting of burnout among lecturers has increased dur-

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ing and after the COVID-19 pandemic [3, 4]. Lecturers become stressed and overwhelmed due to the added pressure of "compulsory use of new technology" [5] and actively search for tools to help them regain control of their growing workload.

In this study, we discuss a specific method that we, as lecturers, used and are still using to manage the marking load of more than 700 second-year students taking a compulsory second-year module, focussing on advanced applications of Microsoft Excel (only described as Advanced Excel in the rest of this paper). The number of registered students is steadily growing due to the drive towards digital insight acquisition for students in the various faculties outside of economics. Impetus is added by simultaneous demands from industry that graduates possess spreadsheet skills. Despite the growing student numbers, the size of the lecturing team remains constant.

While this case study describes one assessment method, it may prove useful to educators who face similar problems, and support them in implementing small changes that may spare them considerable effort.

Our main research question is: How can automated marking best be used to efficiently and accurately assess large groups of students? We will also touch on lessons learned in automated marking, improving marking efficiency, and the constraints of the available tools.

2 Background

The road that led us to pose this question, can be traced back to the original assessment method of the module described in this paper. Traditionally, in face-to-face teaching, students completed paper-based tests.

This was also true for the Advanced Excel module. Students sat for their assessments in computer labs, each with an Excel file to complete, and the instructions on a piece of paper. They had to complete the exercises on the spreadsheet and copy the formulas onto the paper, which was then marked by a team of lecturers. The final marks were manually entered into the Learning Management System (LMS) by an administrative assistant. The exercise was labour-intensive and error-prone.

When the Covid-19 pandemic hit and all in-person interaction was curtailed, instruction and assessment were abruptly moved online. The Advanced Excel lecturing team had to implement the online assessments themselves and also had to complete all the marking by themselves. The students in their turn had to adjust to attending virtual lectures and a new process of completing their tests.

Setting tests online formed one aspect of assessment, but another equally important issue was the marking of the online tests. The Advanced Excel module demanded that the students' formulas be marked and not the just resulting value, as is done in many introductory Excel courses. However, the lecturing team had no other tools at hand than the University's LMS. We set about implementing online tests that could be partially automatically marked. This was done using the built-in pattern-matching functions of the LMS to assign scores to each answer, which was in the form of a short-answer question. This solution offered some relief but still required human intervention to assign marks to partially-correct formulas. This case study illustrates our jour-

ney towards automating Excel assessments, and the lessons we learned (and are still learning!) along the way.

3 Literature Review

A short literature review was performed to position our study. We identified a considerable corpus of academic literature on automatic grading (or marking as it is also called) but we start by mentioning that Excel is increasingly seen as a sought-after skill for various graduates. We also review the position of the lecturers who teach it.

3.1 The growing pressure on lecturers

The global Higher education (HE) sector is a rapidly changing area of work [6]. Class sizes are growing and the preparedness levels of students are diverging. Repercussions come in the form of increased marking load and the diversity of student needs. (Student needs range from a need for counselling, to learning and study skills development). The preparation and delivery of courses require a significant investment in time of the lecturer. All these considerations put extra pressure on lecturers [7] to meet these demands.

3.2 Excel as a sought-after graduate skill

Excel is an essential skill required by Accounting graduates to enhance their employability when entering the accountancy profession [8]. It is also a skill that is increasingly demanded by a variety of other disciplines [7- 10].

Formby, Medlin and Ellington conducted a study at their university to identify Excel skill sets that were deemed necessary by the future employers of their current students. They surveyed advisory boards, recruiters, and various other relevant parties and found that Microsoft Excel was ubiquitous in business. The need and opportunities for Excel based analytical skills are therefore widespread and pervasive. They recommended that
universities institute appropriate curriculum enhancements to improve their graduates' competitive marketability [11], [12].

3.3 Innovative marking (or grading) tools for Excel

Automated assessment tools are an active field of research. The terms marking and grading are used in literature to refer to the same concept. Many automated marking systems for programming assignments have been documented [13] and they show that the available technology architecture determines the benefits [14].

Assessment of writing falls into one of two forms: Automatic Essay Scoring and Short Answer Grading. The automated marking systems designed for grading essay questions are necessarily more complex than those grading short answers, as essays require text understanding and analysis [15].

Assessment for large classes requires additional functionality for the coordination of a lecturing team consisting of lecturers, tutors and teaching assistants. Enterprise level products include Moodle Workshops, Turnitin GradeMark, Waypoint, WebMark, and newer systems such as LightWork, RemarksXML,Blackboard Grade Centre, and Turnitin 2 GradeMark [16].

McNeill [17] provides a list of desired attributes for automatic grading systems after listing various automated grading systems for Excel assignments. Graders for generic Excel assignments have been written using Microsoft Access [18] and ASP.Net [19]. Other grading systems are provided as textbook supplements such as SAM (Cengage Learning) and SNAP (Paradigm Education Solutions). A version of SIMnet (McGraw-Hill) grades student formulas by comparing the formula as a text string to the solution text string, but only exact matches are counted as correct. Various publisher evaluation tools for spreadsheet grading simulate an Excel environment (such as SAM, SIMnet and Pearson's MyAccountingLab) and provide immediate grading and feedback to students. Very few of these systems accommodate instructor-developed spreadsheet assignments. McNeill identified a need for a grader that manages customised and more complex spreadsheet assignments. He developed MAGE as an Excel add-in [17].

Hekman [9] also investigated Excel automatic graders and found a variety of solutions written by individuals, ranging from files submitted through web pages [20] to spreadsheets with embedded macros [21]. One automatic grader required the students to complete a spreadsheet and complete an online quiz based on the spreadsheet [22]. He concluded that most of the autograders require dedicated programming for each assignment, and that some can grade graphs as well, but that none are completely automated without instructor interaction. Using the LabVIEW programming language, he developed a completely automated program to grade spreadsheets and graphs. The program uses ActiveX to read information about each worksheet in an Excel file, and communicates with Microsoft Outlook through ActiveX which allows the downloading and grading of students' homework submissions. For each submission, the program sends an email reply to the student with feedback on their submission.

Sheludko [23] examined automated assessment tools specifically for spreadsheet assignments. He tested various examples of spreadsheet models that contain self-assessment functions [10]. He found them to represent simple test cases where the spreadsheet processor uses data validation functions to compare single cells with reference values. Many of them do not test the formulas but only the final answer, and many need the teacher to manually review the tests, and collect the marks themselves. Adding new assignments requires lecturers to edit the code of the automated marking tool.

3.4 Free marking tools currently available

There are few free marking tools available, and even fewer spreadsheet marking tools in particular. A new automated Excel marking tool that is freely available (see [23]) makes use of the Google Cloud environment but it demands a considerable in-

vestment of time from the lecturer to set up. When all Excel files have been set up and sent to the marking tool, the final grades are received and this requires an additional step from the lecturer to upload the marks to their LMS.

3.5 The need for using technology to assist in marking assignments

The use of technology in the process of marking assignments and assessments has proven benefits for both students and faculty. Students benefit from even the most basic automated assessment in the form of immediate feedback and faculty benefit by being freed of many hours of marking.

Feedback is a critical component of teaching, be it summative or formative [19]. Automated feedback can be applied on a formative basis or to support summative marking, and technology can be effectively harnessed to do so as class sizes grow. It simultaneously shortens turnaround times which satisfies learner expectations [24]. Students may enter incorrect answers into their tests, convinced they are correct. An immediate response is pedagogically important [25]. Even rudimentary feedback provided by an automated assessment system can immediately provide students with information about the correctness of their solutions. To see the correct answer even in the absence of any feedback message, guides a student towards the required response. Such personalised feedback is even more important in large groups [14]. Accuracy of marking is crucial [26].

The workload of teachers may be drastically reduced by automated assessments, as manual assessments are very time-consuming [27]. The phenomenon of automated assessment is here to stay since the number of students is growing while the teaching staff numbers remain constant. In addition, automated assessments are more consistently graded which is an advantage when compared with grading done by humans [14].

4 Method

Case study research can be used to illuminate one's understanding of a complex phenomenon and can be used to gain an understanding of an issue in a real-life setting. It is both exploratory and explanatory, answering the how and why question, and sometimes also the what research questions. Outcomes can lead to an in-depth understanding of processes, practices and relationships [28].

In this paper, we use a single qualitative case study approach to show how we implemented automatic grading of advanced Excel formulas using only the existing functionality of a well-known learning management system. It is a pragmatist representation of our own experiences, where we focused on an existing system and are still effecting stepwise improvement on this system. We describe the problem and how we are addressing it, in the hope of contributing a practical solution that may be implemented by others.

The case study describes a single-semester course in Advanced Excel and how the grading of assessments changed over time, from paper-based to fully online. It is both

exploratory and explanatory in the sense that we investigated other approaches to inform ours, and then describe our attempted solution toward automated grading of assessments with the tools we have at our disposal.

5 Description

The Department of Informatics at the University of Pretoria presents an Advanced Excel course as a service module to second-year accounting students from the Economics and Management Sciences faculty. It is a semester module that caters to more than 700 students. It teaches advanced concepts in spreadsheets and query languages, empowering students to solve complex problems in the real world. The two departments collaborate on the content and adjust it regularly to ensure the most applicable functionality of Excel forms part of the curriculum. It remains the lecturer's responsibility to know all the content.

The Advanced Excel module is taught weekly in computer laboratories, accommodating roughly seventy students per session, with 12 scheduled sessions of 2 hours each. The content is thus repeated 12 times every week. In every practical session, there needs to be one lecturer and one teaching assistant. The team consists of two permanently appointed lecturers and two assistant lecturers (postgraduate students), and two to three teaching assistants. Seeing that the teaching assistants are still undergraduate students, they assist with administrative activities and do not present lectures.

An assignment is due per study unit, for the students to practice their newly acquired spreadsheet skills. These assignments have to be marked promptly and feedback provided to the students.

Assessments were traditionally performed on paper. Students attended the computer labs at pre-arranged times and were presented with a selectively empty Excel file, where they had to complete formulas on the spreadsheet according to questions on a paper test. Students then had to write the formulas on the answer paper.

When the COVID-19 pandemic hit, this face-to-face model was instantly replaced by an online lecturing and assessment process. The lecturers took turns recording walkthrough videos mirroring the material presented in class, and made it available to students weekly. One online class per week was presented to all 700+ students where the video content was reiterated and question-and-answer sessions were held on the study unit content. This practice shortened the class time and freed up some time for the lecturers to implement the assessments online. The team used the time to migrate the assignments online, and to create online assessments. The assignments and assessments were created as online tests on the LMS. The team had to cope with the workload as no change was made to the Advanced Excel team either during or post the COVID-19 pandemic.

The expense of purchasing automated Excel marking tools was and is prohibitive. The team started experimenting with specific BlackBoard LMS tools to determine how much of the assignment and assessment marking could be automated. The ap-

proach required careful planning and structuring of assessments, and instructions to students to complete the online tests.

The first question in each online test instructed the students to download an Excel file (which contained the instructions) and save it to their device using their student number. Students had to keep saving their Excel files as they worked, in case of a power cut or computer malfunction. The contents of the online test were saved automatically (because it was running on the LMS) but saving the Excel file was the students' responsibility. Each test question required the students to copy the formula from a certain cell and paste it into the space provided in the online test. The last question of each online test always instructs students to upload their Excel files to the LMS.

Many of the simpler functions were set to grade automatically using the Match functionality of the LMS. It performed string and pattern matching (see Figure 1).

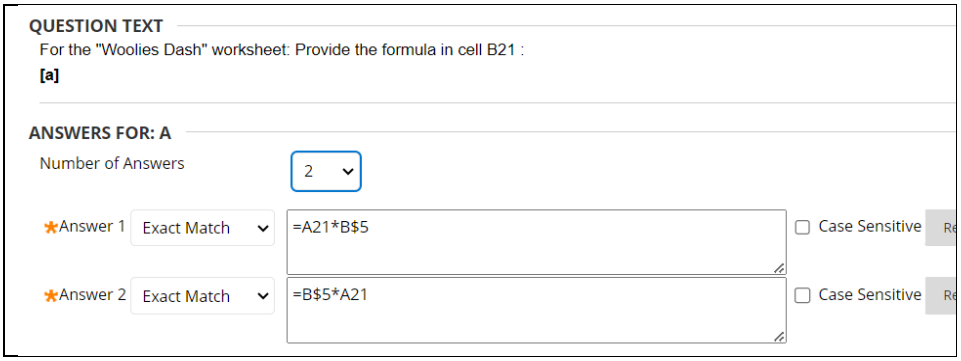

Fig. 1. Online test question setup specifying possible answers using the Match functionality.

Many formulas, although longer, were sufficiently simple so that most of the possible correct combinations could be specified (see Figure 2).

Copy the formula from cell K9 of the "Penalties" worksheet, and paste it in here.
Answers for: a
=IF(B9=J$3,K$3*G9,IF(B9=J$4,K$4*G9,K$5*G9))
=IF(B9=J$3,G9*K$3,IF(B9=J$4,K$4*G9,K$5*G9))
=IF(B9=J$3,K$3*G9,IF(B9=J$4,G9*K$4,K$5*G9))
=IF(B9=J$3,K$3*G9,IF(B9=J$4,G9*K$4,G9*K$5))
=IF(B9=J$3,G9*K$3,IF(B9=J$4,G9*K$4,G9*K$5))
=IF(B9=J$3;K$3*G9;IF(B9=J$4;K$4*G9;K$5*G9))
=IF(B9=J$3;G9*K$3;IF(B9=J$4;K$4*G9;K$5*G9))
=IF(B9=J$3;K$3*G9;IF(B9=J$4;G9*K$4;K$5*G9))
=IF(B9=J$3;K$3*G9;IF(B9=J$4;G9*K$4;G9*K$5))
=IF(B9=J$3;G9*K$3;IF(B9=J$4;G9*K$4;G9*K$5))

Fig. 2. All possible combinations of a simple IF statement

When students used innovative formulas that still performed correctly, these formulas were added to the list of correct answers, and the LMS immediately updated the marks.

While the automatic grading of the simpler formulas was automatic, the team needed to manually grade the complex formulas (see Figure 3). The complex formulas were difficult for the students to complete and students sometimes attempted only part of the formula. Then the team allocated marks accordingly.

Formula for automated recommendation

```
=IF(NOT(OR(K36:M36)),"Reject",IF(OR(AND(K36,NOT(OR(L36:M36))),AND(
OR(L36:M36),NOT(K36))),"Further Evaluate","Accept"))
```

Unit Price formula

```
=IF(ISBLANK(J24),"-",
VLOOKUP(
IF(VLOOKUP(J24, L3_Products, 3, FALSE) = 1, J24, L24),
CHOOSE(VLOOKUP(J24,L3_Products,3,FALSE),L3_Price1,L3_Price2),
2
VLOOKUP(J24,L3_Products,3, FALSE)>1)
)
```

Shipping formula

```
=INDEX(
(Shipping1,Shipping2,Shipping3),
VLOOKUP(O19,L3_States,3,FALSE),
MATCH(O20,L3_ShippingMethod,0),
MATCH(O21,{"Standard","Preferred","Most Preferred"},0))
*M32
```

Fig. 3. Examples of complex formulas in the module

Sometimes students use blanks in their formulas, because it aids in the readability of the longer formulas. This works correctly in Excel, because Excel ignores blank spaces inside formulas. However, the student then gets zero because the basic text match on the LMS automated marking does not work. We had to request students to remove any blanks from their formulas before copying them onto the online test. A simple pre-processing function from the LMS that allows the removal of blank spaces from the answer text, would have been invaluable.

The LMS also disallows the uploading of images and therefore the grading of any charts or graphs in Excel, had to be done manually. This limitation on the part of the LMS forced the team to download every student's Excel file, opening it, inspecting the charts and then entering the grade on the online test. This is time-consuming and forms one of the drawbacks of the process.

When all manual grading is done, the grades immediately reflect in the Grade Centre of the LMS. A significant advantage of the online grading system, is that the pre-

viously in-person perusal process is now more efficiently done online. Perusal is easily accomplished by opening the assessment for students during a pre-arranged time. The entire test is displayed, showing the students' responses, the correct options, and the grade earned for each answer. To query the grading of any question, students are provided with a link to a Google Form. The form contains a list of all questions in the assessment. A student can enter their query at any relevant question number. When perusal closes, the team checks all queries and re-grades accordingly. This happens directly on the LMS's Grade Centre and therefore the marks are immediately available.

6 Discussion

The research problem spotlighted in this paper focuses on how automated marking can best be used to efficiently and accurately assess large groups of students. An implementation of automatic marking of assessments for an advanced Excel module with over 700 students was used as a case study. We as lecturers of the module used existing tools available, in the form of the university's learning management system, to create online tests containing basic text-matching functions of short answers. No additional programming skills were necessary to implement the online tests. However, with such simple tools, it was impossible to fully implement autograding. The more complex formulas had to be marked manually.

While such an implementation is far from being fully automated, it still provides three main advantages: faster and accurate marking of shorter answers, transparency of marking and immediate feedback to students. The last aspect, immediate feedback, offered an unexpected bonus. Students used it as formative feedback. This became apparent to us when we created short online tests for students to complete during their practical sessions, to familiarise them with the process of completing an online test. The incentive to complete the quick test was that it would serve as an attendance mark. Therefore the test settings were such that the students could immediately see the correct answer upon submission. They could also retry and resubmit to get a better mark. It was an immediate learning opportunity for them to see that all aspects of their formula had to be correct before they received a mark. Seeing the actual formulas is better feedback than seeing a simple mark awarded [18], and eliminating the time lag between submission and feedback [9] offers an excellent learning opportunity. Matthews et al. [19] and Cutting et al. [24] emphasise the importance of immediate feedback as a key component of successful learning among students.

The quick tests could only be implemented for the short formulas. However, leaving the complex formulas for class is not necessarily a failing. Fenwick [30] found that entirely automated marking systems deny students formative feedback from more experienced programmers. Doing the exercises in class increases their opportunity to correct errors in their practice by consulting with the lecturer.

Assignments were implemented in the same way - as online tests that could be accessed throughout the week and resubmitted repeatedly, with the correct answers available after each submission. We saw that students also used their assignments as

learning opportunities. To receive better marks, they revisited their Excel files, replaced their erroneous formulas with the correct ones, and resubmitted the assignment. The enthusiasm of many students to retry and resubmit, mirrors the finding from Blayney and Freeman [29] who saw that self-assessment feedback improved the attitudes of students to learn important concepts.

The module was structured in such a way as to keep the student working consistently to keep up with course content and to keep practicing the assessment process. When students repeat the process during formative assessments, they get familiar with the examination process which allows them to better focus on content during summative assessments.

The limitations of the automatic marking described in this paper lie in the lack of preprocessing functions in the LMS for the automatic grading of complex formulas. The formula is entered as a short answer, and simply compared to a set of strings representing correct answers. Short answers are easier to mark than essay-type answers, although the answer has to be checked precisely before awarding marks. Nevertheless, the basic match functions of the LMS (used by the authors of this study), are not sophisticated enough to allow the implementation of pre-processing functions. The inability of the LMS to accept images as answers presented another significant limitation. It disallows image uploads, preventing students from copying their graphs onto the online test. This exponentially increased the marking time. Each student's Excel file had to be downloaded and opened before a mark could be awarded to any graphing or charting questions. Interestingly enough, the conditional formatting results could be copied to the online test because the content represented text and not images.

Another set of limitations lies in the students' use of the system. The complicated process the students have to follow in terms of downloading the file, saving it on the local machine's hard drive using their student number, copying each formula as they work to the online test, regularly saving their Excel file and finally uploading their Excel file to the LMS, is too onerous for many. In the stress of implementing the Excel operations for the test, they forget certain details of the process. There are various common errors students make when completing an online test. They use blanks in their formulas and forget to remove them for the online test. They forget to copy their formulas to the online test before the time runs out, or they forget to upload their completed Excel file at the end of the test. Invigilators have to keep reminding them and despite repeated communication of instructions, students still forget. This causes them to lose many marks unnecessarily.

Marking efficiency was improved by assigning certain questions to be marked by specific team members. The LMS assisted in allowing the team to work on a single question at a time. Marking is significantly faster when the team members each focus on one question in the assessment.

Further improvements that the team hopes to pursue include engaging with the LMS administrators to create a better pre-processor for the text matching functions, and attempts at simplifying the assessment process for the students.

7 Conclusion

The question pursued in this paper pertains to ways that automated marking via LMS can be harnessed to efficiently and accurately assess large groups of students in an Excel module. We found that an effective auto-grading system depends equally much on the process of test-taking than on the marking functionality. We found that the speed and efficiency of the marking depend on how accurately the students follow the test instructions. The case study ultimately echoes the literature in that automatic grading for advanced spreadsheet examinations does not allow a completely hands-free approach. This is because the complex formulas each carry a high mark value, and have to be partially graded. The simple formulas may be marked automatically, but the complex formulas still need to be checked and graded manually.

The tools used in this case study represent standard LMS functionality and require no programming skills to implement. However, the simplicity of the matching tools in the LMS proved such a constraint that the manual marking load far exceeded the questions that could be automatically marked. Despite this drawback, a significant improvement was realised in the perusal process as well as in terms of the marks accurately reflecting on the grade centre throughout.

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