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Automated Multiple-Choice Test Checking System

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Abstract: The primary goal of this study was to address the issues associated with teachers manually checking exam papers. The researcher proposed automating the process of checking exam papers to reduce the burden of manual labor and improve teachers' health and well-being. The study utilized a quantitative research approach, incorporating statistical analysis. Survey questWe used survey questionnaires to gather relevant data from teachers at Benguet State University about the challenges they faced when manually checking students' test pThis study used statistical tools like the mean and t-test to determine the significant difference between manual and automated checking of students' test papers. are grTeachers face significant challenges when manually checking test papers, including the high volume of exam papers, the slowness of the process, the occurrence of errors, and the lack of sufficient time to complete the task. developed for checking the multiple-choice test implemented optical character recognition (OCR). The ad hoc method for the marked answer recognition algorithm corrects the wrong character interpreted by the OCR, processes to get the appropriate letter answer from the marked answers, and checks for valid answers. There is a highly significant difference between the manual and automated checking of multiple-choice test papers in terms of efficiency. There is a highly significant difference in OCR accuracy between the (Pen Colour + Full Shading) and (Pen Colour + X Marking) answer markings. The OCR is not perfect for recognising the marked answers on the answer sheet.

Keywords: ad hoc method for marked answer recognition algorithm, automated checking, multiple-choice test, optical character recognition

INTRODUCTION

Teaching is a noble profession, as it carries great responsibilities for the future of our students and for the progress of our country. Teachers constantly carry a heavy workload from school to home. Besides teaching, checking quizzes and/or exam papers is a demanding job to evaluate students' performance. Manually checking students' test papers is a slow process, tiring, time-consuming, and vulnerable to errors, especially when the volume is high [1]. Overworked and stressed through work overload, writing lesson plans, creating tests, and correcting papers contribute to burnout that affects the teacher's quality of life [2].

The significant impact of incorrectly calculated student results on the academic careers of students and the university as a whole necessitates the meticulous execution of this task through an automated system [1]. A study of manual checking at Sucat Elementary School, Muntinlupa City, Philippines, took one week to gather the results of the examination. It consumed days and hours before classes resumed. Due to this, faculty members encounter difficulties in maintaining student records. Occasionally, teachers struggle to accurately record student exams, leading to errors in recording each student's examination results. Consequently, some students inadvertently receive a low grade in their overall average, particularly when the exam holds a significant weight in the grading system [3].

BL Soft Co., Ltd. is an optical mark reader (OMR) solutions provider that offers an automated system for checking examination papers at schools in South Korea. Teachers used to manually check and analyze exam results, taking up most of their time. But after implementing an automated checking system, work efficiency at schools greatly improved [4].

The old-fashioned manual system of answer script correction is tiresome and time-consuming [5].. The system consumes and wastes human resources. We can

categorize examinations into two types: objective and subjective. Competitive exams typically follow MCT formats, necessitating their conduct and evaluation on computer screens. Currently, almost every competitive exam is conducted in online mode due to the large number of students appearing in them [6]. Adrian Rosebrock developed a bubble sheet multiple-choice scanner using OMR, Python, and OpenCV. Optical Mark Recognition, or OMR for short, is the process of automatically analysing human-marked documents and interpreting their results [7].

A recent study of a natural language processing-based automatic answer checker used NLP (Natural Language Processing) to check or evaluate an answer sheet. The main goal was to save time and manpower by allocating marks based on keywords rather than length of answers. Often, manual evaluation of answers can result in different marks for the same answer. However, the application distributes marks evenly based on the administrator-provided keywords [8]. A similar study on an automated answer-checker, which evaluates subjective or descriptive answers, implemented natural language processing techniques such as stopword removal and tokenization. The system evaluates each student's answer using the same preprocessing as the teacher's reference answer. The designed algorithm evaluates the answers given by students and assigns a score based on the AI, which is as good as scores given by a human being [9].

Another study presented another solution for automated multiple-choice tests that uses techniques from mathematical morphology and is capable of acquiring images from computer cameras (and eventually a myriad of alternative devices) and achieves high accuracy in the results by performing the algorithm using Matlab commands [10]. A similar study reported that the benefits of multiple-choice tests have led to their widespread use as a method to assess students' learning. The machines require expensive equipment to correct their answer sheets. The researchers came up with an improved way to fix multiple-choice test sheets by using mathematical morphology, thresholding, and neighbourhood. This method will improve overall correction accuracy by making it easier to spot options that were only partially marked [11]. Similarly, they developed an application for Android mobile devices using the OpenCV library. We used the app to correct hundreds of multiple-choice test sheets in real conditions, and it demonstrated excellent results, accurately grading tests instantly and providing statistical tools for analysis. This study used mathematical morphology, an image segmentation technique, to circumvent limitations resulting from images captured under non-ideal conditions, yielding even better results than experiments conducted under controlled conditions [12].

In terms of efficiency, or the ability to do something with the least amount of time, resources, effort, or performance expended, there was a clear and significant difference between the manual process and the alternative OMR process. In fact, the difference was very large in favour of alternative OMR [13]. Despite the widespread use of OCR, its accuracy remains significantly lower than that of a second-grade child, let alone a moderately skilled typist. Even 99% accuracy translates to 30 errors on a typical printed page of 3000 characters (and it takes an alert proof reader to catch them all). In nearly all applications, a human operator must either correct the OCR results or reject a significant portion of the documents for operator entry [14].

The researcher experimented with and used optical character recognition (OCR) technology as another alternative solution for developing automated checking of MCT exam papers. The Multiple-Choice Test (MCT) type of exam is processed by automated paper checking. The students answer the test by fully shading the circle that corresponds to the letter of choice. There are five (5) letters (A, B, C, D, and E) to choose from, but only one answer. The students must use a black ballpoint pen to blacken or shade the chosen circle completely. A computer scanner device scans the students' test papers or answer sheets. The developed software application scans the shaded circles for answers, counts, and totals the scores. The test items can have a minimum of 15 points and a maximum of 80 points. The answer sheets can be a letter or A4 paper size.

The main objective of this research was to design and develop an automated multiple-choice test-checking system. The study's specific goals were to find out how hard it is to check students' test papers by hand, how to make a software tool that can automatically check exam papers using OCR technology, how much faster and more accurately OCR works when checking multiple-choice tests by hand versus automatically, and how much better OCR works when marking answers with pen colour and full shading versus pen colour and X marking.

MATERIALS AND METHODS

Research Design

This study used quantitative research with the use of statistical analysis to describe the degree of problems in checking students' test papers manually and to compare manual and automated checking of multiple-choice test papers on efficiency and also between (Pen Colour + Full Shading) and (Pen Colour + X Marking) answer markings on OCR accuracy.

Sources of data

The researcher gathered data from 170 random college teachers at the Benguet State University-La Trinidad Campus on problems encountered in checking

students' test papers manually during the school year 2018–2019, earlier before the COVID-19 pandemic, and from August to September 2022.

The researcher administered MCT examinations with 85 students and 40 total items. The researcher conducted tests, both manual and automated, and assessed the effectiveness and precision of the software application for automated multiple-choice test checking.

Data Instrumentation

The data collection instruments administered were survey questionnaires, a five-point Likert scale, and a p-value scale. Three (3) experts evaluated the survey questionnaire's validation using face validity. The researcher conducted experiments on two (2) answer markings and four (4) pen colors, as shown in Figure 1.

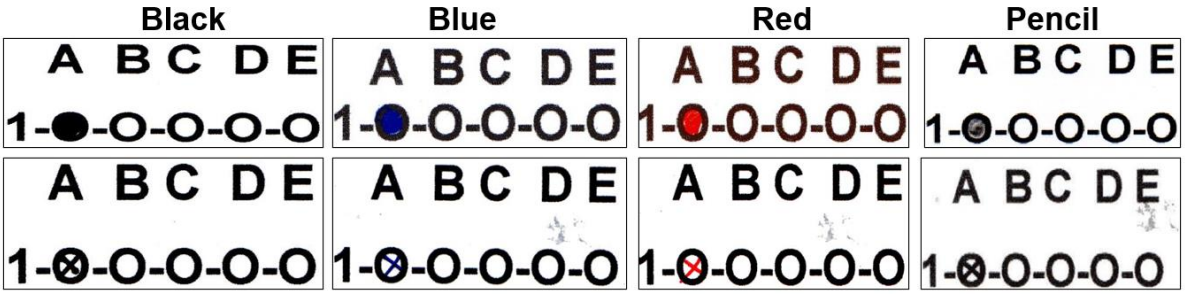

Figure 1: Two(2) Answer Markings and Four(4) Pen Colors.

Treatment of Data

The research implemented the statistical methods such as the mean and repeated measures t-Test. To obtain the degree of problems in checking students' test papers, the mean was computed from the items corresponding to certain problems. The means were interpreted using the Likert range scale of Table 1.

Table 1: Likert Range Scale for Degree of Problems

Range	Descriptive Equivalent
4.21 – 5.00	Severe Problem
3.41 – 4.20	Serious Problem
2.61 – 3.40	Moderate Problem
1.81 – 2.60	Minor Problem
1.00 – 1.80	No Problem

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To determine the significant difference between the manual and automated checking of students' test papers on the efficiency, the two (2) means were computed on both manual and automated checking of students' test papers. Each exam paper checked was measured its time for both automated and manual. The means were interpreted using the Likert range scale of Table 2.

Table 2: Likert Range Scale for Efficiency.

Range	Descriptive Equivalent
1.00 – 1.80	(≤ 1 min) Very Efficient
1.81 – 2.60	(2 mins ≥) Efficient
2.61 – 3.40	(3 mins ≥) Moderately Efficient
3.41 – 4.20	(4 mins ≥) Somewhat Inefficient
4.21 – 5.00	(5 mins ≥) Inefficient

The repeated measures t-Test was used to establish if there was a significant difference in comparison between the two (2) mean scores of manual and automated checking of students' test papers and also in comparison between the two (2) mean scores of (Pen Color + Full Shading) and (Pen Color + X Marking) answer markings.

RESULTS

1. Determine the degree of problems in checking students' test papers manually.

Table 3 summarizes the degree of problems in checking the students' test papers manually. It shows that the high volume of exam papers to check is a severe problem on most of the teachers because of their classes have more than 40 students per class. Each teacher has an average of seven(7) classes per semester. Most teachers need more vacant time to focus in checking the exam papers. After the midterm exam, teachers are diligent to teach the next topics for the final period, and weekends are not enough to finish all the checking. Also, teachers feel boredom when they check in the long period of time that leads to errors in counting and checking. A lot of teachers have other commitments besides teaching that they experienced stress or fatigue that contribute to the delay and accuracy of the checking. Some other problems raised like pending quizzes unchecked that added the total volume of test papers to check and stricken with an ill-disease that hampers the ease of checking.

Table 3: Degree of Problems in Checking Students' Test Papers Manually

Problems	Mean	Descriptive Equivalent
1. The volume of exam papers to check is too many.	4.25	Severe Problem
2. Your speed in checking manually is slow.	3.5	Serious Problem
3. You make mistake in counting the total check scores.	2.75	Moderate Problem
4. You make mistake in checking like for instance you check a wrong answer or you mark wrong the correct answer.	3	Moderate Problem
5. You feel boredom while checking in the long run.	3.75	Serious Problem
6. You are busy to your other commitments.	4	Serious Problem
7. Not enough vacant time to focus in checking the exam papers.	4.25	Severe Problem
8. Late to conduct the schedule of exam in your class because of change schedule or you had a make-up class.	2.5	Minor Problem
9. You have stress or fatigue because of your passion for teaching.	3.5	Serious Problem
10. You lack rest of mind and body relaxation.	4	Serious Problem
11. Others, please specify • There are some pending quizzes not yet checked that added the volume of test papers to check. • Stricken with an ill-disease that hampers the ease of checking.	3 4	Moderate Problem Serious Problem

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2. Design and develop a software tool to automate the checking of exam papers using OCR technology.

The physical view shows the packages fit on the various physical parts of the system [15]. In Figure 2, teachers conduct examination. After the examination, the answer sheets are scanned by an image scanner device that the answers sheets are turned into digital image files. The image files are then process and check by a computer using the developed automated multiple-choice test checking software application.

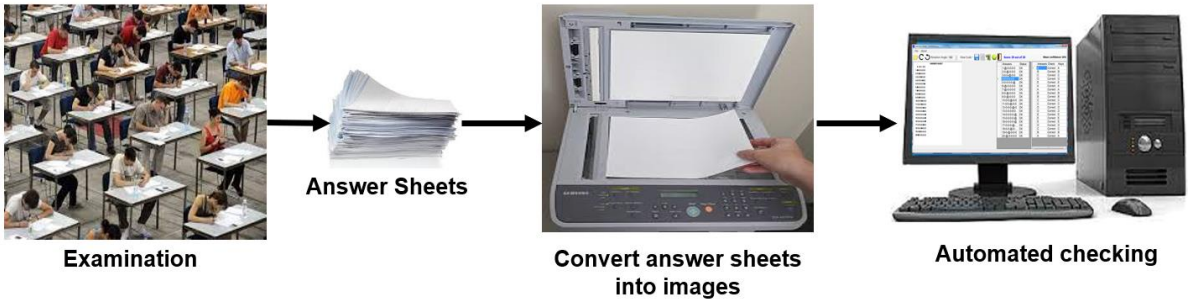

Figure 2. Physical View.

The logical view shows the functional requirements of the system [15]. In Figure 3, the answer sheet image is processed by the OCR and determines the answers from the fully shaded circles. The recognized answers are then compared to the key answers by the checker. Finally, the correct answers are scored
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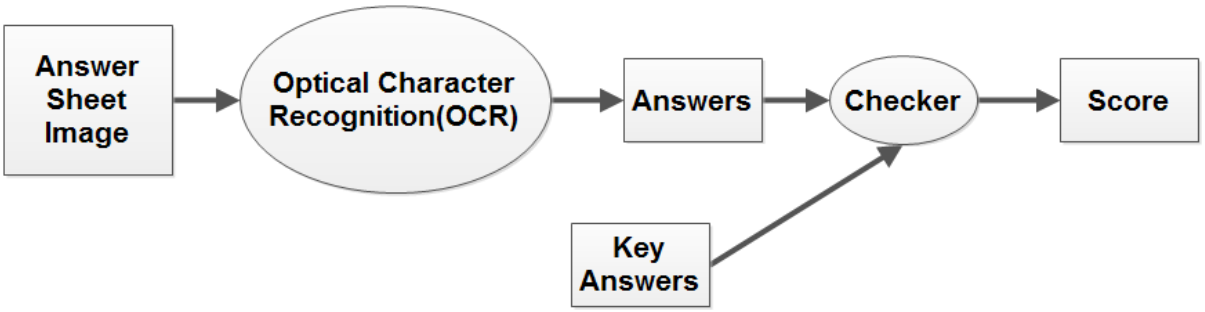

Figure 3. Logical View.

Ad Hoc Method for Marked Answers Recognition Algorithm

The OCR is not 100% accurate to recognize characters from the answer sheet. The OCR recognizes the empty circle as either letter 'O' or zero '0' or "O0" or "0O" while it recognizes the fully shaded circle as either '@', '8', '®', '®9', '©', etc. Sometimes it does not recognize it at all. In order to deal to the imperfection of OCR, an improvised algorithm solution was cleverly designed to compensate the issues. The ad hoc method for marked answers recognition algorithm shows the technical steps to be performed by the computer to correct the wrong character interpreted by the OCR and process to get the appropriate letter answer from the marked answers and check for valid answers as shown on Table 4.

Table 4: Ad Hoc Method for Marked Answers Recognition Algorithm

Algorithm: Ad Hoc Method for Marked Answers Recognition
Input: Set with OCR determined string of characters $S = \{x_i\}_{i=1}^{N}$ where N represents total number of items. Initialize an array of determined answers *T* and array of status *V*. Output: Student answers dataset *T*
Step 1. Take s_i from *S*, and parse and replace "O0" or "0O" to zero "0".
Step 2. Take s_i from *S*, and validate if it contains character letter 'O' or zero '0' then count if it is four(4). If the count is four(4) then it is valid otherwise it is not, it means it has more than one(1) answers or possible no answer.
Step 3. If the result of validation is true then set the status V_i to "OK" means the answer is detected otherwise the status is "?" means undetected.
Step 4. If the status V_i is "OK" then set the T_i the appropriate alphabet letter(A,B,C,D,E) answer.
Step 5. Repeat steps 1 to 4 until all total items are processed. All these generated OCR determined string of characters make up student answers dataset *T*.

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3. Determine the significant difference between the manual and automated checking of multiple-choice test papers on the efficiency.

Based on the results of Table 5, there is a highly significant difference between the manual and automated checking of multiple-choice test papers on the efficiency($t(84) = -2.39$, $p = 0.031$). The interpretation of the mean in automated is moderately efficient while the interpretation of mean in manual is somewhat inefficient. The automated(Mean = 2.65) has lesser time it takes to finish checking the answer sheet than manual(Mean = 3.55). Cohen's d(-0.62) suggests that this is a medium effect size.

Table 5: Difference between the Manual and Automated Checking.

Procedure	Mean	Descriptive Equivalent	P-Value	Cohen's d
Automated	2.65	Moderately Efficient	0.031	-0.62
Manual	3.55	Somewhat Inefficient		

4. Determine the significant difference between the (Pen Color + Full Shading) and (Pen Color + X Marking) on the OCR Accuracy.

Based on the results of Table 6, there is a highly significant difference between the (Pen Color + Full Shading) and (Pen Color + X Marking) answer markings on the OCR accuracy($t(29) = 9.91$, $p = 0.000003852$). The (Pen Color + Full Shading) (Mean = 3.52) has higher OCR accuracy than (Pen Color + X Marking) (Mean = 2.43). Cohen's d(1.81) suggests that this is a large effect size.

Table 6: Difference between the (Pen Color + Full Shading) and (Pen Color + X Marking).

Procedure	Mean	P-Value	Cohen's d
(Pen Color + Full Shading)	3.52	0.000003852	1.81
(Pen Color + X Shading)	2.43		

Based on the results of Table 7, a black ball point pen used to full shading the circle method of answer marking has the highest OCR accuracy(the mean of 30 samples each type of answer markings). Full shading the circle has higher OCR accuracy than X marking. Using blue, red ball point pens and pencil have lower OCR accuracy. The OCR technology hardly recognized the pencil as answer marking tool.

Table 7: Answer Markings.

Answer Markings	OCR Accuracy
Black + Full Shading	94%
Blue + Full Shading	70%
Red + Full Shading	50%
Pencil + Full Shading	5%
Black + X Marking	70%
Blue + X Marking	65%
Red + X Marking	25%
Pencil + X Marking	5%

Manual VS Automated Checking

Type of Exam: Multiple-Choice Test
No. of Exam Papers: 85 Total Items: 40 pts

Table 8: Results of Manual vs Automated Checking.

	AUTOMATED	MANUAL
Completed Time	2 hrs. 2 min. 41 sec.	3 hrs. 4 min. 9 sec.
Checking Accuracy:	100%	95%
Average OCR Accuracy of Shaded Circle Answers Detection:	94.47%	n/a

Based on the results of Table 8, the automated checking is faster to check than the manual checking. The checking accuracy of automated, that is it compares the student's answers with the key answers and counts the correct answers, is 100%. On the other hand, the manual checking is 95% checking accuracy with 5% margin of error. In the manual checking, a 100% checking accuracy is achieved when we check the exam papers slowly but surely, thus the amount of time to spend checking will be longer. The automated checking is not perfect to detect the full shaded circle answers and needs human assistance in editing those blank answers or undetected full shaded circle answers.

Software Development Findings

The following additional findings are results of computer laboratory experiments conducted while developing the Lacea Quiz Checker software application.

1. The OCR is not perfect to recognize the marked answers on the answer sheet.
2. Full shading has higher rate of OCR accuracy than mark X.
3. Black ink pen contributes to high rate of OCR accuracy than blue, red ink pens and pencil.
4. Large font size contributes to high rate of OCR accuracy than small font size. The font size used in the answer sheet is 20 pts.
5. When you save the scanned image twice or more, it lowers the OCR accuracy.
6. When you rotate the scanned image counter clock-wise, it lowers the OCR accuracy.

Pros and Cons of Lacea Quiz Checker

The Table 9 shows the benefits and disadvantages of using the developed software application.

Table 9: Pros and Cons.

Pros	Cons
1. t implemented the OCR technology to detect the shaded circle answers.	1. t is not perfect to detect the shaded circle answers.
2. CR accuracy of shaded circle detection is 94%.	2. t needs human assistance in editing the blank answers or undetected shaded circle answers.
3. t checks and counts the correct and incorrect scores with 100% checking accuracy.	
4. t is better and faster in checking exam papers than manual checking.	
5. t can process the following types of answer sheets. • 4 and Letter paper sizes. • ariety of total items such as 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75 and 80 points.	

DISCUSSION

The research completed yielded the following main results: (i) the high volume of exam papers to check was a severe problem on most of the teachers; slow to check was a serious problem; mistakes in checking was a moderate problem; not enough vacant time to focus in checking the exam papers was a severe problem; (ii) the designs of the software consisted of physical and logical views; the ad hoc method for marked answers recognition algorithm was devised to address the flaw of the OCR; (iii) there was a highly significant difference between the manual and automated checking of multiple-choice papers on the efficiency; (iv) there was a highly significant difference between the (Pen Color + Full Shading) and (Pen Color + X Marking) answer markings on the OCR accuracy; the black pen color with full shading has the highest OCR accuracy.

The mean score for the high volume of exam papers to check is 4.25, indicating a severe problem. Most teachers have more than 40 students per class, with an average of seven classes per semester.

The developed software's physical view design displayed the actual equipment and devices used for automated checking. The developed software's logical view design demonstrated the features of automated checking. The OCR was not accurate enough to detect the fully shaded circle answers, but it has 94% accuracy. We implemented an improvised algorithm solution during the software development process to improve the accuracy by +2%. We formulated the ad hoc method for the marked answer recognition algorithm to rectify any incorrect characters interpreted by the OCR, extract the correct letter response from the marked answers, and verify the validity of the answers.

There was a highly significant difference between the manual and automated checking of multiple-choice test papers in terms of efficiency ($p = 0.031$). Efficiency means the ability to check the exam papers in the least amount of time. We interpret the automated system's mean of 2.65 as moderately efficient, and the manual system's mean of 3.55 as somewhat inefficient. The automated system (mean = 2.65) has a shorter time it takes to finish checking the exam papers than the manual system (mean = 3.55). The effect size was medium (Cohen's $d = -0.62$).

There was a highly significant difference in OCR accuracy between the (Pen Colour + Full Shading) and (Pen Colour + X Marking) answer markings, with $p = 0.000003852$. OCR accuracy refers to the OCR's precision in recognizing the shaded or marked circle answers. The (Pen Colour + Full Shading) has a mean of 3.52, which is higher OCR accuracy compared to the (Pen Colour + X Marking) with a mean of 2.43. The effect size was large (Cohen's $d = 1.81$). Black ink pens contributed to a higher rate of OCR accuracy than blue, red, and pencil pens. Full shading has a higher rate of OCR accuracy than Mark X. The black pen with full shading has the highest OCR accuracy, at 94%.

The automated multiple-choice checking software application implemented OCR technology to detect the shaded circle answers. Since the OCR accuracy of shaded circle detection is 94%, it needs human assistance in editing the undetected shaded circle answers. However, it checks and counts the correct and incorrect scores with 100% checking accuracy, and it is better and faster at checking exam papers than manual checking.

CONCLUSIONS

Teachers face significant challenges when manually checking test papers, including the large volume of exam papers, the slowness of the checking process, the occurrence of errors, and the lack of sufficient time to complete the task. The design and development of the software demonstrates the physical and logical aspects of the model. The ad hoc method for the marked answer recognition algorithm corrects the wrong character interpreted by the OCR, processes to get the appropriate letter answer from the marked answers, and checks for valid answers. There is a highly significant difference between the manual and automated checking of multiple-choice test papers in terms of efficiency. There is a highly significant difference in OCR accuracy between Pen Colour + Full Shading and Pen Colour + X Marking. Full black shading using a black-coloured ballpoint pen is the best method for answer marking. The OCR technology is not perfect for recognising the marked answers on the answer sheet. Therefore, we must provide teachers with ample time to review the exam papers. Teachers who are aged 55 and above or stricken with illness should have a class population of no more than 30 students.

DISCLOSURE

Funding: This research received materials funding from the BSU Office of Research Services

Software Patronage: One of the main outputs of this research is a software application that checks multiple-choice exam papers using Optical Character Recognition(OCR) technology. The Lacea Quiz Checker software application can be obtained for free at this URL: https://drive.google.com/file/d/1e37bL0JMTh3QtlUVbG27Kv3EXwD2rSVK/view?usp=sharing. Also, you can watch the demo at this URL: https://youtu.be/JPdiO8_Q3ds

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Conflicts of Interest: None.

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