The Effects of Extended Exam Time on the Performance of Regular Engineering Students

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Abstract

Usually, exam time is imposed by the educational institution to facilitate examining a huge number of students within a limited time frame. While the instructors might consider the mid-level (both in knowledge and skills) students while preparing the exams, slower students might get overlooked. In this research, four midterm exams were used to study the effect of extended exam time on the students' performance. The four exams were given to the students with a standard established time limit, and, in a different semester, were given to another group of students with extended time. The results proved that students generally performed better in the extended time exams with higher differences for mid-level students than for top and low level. It is recommended that instructors should consider the slower (in reading, writing and/or doing calculations) students while preparing their limited time exams.

Keywords
Extended exam time; Engineering students; Classroom assessment; Exam content.

1. Introduction
Classroom Assessment (CA) is defined as a straightforward approach designed by a faculty member to identify what, how much, and how well their students are taught (Angelo 1995). CA is the primary source of information for students, parents, and instructors about the students' learning process (Brookhart 2003). The two primary purposes of CA are known to be formative and summative. Formative assessment is designed and conducted to direct the teaching process to achieve its goals. The feedback from such an appraisal helps the instructor to judge their teaching techniques and to adjust them as needed. On the other hand, the summative assessment aims at providing third parties (parents, school

administrators, job managers, etc.) with reports about the learning wellness of the students (Brookhart 2003 and Bonner 2013). An instructor should prioritize accuracy in a CA outcome to achieve its purposes.

Among CAs, exams are the most common tool used by instructors in higher education. When designing an exam, two factors should be considered: 1) question formats and 2) exam time length. Several types of question formats may be utilized for conducting exams such as multiple-choice questions, essay questions, and short answers. Selecting the most suitable form of questions depends on the course material and intended learning outcomes. On the other hand, exam time length should be long enough for the students to deal with all the questions appropriately, permitting even the slowest student to finish before the end of the exam period (McKeachie and Svinicki 2013). However, this is not always the case as students differ significantly in their solving speed due to their intellectual and cognitive skills. Some references recommend guidelines for estimating the test period for each question (McKeachie and Svinicki 2013).

Wrong estimation of exam time length might lead to failure or low performance for some students who would, otherwise, do better in the exam. Students with a slow reading rate suffer from poor comprehension, followed by the slow development of general cognitive skills, which leads to academic failure (Hempenstall 2013). While reading skills develop early in the student, reading problems will continue throughout their educational career, and the gap will widen between the late-starters and early-starters with time (Hempenstall 2013). Those students are more vulnerable to losing points in the exam due to its limited time length, and hence, suffer higher failure rates. These elevated failure rates might lead to higher stress, anxiety, and depression symptoms associated with exams (Yusoff 2013). It also might raise the dropout rate as the students who failed at least one unit had about four times higher risk of dropping out than those who did not fail any units (Walker-Gibbs et al. 2005).

1.1 Objectives

In this paper, the effect of adding a short extended time to the regular test period on students' grades is studied. The focus is on industrial engineering senior and junior students. This study assumes that some college students might have problems in their developed learning skills that can lead to significantly lower performance in the exam due to time pressure. It was predicted that the students' scores would be affected significantly with the extended time, particularly mid-level students.

2. Literature Review

There are multiple aspects of research in the relation between extended exam time and students' performance. One of the main aspects is the use of the extended time to aid students with a learning disability (LD) to put them on the same page as their peers with no learning disability (non-LD). Alster (1997) studied the effects of extended time on the performance of LD students versus non-LD students in the ASSET Elementary Algebra Test. The participants (both with approved LD and without LD) were selected from five community colleges in California with ages ranging between 19 and 46 years old. One half of the exam was administered to the students within regular time (12 minutes), and the other half was administered with no time limit. The study results proved that both LD students and non-LD students performed significantly better in the extended time exam. However, the scores of the LD students increased significantly higher than that of the non-LD students.

Cohen et al. (2005) conducted two studies to investigate the effects of extended time and content knowledge on 9th grade students' performance in a statewide mathematics test. The participants were 1250 LD students and 1250 non-LD students. Analysis of variance of the mean test scores proved that accommodation status (with or without extended time) has a significant effect on the students' performance. However, using differential item functioning (DIF) analysis showed that extended time was not the main factor in the varying performance. Rather, the competency in mathematics appears to be the main differentiating criteria amongst the students. They conclude that extended time (or test accommodations in general) is only a tool to allow students present their knowledge, no more than a 'reading glasses' as they express.

Lewandowski et al. (2008) studied the effect of extended exam time on the performance of students with reading disability versus that of students without disability. 64 high school students (half of them have approved reading disability) participated in a reading comprehension test. The study concluded that both groups of students benefited from the extended time with the non-disabled students achieving higher benefit. However, the extended time allowed disabled students to attempt the same number of questions as the non-disabled students. In this paper, the authors raise questions about the actual value of extended time as an accommodation for disable students.

Another aspect of research in this area is the significance of reducing or extending the exam time, and the exam content accordingly, on the higher education students' performance. Lee et al. (2014) investigated the possibility of shortening the standard exam time from a usual value of 3.0 hours to 2.0 hours without affecting the exam output. The goal of this research was to set up a systematic approach for instructors to evaluate the shortening possibility of their subjects' exams. They applied their technique on 10 different subjects, and the results proved that shortening the exam time to 2.0 hours is justified. The researchers encourage university instructors to consider this technique in order to reduce the time-consuming and tiring grading tasks.

Jensen et al. (2013) studied the effect of increasing exam time on the students' performance and cognitive fatigue. The study was applied on undergraduate biology exams offered to non-major biology students. The results demonstrated that increasing the exam time, and the exam content accordingly, enhanced the students' performance. Regarding the cognitive fatigue, the study supported the opinion that students do not experience cognitive fatigue due to exam length.

Connelly et al. (2005) studied the relationship between the handwriting fluency and exam performance in a cohort of UK second year undergraduate students. The participants in the experimental study were 22 psychology undergraduate students at South Bank University. Participants were asked to fulfill two writing tasks: unpressurised (training task with no grades) and pressurized (graded exam). The study revealed that slow speed of hand-writing did not affect the students' performance in the unpressurized writing task while it had a significant effect in the pressurized writing task. Vilenius-Tuohimaa et al. (2008) studied the relationship between the performance of fourth grade students in both reading comprehension and word math problems. The participants were 225 students aged between nine and ten years. The study outcome proved a strong relationship between the students' performance in both tests suggesting that problems in reading comprehension skills will result in word math problems' skills.

3. Methods

Grades of eight midterm exams of three mandatory industrial engineering undergraduate core courses, recorded over two semesters, were used in the analysis. The eight exams were divided into 1) regular time exams and 2) extended time exams. The exams' difficulty level was comparable for each course across semesters. In the compared semesters, the same instructors taught the courses. Specific information for both the regular and extended exam time are presented in Table 1.

Table 1: Specific information on the exams

Exam	Course Name	College Year	Regular Time Exams		Extended Time Exams	
			Semester	Students/Group	Semester	Students/Group
1	Human Factors Engineering	4	Fall 2016	60 / Group 1	Fall 2017	77 / Group 2
2	Human Factors Engineering	4	Fall 2016	57 / Group 3	Fall 2017	75 / Group 4
3	Manufacturing Economics	5	Fall 2016	20 / Group 5	Fall 2017	29 / Group 6
4	Design and Analysis of Experiments	4	Fall 2016	34 / Group 7	Spring 2016	19 / Group 8

Exams 1 & 2 (Course name: Human Factors Engineering):
Human Factors Engineering is a three-credit-hour undergraduate course offered to industrial engineering junior (fourth year) students; it introduces students to the field of human factors engineering so that they can fully recognize the capabilities and limitations of human beings (operator or user) in order to enhance certain desirable values such as safety, job satisfaction, efficiency, and well-being. The course also helps the student in understanding how to optimize the relationship between people and technology. No pre-requisite courses are needed for this course. The regular exam time for both exams was one hour, while the extended exam time was one hour and fifteen minutes. Exam 1 was offered in the eighth week of the semester while exam two was provided in the twelfth week of the semester.

Exam 1 was an MCQ (multiple-choice questions) midterm exam worth 10% of the final course grade. It consisted of 20 questions; each question comprised one statement and five choices (A, B, C, D, and E) with only one correct answer. Exam 1 covered an introduction to human factors and human-machine systems (5 questions), and information processing (15 questions). The questions were randomly (and uniquely) selected from a database that has accumulated a total of about 65 questions on these topics. In order to increase the comprehensiveness of the assessment, question types have been (as much as possible) equally varied among identification (e.g., by showing a figure representing an experiment), definition, numerical, and inquiry (e.g., assessing whether or not the student understands a specific concept) problems.

Exam 2 was similar to exam 1 in structure but covered different contents of the course material. It covered controls and compatibility (10 questions), and human visual capabilities (10 questions). The questions were randomly (and uniquely) selected from a database that has accumulated a total of about 55 questions on these topics. Similarly, question types have been (as much as possible) equally varied among identification.

Exam 3 (Course name: Manufacturing Economics):
Manufacturing Economics is a three-credit-hour undergraduate course offered to industrial engineering senior (fifth year) students. It introduces students to the field of manufacturing economics with an emphasis on topics such as labor cost analysis, materials cost analysis, overhead cost calculations, operation cost estimation, product cost estimation, and product pricing. A course in work analysis and design is a pre-requisite for this course. The regular exam time for this midterm course was one hour while the extended exam time was one hour and thirty minutes.

The questions were randomly (and uniquely) selected from a pool of problems developed by different professors over the past five years to cover those topics equally (as much as possible). This database consisted of 40 problems about the labor cost analysis, 40 problems about the materials cost analysis, 15 problems about overhead cost calculations, 80 problems about the operation and product cost estimating, and 40 problems about product pricing. The exam was based on problem-solving with no theoretical or essay questions (those are left for the final course exam). Only relevant math skills are needed to solve this exam's problems. The exam was offered in the eighth week of the semester.

Exam 4 (Course name: Design and Analysis of Experiments):
Design and Analysis of Experiments is a three-credit-hour undergraduate course offered to industrial engineering junior (fourth year) students, which introduces students to the field of design of experiments. It covers topics such as a test of hypothesis, one-way ANOVA, factorial design, fractional factorial design, regression, and response surface methodology. A course in engineering statistics is a pre-requisite for this course. This midterm exam was an open book exam with a regular time of one hour and thirty minutes while the extended exam time version was an exam without any time limit.

Exam 4 was based on problem-solving with the necessary math skills needed to solve the problems. A significant part of each problem's grade was devoted to formulating the hypothesis to be tested, and drawing appropriate conclusions from the calculations/analysis results. Additionally, describing plots and writing relevant comments was a significant part of the exam (e.g., residual plots and interaction plots.) The exam was offered in the tenth week of the semester.

3.1 Participants

All participants were students in the Department of Industrial Engineering, College of Engineering, King Saud University. All students were males (only males are admitted in this college) registered in their fourth or fifth year of the five years industrial engineering program. Student groups who were granted an extended time were informed about the experiment. All participants belonged to the same ethnicity, age group, and native language (Arabic).

Comparisons using *t*-test were made between the GPAs of participants in each exam. Group 1 vs. Group 2 showed no significant difference in GPA (p-value = 0.06). Note that students in Groups 1 & 2 are the same students of Groups 3 & 4, respectively, except that some students dropped the course before the second midterm. Group 5 vs. Group 6 showed no significant difference in GPA (p-value = 0.39). Group 7 vs. Group 8 showed a significant difference in GPA for the favor of Group 7 (p-value = 0.02, Cohen's d = 0.71).

3.2 Statistical Analysis

Four exams in three different undergraduate courses were conducted under two different time limits: regular time limit and extended time limit. All the exams were graded out of 100 points before statistical analysis was conducted using SPSS software. The *t*-test was used to compare groups taking the same exam under different time conditions (Groups 1 & 2, 3 & 4, 5 & 6, and 7 & 8) to investigate the effect of extended time on the students' performance with a significance level of $\alpha = 0.05$.

Anderson darling test was used to evaluate the normality of the populations. The test proved normality of populations associated with Groups 3 to 6 and deviation from normality for populations associated with Groups 1, 2, 7, and 8. However, the *t*-test was used for all the groups as the F-test for variance equality proved equal variance between populations of Groups 1 and 2 and between populations of Groups 7 and 8. Hence, the expected error in the *t*-test outcome, due to non-normality, may be neglected (Boneau 1960).

Between-group effect sizes were calculated using Cohen's d (Cohen 1988) and corrected for small sample size as suggested by Hedges and Olkin (1985). The effect size was interpreted, as suggested by Cohen (Cohen 1988) and expanded by Sawilowsky (2009) into 0.2 (small effect), 0.5 (medium effect), 0.8 (large effect), 1.2 (very large effect) and 2.0 (huge effect.) Besides the comparison between all the participants in the groups, subgroups were also compared: top-level students (T), mid-level students (M) and low-level students (L), while each subgroup was taken as one-third of the group after arranging the grades high to low. In all cases, the alternate hypothesis was that the students who received the extended time would perform better than the students with regular time.

4. Results

The results of the *t*-test indicated a significant difference between Groups 1 and 2 with a small to medium effect (*p*-value = 0.049 and Cohen's d = 0.28). There was no significant difference between subgroups 1T and 2T (p-value = 0.126). There was a significant difference between subgroups 1M and 2M (*p*-value = 0.000 and Cohen's d=1.23). In addition, there was a significant difference between subgroups 1L and 2L (p-value = 0.020 and Cohen's d=0.62). Overall, the variance was reduced from 278.9 to 190.4; while in subgroups T, M and L, it changed from 27.4 to 37.5, 13.9 to 13.1 and 190.7 to 73.4 respectively. F-test for equality of variance proved significance only for subgroups 1(L) vs. 2(L) with p-value 0.012. All results are summarized in Table 2.

Table 2: summary of the statistical analysis results of Exam 1

Group	n	Mean	Variance	t	p-value	Cohen's d
1	60	70.33	278.9	1.66	0.049*	0.28
2	77	74.67	190.4			
1 (T)	20	87.00	27.4	1.16	0.126	0.34
2 (T)	25	89.00	37.5			
1 (M)	20	71.75	13.9	4.21	0.000*	1.23
2 (M)	26	76.35	13.1			
1 (L)	20	52.25	190.7	2.10	0.020*	0.62
2 (L)	26	59.23	73.4			

The results of the *t*-test indicated a significant difference between Groups 3 and 4 with a small to medium effect (p-value = 0.006 and Cohen's d = 0.44). In addition, there was a significant difference between subgroups 3T and 4T (p-value = 0.000 and Cohen's d = 1.17). There was a significant difference between subgroups 3M and 4M (p-value = 0.000 and Cohen's d = 1.94). There was a significant difference between subgroups 3L and 4L (*p*-value = 0.030 and Cohen's d = 0.58.) Overall, the variance was reduced from 169.8 to 186.6; while in subgroups T, M and L, it changed from 28.1 to 31.7, 7.9 to 10.7 and 71.7 to 37.2 respectively. F-test for equality of variance proved non significance for overall and sub-groups comparisons. All results are summarized in Table 3.

Table 3: summary of the statistical analysis results of Exam 2

Group	n	Mean	Variance	t	p-value	Cohen's d
3	57	70.61	169.8	2.54	0.006*	0.44
4	75	76.60	186.6			
3 (T)	19	84.21	28.1	3.97	0.000*	1.17
4 (T)	26	90.96	31.7			
3 (M)	19	71.32	7.9	6.49	0.000*	1.94
4 (M)	25	77.40	10.7			
3 (L)	19	56.32	71.7	1.93	0.03*	0.58
4 (L)	25	61.20	67.2			

The results of the *t*-test indicated a significant difference between Groups 5 and 6 with a medium to large effect (p-value = 0.01 and Cohen's d = 0.68). In addition, there was a significant difference between subgroups 5T and 6T (p-value = 0.015 and Cohen's d = 1.2). There was a significant difference between subgroups 5M and 6M (p-value = 0.001 and Cohen's d = 1.66). There was a significant difference between subgroup 5L and 6L (p-value = 0.008 and Cohen's d = 1.28). Overall, the variance was reduced from 419.8 to 211.4; while in subgroups T, M and L, it changed from 44.2 to 16.7, 8.4 to 20.2 and 283.2 to 119.0 respectively. F-test for equality of variance proved significance only for the overall comparison between groups 5 and 6 with p-value 0.03. All results are summarized in Table 4.

Table 4: summary of the statistical analysis results of Exam 3

Group	N	Mean	Variance	t	p-value	Cohen's d
5	20	62.25	419.8	2.39	.010*	0.68
6	29	74.00	211.4			
5 (T)	6	79.17	44.2	2.42	0.015*	1.20
6 (T)	9	89.00	16.7			
5 (M)	7	70.00	8.4	3.55	0.001*	1.66
6 (M)	10	77.00	20.2			
5 (L)	7	40.00	283.2	2.74	0.008*	1.28
6 (L)	10	58.00	119.0			

The results of the *t*-test indicated no significant difference between Groups 7 and 8 or between their subgroups with all *p*-values higher than 0.05. However, the difference in favor of students with regular exam time was highest for the top students and lowest for the medium students with Cohen's d = 0.63 and 0.07, respectively. Overall, the variance changed from 613.6 to 635.5; while in subgroups T, M and L, it changed from 6.3 to 54.2, 207.1 to 114.7 and 166.7 to 19.4 respectively. F-test for equality of variance proved significance only for 7 (T) vs. 8 (T) and 7 (L) vs. 8 (L) with p-values 0.004 and 0.01 respectively. All results are summarized in Table 5.

Table 5: summary of the statistical analysis results of Exam 4

Group	N	Mean	Variance	t	p-value	Cohen's d
7	33	74.00	613.6	0.60	0.276	0.17
8	18	69.67	635.5			
7 (T)	11	97.40	6.3	1.37	0.093	0.63
8 (T)	7	94.14	54.2			
7 (M)	10	75.20	207.1	0.15	0.440	0.07
8 (M)	7	76.14	114.7			
7 (L)	11	44.50	166.7	1.33	0.102	0.50
8 (L)	6	38.83	19.4			

5. Discussion

It is factually undeniable that everything in our life runs against time, especially in the professional engineering realm. Construction projects, production schedules, supply chains deliveries, new products introduction and many other engineering applications are all bounded by time. All of this makes it important to train engineering students to develop their engineering knowledge and skills against time. However, a debatable argument of whether to develop those engineering skills by adding the time pressure factor to exams assessment or postpone such pressure exposure to their early professional life where the scope of the engineering problems is eminent and professional supervision and support are available. Lewandowski et al. raised the question regarding the instructors' need to test the speed of the students as a skill by itself. This study aims to confirm the significance of relationship between exam time and exam content on the students' performance.

The results obtained in this study support the assumption that exam time limit affects students' scores significantly. In three of the four studied exams, the *t*-test results indicated a significant difference between students' scores in regular exam time and extended exam time with p-values ranging between 0.006 and 0.049. These conclusions match those of Alster (1997) and Cohen (2005) for students without learning disability. The fourth exam did not show a significant difference between students' scores in regular time and extended time. This might be due to the nature of this exam being an 'open book' exam. It might also be due to the significant difference in the students' level (measured by accumulative GPA) in favor of the regular exam time students. The given exam time extension might have closed the gap between the students.

In exams 2 & 3, the results showed significant differences between top, medium and low-level students in both groups with a p-value for exam 2 ranging between 0.000 and 0.030 and the p-value for exam 3 ranging between 0.008 and 0.015. For exam 1 only medium or low-level students had significantly different scores with p-values ranging between 0.000 and 0.020. These results show that students on all levels, generally, benefited from the extended time.

The effect size numbers show that middle-level students benefited more from the time extension than the other two groups in exams 1, 2, and 3. In exam 1, Cohen's d value for mid-level students was 1.23 (very large effect) compared to 0.62 (medium to high impact) for the low-level students and no significant difference for the top-level students. In exam 2, Cohen's d value for mid-level students was 1.94 (almost huge effect) compared to 1.17 (large effect) and 0.58 (medium to large impact) for top and low-level students, respectively. In exam 3, Cohen's d value for mid-level students was 1.66 (very large to huge effect) compared to 1.20 (very large effect) and 1.28 (very large impact) for top and low-level students respectively. These results verify that mid-level students are the most vulnerable to the exam time limitations, as they might have the needed knowledge and skills to perform better in the exam. Still, their scores are restricted by the exam time.

Results of F-test for the equality of variance indicated non-significance for all comparisons amongst exams 1-3 except for group 5 vs. group 6 and for group 1 (L) vs. group 2 (L). In both cases, the variance was significantly lower in the extended time exam with p-values 0.03 and 0.01 respectively. The values of the variance in Tables 2-4 show mixed pattern with the trend towards reduction in the extended time exams. Variance comparisons in exam 4 do not seem to provide a useful interpretation which may be due to the small size of the tested sample.

6. Conclusion

As the exam time limitations, imposed by the educational institutions, might be hard to change, the research results recommend that the exam content be reviewed as the exam time might not be sufficient for all students to perform up to their level of knowledge and skills. The instructors might consider the average level (in both knowledge and skills) students' capability to finish all questions within the given exam time. However, it is easy to overlook the slower students who might perform much better if they had extra time for reading, writing and/or doing calculations.

The study in this paper is correlational in nature and does not investigate the causation behind the presented observations. Extra research in this topic is needed for better understanding. Several limitations apply to this study due to the nature of participants and structure of considered exams. As mentioned earlier in the paper, all students are senior male engineering students. Also all courses' materials and exams are administered in English language which is the students' second language. Exams considered do not include essay questions (short or long) and do not need sophisticated math to solve them thoroughly.

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Ahmed M. El-Sherbeeny, PhD, is an assistant professor at the Industrial Engineering department (since 2010) and former head of the Alumni and Employment Unit (2013-2018) at the College of Engineering, King Saud University. He completed both his PhD (2006) and Master's (2001) degrees in Mechanical Engineering from West Virginia University (WVU), where he was a graduate teaching and research assistant. El-Sherbeeny's research interests include Human Factors, Safety, and Environmental Engineering, as well as Engineering Education.