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Evaluating Cognitive Skills Development in Undergraduate Engineering Students: A case study utilizing the EAS Test

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Background: This study aims to assess the percentiles of junior engineering students' abilities as they progress academically and to investigate if factors such as academic advancement, age, gender, and CGPA may influence their cognitive skills. To achieve this, the Employability Aptitude Survey Cognitive Test (EAS-test) was administered. Four tests-numerical ability, space visualization, numerical reasoning, and symbolic reasoning responses were selected from the battery of ten tests to calculate the students' overall performance. The percentiles of students' abilities were then determined to fulfill the study's objective. Materials and Methods: Approximately 108 undergraduate students from the Department of Industrial Engineering (IE) at Benghazi University, spanning the second, third, and fourth years during the academic year 2022-2023, were chosen for the study. Analysis of variance (ANOVA) was utilized to analyze the data. Results: The results revealed a significant difference in raw test scores among students' abilities. However, the ability in space visualization tests was found to remain unaffected by academic progression. Furthermore, as students progressed through each semester, the diversity in CGPA groups was observed to have a notable impact on the percentiles of students' aptitudes.
Likewise, strong correlations between CGPA and students' percentile proficiency were identified. Key Word: aptitude, EAS-cognitive tests; student's percentile; engineering, rententability-threshold; battery score; employability skills, performance skills.

I. Introduction

To ensure the success of engineers, students in the College of Engineering must demonstrate proficiency in essential skills. Many of these skills are acquired through academic experiences such as numerical ability, space visualization, numerical reasoning. and symbolic reasoning. Additionally, students' abilities in speed and accuracy, as well as generic skills like oral and written communication and teamwork, enable them to progress successfully in their academic careers. Therefore, improvements in students' aptitudes should be continuously evaluated (Dlhin, Mackieh, & Adesina, 2020). Particularly in engineering programs, the demand for a minimum level of mastery of required mathematical foundations and competencies associated with reading skills and abilities is an essential element. Without these, first-year engineering students encounter complications in their academic performance, severely disrupting their academic careers.

Cognitive abilities tests provide information about the learning outcomes of students that help in the assessment of the academic performance they gained during their studying years. In particular, the detection of skills and competences in relation to mathematical and analytical thinking, reading comprehension, and the structure of the language, allows detecting the potential of candidates to successfully complete the first year of undergraduate level [2].

The significance of cognitive ability and employment experience was evaluated in the prediction of work performance by [3]

The study used the Employee Aptitude Survey) to identify work performance [4]. The findings showed that work performance was significantly predicted by both ability and experience. The tests that have been developed to assess general mental ability (GMA) have been employed in the selection of employees by many organizations, and research has validated this by showing a positive relationship between cognitive ability tests

(CAT) and performance [5]. On the other hand, the cognitive or mental ability (GMA) has a great impact on job knowledge; that is, employees who score high on the GMA tests gain job knowledge very fast, which is a major reason they perform better on the job [6]. The impact of age, financial situation, and gender on undergraduate students' academic performance was investigated. The findings revealed that neither gender, age, nor financial status are significant predictors of academic performance. It was recommended that counseling centers should be opened to handle the varying problems confronting students, irrespective of age, financial status, or gender [7].

Spatial visualization serves as a dependable predictor for students' performance on physics conceptual evaluation tests before Microcomputer-Based Laboratory (MBL) instruction. Following MBL instruction, students experienced a significant increase in their levels of spatial visualization. Moreover, a group of science teachers presented with different types of MBL activities also showed a significant increase in spatial visualization ability [8].

The relationship between academic performance and students' gender, age, and financial status particularly when these variables are taken together in a school setting was studied. Cognitive development and maturity (which are associated with age) are necessary for the worthwhile performance of students. The age of the individual, as it increases, usually affects various developmental changes, and it affects every area of human performance [9].

Gender relates to the difference in sex (that is, either male or female) and how this quality affects their dispositions and perceptions toward life and academic activities [10]. This has necessitated the need to find out if there is any significant difference between male and female undergraduates as reflected in their academic performance.

II. Material And Methods

This study aimed to explore and evaluate the development of students' abilities over successive academic years. Study Location: Conducted at Benghazi University in Libya, specifically within the Industrial Engineering Department, the research utilized the Employee Aptitude Survey (EAS) test to assess students' aptitude, computing both Battery and Percentile scores. Although this survey consists of 10 tests, this study will use only 4 tests are Numerical Ability (EAS-2), Space Visualization (EAS-5), Numerical Reasoning (EAS-6) and Symbolic Reasoning (EAS-10. Furthermore, the study investigated how students' academic level and CGPA influenced their performance on the Battery and Percentile metrics.

Study Duration: During the fall and spring semesters 2022-2023, and they were carefully selected from all academic levels from the third to the eighth semester.

Sample size: 108 undergraduate students between the age of 21 and 30 years old across all academic levels.

Procedures for data gathering: Firstly, permission was obtained from the faculty members to administer EAS tests on students during lecture hours. The completion of all four tests requires 45 minutes. Before commencing the test, students are instructed to carefully read the instructions provided on the first page of the test paper, followed by attempting a sample test to ensure understanding of the test format. Once confident, they are instructed to flip the paper and begin the test. The numerical ability test, comprising three parts, requires a minimum of 10 minutes for completion, while the remaining tests take approximately 5-7 minutes each. A break of 3-5 minutes was permitted between the two tests. Furthermore, pertinent personal information such as age, CGPA, and cumulative credit hours relevant to this study were extracted from the student enrollment database.

Calculation of Raw Scores, Battery, and Percentile: The raw score represents the number of questions answered by participants, irrespective of the test's total question count or individual question value. Each correct and incorrect response was tallied. It's important to note that each test employs different raw score formulas. The battery score is computed using the following formula:

Battery Score 0.5* (EAS 2) +0.5* (EAS 5) + EAS 6+ EAS 10 (1)

Percentiles for each student were derived from the norm table for junior engineers (Ruch, 1994). In the statistical analysis, variables were categorized as independent and dependent. The dependent variable is the students' percentile, while academic years, CGPA groups, and age groups serve as independent variables. Normality assumptions were assessed using normal tests, frequency histograms, and normal plot of residuals. Statistical analysis was conducted using the Minitab 17 software package. Research questions: The following research questions engineer during the academic study are proposed to evaluate the progression of student's abilities as a junior

(i) Is the students' percentile affected by the following factors: Academic progress levels from the third to eighth semester, CGPA and students' ages? In addition, verifying the strength of the correlation between students' percentile and those factors.

(ii) Determine which of the students' abilities (numerical ability, space visualization, numerical reasoning, symbolic reasoning) are affected by academic progress?

(iii) Does the student's gender effect on their percentiles of abilities?

Data Analysis: All necessary information required for the research was entered into an Excel software file. Subsequently, the total cumulative credit hours (CUM.CH) were extracted from the database of the Industrial Engineering Department at Benghazi University to determine the academic level of each student. The number of semesters spent during their academic study was then calculated. The data were analyzed using Minitab Software 17, employing the General Linear Model (factorial model with 3 factors), one-way ANOVA model, and Two-Sample T-Test to examine the hypotheses and address the research questions.

III. Result and analysis

The assumptions of normality are confirmed by residual analysis, as shown in figure 1, the data has normal distributed.

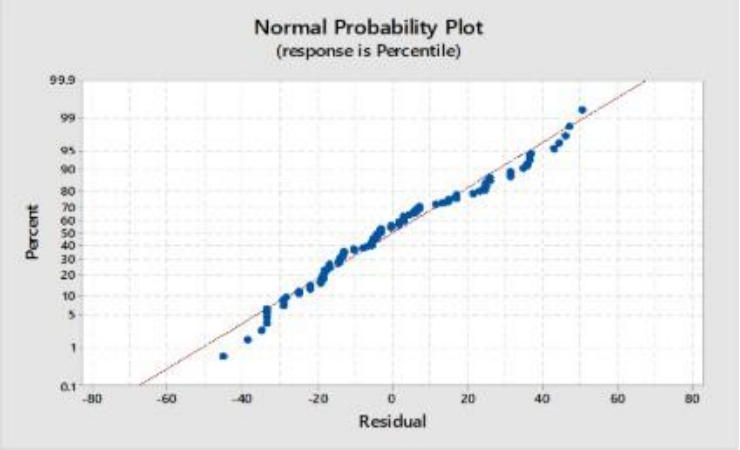

Figure 1: Normal probability plot

Thus, ANOVA with a significance level (a) of 5% is an appropriate test for data analysis. Table 2 presents the mean, standard deviation, maximum values, and minimum percentile values for the students. The sample consisted of 108 undergraduate students from Benghazi University's Industrial Engineering Department, aged between 20 and 31 years.

The distribution of participants was as follows: 63.8% females and 36.2% males. Only 4 students (3.7%) were over the age of 30. The majority of students (63%) fell within the age group of 22-25 years.

Regarding CGPA, 20.4% of students had a CGPA below 2, while the largest percentage (44.4%) had a CGPA between 2 and 2.49. Conversely, only 2.8% of students achieved a CGPA greater than 3.5.

In terms of semester distribution, the sample included 17.6% of students in the third semester, 19.44% in the fourth semester, 12.96% in the fifth semester, 18.51% in the sixth semester, 18.51% in the seventh semester, and 12.96% in the eighth semester. The ANOVA explores that there is a significant difference between students' percentile and academic level (p-value-0) Hence, we can conclude that student's percentile is affected by academic levels. The students' abilities progress as students' improvement in their academic studies. There is a positive relationship between academic level and the percentile of students' abilities as illustrated in Table 1 where the average of students' percentile is increased from 15.4 for students in the third semester to 55 for students in the eighth semester. As students improve in their academic study, they are ready with all the required knowledge and skills that qualify them to enter the labor market; Thus, the seventh and eighth students have higher abilities than the rest of the students' levels. In the most time new students feel in weakness of their confidence, and they tend to be disinclined to take any decision. some of them confirmed that they do not got along to team-work with their classmates in order to discuss their studies. These behaviors are capable of poorly affecting their knowledge of how to align themselves with their studies and how to influence on their personal aptitude and competence when challenged by some learning problems. Since they are new and cannot adapt smoothly in the university environment, especially in our Arab culture. It may be caused by the lack of ability to understand how the personal dimension affects learning. Therefore, all university students must realize their limits in the way for acquiring the knowledge and concepts necessary to learn and retain basic skills through training courses, seminars in human development, educational forums for new students, so that they will be aware of the behaviors, tasks and duties with great knowledge of what to do when they enrollment in the university studies. In addition, it can be held that the student percentile also differs significantly regarding to the CGPA groups at (p-value 0.000) See Table 2. This means that students with a high CGPA get higher percentile than the rest of the students as shown in Table 1 where the students with CGPA greater than 3 they get the

average of percentile more than 70 However, students' ages do not have any significant effect on their percentile (p-value 0.135). This implies that age would not influence the estimated percentiles. as shown in Table 2. The reason for this result is due to the fact that students may enrollment to the university studies while they are old, and sometimes the students are late in passing some difficult courses and may get old while they are still in the first semesters. On the contrary, we find students who are regular in their studies and make great progress and reach graduation at ages between 23 and 24. Thus, this confirms and gives more credibility to this study.

The students with the highest percentile efficiency score are students between the ages of 22-25 where they were regulars in their studies and in the final academic year (seventh and eighth semesters), and their CGPA is greater than 3. In addition, distinction, superiority of the students in seventh semester appeared from the rest of the semesters, and the highest efficiency was 99% for the student whose CGPA-3.45 and studying in the seventh semester with age of 23.

Table 1: Descriptive statistics of students' percentile

Source	Variables	count	% students	mean	st.dev	min	max
Gender	m	39	36.1111	36.49	26.62	2	99
	f	69	63.8889	31.1	25.31	1	85
Age groups	<=21	14	13.0	29	22.2	1	70
	22-25	68	63.0	35.9	28.1	1	99
	26-29	22	20.4	29.8	21.7	5	70
	>=30	4	3.7	17.5	2.9	15	20
Academic levels	3	19	17.6	15.4	16.2	1	60
	4	21	19.4	23	18.9	1	70
	5	14	13.0	26.8	18.2	5	70
	6	20	18.5	34	23.2	5	80
	7	20	18.5	48.5	29.5	10	99
	8	14	13.0	55	25	10	90
CGPA groups	<2	22	20.4	7.9	6.95	1	30
	2-2.49	48	44.4	24.50	15	1	70
	2.5-2.99	24	22.2	46.7	18.1	20	80
	3-3.49	11	10.2	80.36	8.86	70	99
	>=3.5	3	2.8	71.7	12.6	60	85

Upon our results that mentioned above, The fit regression was used to find predication model and the coefficient of determination founded (R2) was 78.97%, which indicated a good fit between the predicted values of students' percentile and independent variables (academic levels, age and CGPA). Hence, the results have a fairly good percentage forecast. The mathematical model is given by Regression Equation:
Percentile-66.438.07 CGPA + 5.06 Semester - 0.790 age

Table 2: General Linear Model: Percentile versus Academic levels and Age

Factor	**Type**	**Level**	**Value**		
CGPA-Group	fixed	5	< 2 , 2-2.49 , 2.5-2.99 , 3-3.49 , >=3.5		
Age-Group	fixed	4	≤21, 22-25, 26-29, ≥30		
Academic levels	fixed	6	3,4,5,6,7,8		
Source	**DF**	**Adj SS**	**Adj MS**	**F**	**P**
CGPA_Group	4	24263.4	6065.8	40.77	0.000
Age-Group	3	846.5	282.2	1.9	0.135
Academic levels	5	4923.1	984.6	6.62	0.000
Error	95	14134.1	148.8		
Total	107	71224.8			

Additionally, the correlation analysis achieved between percentile and (CGPA, academic levels and ages) of students. It shows that, a significant correlation between students' CGPA scores and percentile (r 0.840). The analysis also shows that there is no correlation between the percentile and students' ages (r=-0.014) as shown in Table 3. According to Cohen (1988) and Kim (2018), a correction value greater than 0.5 is described as significant; 0.5 to 0.3 medium, 0.3 to 0.1 small; Anything smaller than 0.1 is described as trivial; The variables of such trivial relationships have no observable relationships.

Table 3:Correlation: Percentile, CGPA, Age, Academic levels

	Percentile	
	p-value	r
Academic levels	0.523	0.000
Age	-0.014	0.89
CGPA	0.840	0.000

As a result, there is a strong correlation between CGPA grades and the percentile of students. The most of students with large CGPA also have established excellence percentile; hence both CGPA and percentile are good measures of performance.

The result of the numerical ability EAS-2 test versus the academic levels, (p0.000), so there is a significant effect between students' numerical abilities and their academic progression as shown on Table 4. Tukey's test was applied to identify the differences between students' level the result shows that the students of semesters 7 and 8 have the highest score 42 & 37 and were classified in the same group A, while the smallest score was in 3rd and 4th semester with value 20.18 and 21.17 respectively so, classified in group C.

Table4: One-way ANOVA: the numerical ability EAS-2 test versus academic levels

factor		level		value		
Academic levels		6		3,4,5,6,7,8		
Source		DF	Adj SS	Adj MS	F	P
academic levels		5	7265	1453.09	16.73	0.000
Error		102	8859	86.86		
Total		107	16125			

Table 5: Tukey pairwise Compersion

Academic levels	N	Mean	Grouping
8	14	42.09	A
7	20	37.98	A
6	20	33.3	A B
5	14	25.57	B C
4	21	21.1	C
3	19	20.18	C

For space visualization ability EAS-5 test, 5 test was not affected by academic levels (p-value 0.523), the reason may be due to the lack of support and emphasis of this skill in the advanced curricula, where it is just taught in the first and second semesters in course of Engineering Drawing. However, there is significant difference between academic years and numerical reasoning EAS-6 test at (p-value

-0.000) based on the students' raw scores. Similarly, Tukey test shows that, the students whose study in eighth semester have the highest score and significantly different from the rest of students especially those in third and fourth semester. For symbolic reasoning, EAS-10 test, significant difference (p-value 0.035) between academic years is observed. This test actually entails how students can easily decipher mathematical symbols and expressions. The multiple comparison tests reveal higher symbolic reasoning ability as the academic year progresses.

IV. Conclusion

This research delved into how the skills of Industrial Engineering (IE) students evolves over their academic journey in relation to their age and CGPA. The findings suggest that students' abilities tend to enhance as they progress academically, aligning with [11]. observation of a positive correlation between academic level and student abilities. Senior students generally exhibit superior skills compared to freshmen and juniors, indicating that skill increases alongside academic advancement. Additionally, academic level plays a crucial role in determining students' retention, as noted by [12] particularly evident in freshmen who may struggle due to a lack of understanding of how personal learning dimensions influence adaptation to university studies.

However, no significant correlation was found between academic years and spatial visualization skills, consistent with [13] findings regarding the influence of physics training in microcomputer-based laboratories. This lack of association suggests educators may not emphasize spatial visualization skills adequately in the curriculum. On the other hand. The results of this study are similar to those found elsewhere [14], where literacy (including mathematics, writing quality, and comprehension) served as indicators for success in the Skills for Tertiary Education Preparatory Studies (STEPS) program.

Furthermore, age does not significantly impact students' performance on the EAS tests, in line with [15] observations on the negligible effects of age, gender, and financial status on academic performance. Consequently, counseling should cater to students of diverse backgrounds. Similarly. [16] found age to have an insignificant effect on academic capabilities, questioning its role as a defining variable in academic performance. Instead, relationships were observed between CGPA groups and percentile scores, as well as between percentiles and academic levels, indicating that as students progress academically, they acquire more skills and achieve higher percentiles on the EAS tests, suggesting an increase in skills as academic levels advance.

Overall, the study underscores the importance of academic progression in enhancing students' abilities, particularly in numerical and symbolic reasoning. It indicates that graduate students from the Industrial Engineering department at Eastern Mediterranean University exhibit higher skill retention, enhancing their readiness for the workplace. However, spatial visualization abilities seem to remain consistent across academic levels.

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