Assessing Basic Computer Skills: A Study of Computer Science First-Year Students in Higher Education

Maria Emília Bigotte
Polytechnic University of Coimbra, Rua da Misericórdia, Lagar dos Cortiços, S. Martinho do Bispo, 3045-093 Coimbra, Portugal
ebigotte@isec.pt

Cátia Rodrigues Mariano
CASPAE-IPSS, Coimbra, Portugal
catia.rodrigues@caspae.pt

Anabela Gomes
Polytechnic University of Coimbra, Rua da Misericórdia, Lagar dos Cortiços, S. Martinho do Bispo, 3045-093 Coimbra, Portugal & CISUC, University of Coimbra, Portugal
anabela@isec.pt

***Abstract*—This research-to-practice full paper looks into how first-year students at a Portuguese higher education institution respond to a Basic Informatic Skills tool. This instrument is used to help the industry better understand the students' preparedness and the domain of critical skills for success in Information Technology (IT) specialized workers. As this instrument has a set of questions regarding mathematical knowledge, problem-solving ability, and logical reasoning, and we believe solid mathematical preparation is essential to succeeding in a computer engineering degree program and career, we applied it to determine how well-prepared students are in mathematics skills at the entrance of a computer engineering degree. The test measures six subscales to identify critical competencies in IT: verbal comprehension, numerical aptitude, attention and resistance to monotony, logical reasoning, coding analysis capacity, and diagrammatic reasoning.**

In general, the student's verbal, numerical, numbers series and code skills of the used instrument (Basic Informatic Skills) were reasonable. Only the attention scale was worse, and the diagram capacity was better. There were only slight gender differences in the average coding and diagrammatic reasoning abilities. Aside from a slight correlation with numerical skills, age did not significantly correlate with any skills. We also determined the correlation among the instrument's several scales and several mathematical subjects, but no correlations were found.

This study promoted reflections on the background of students entering a higher computer engineering degree in relation to mathematically based skills considered fundamental for any engineering course. These aspects lead to considering the effort that must be made in the teaching provided to fill these gaps so that students can achieve academic success with a set of curricular units and ultimately prepare them for the marketplace.

Keywords—Educational level, Undergraduate, First year; Engineering fields, Computer engineering; Outcomes, Computing skills; Mathematics

I. Introduction

Programming is a core component of the computer engineering curriculum, but it is often considered a challenging subject [1-6]. Programming requires a great deal of mathematical knowledge, and studies have suggested a correlation between programming proficiency and mathematical background [7]. According to several studies, having a strong foundation in mathematics and general problem-solving skills is beneficial for most courses in a computer engineering or computer science degree, not just programming [8-9]. Therefore, as preparedness in mathematical skills is crucial to obtaining success in an engineering degree, the primary objective of the study is to investigate students' mathematical skills upon entering a computer engineering degree. Therefore, the discussion in this paper is centred around understanding the foundational mathematical abilities of the students and how they correlate with their performance in mathematical-related curricular units. Questions regarding mathematical knowledge, problem-solving ability, and logical reasoning are recurring concerns expressed in several studies found in the literature as special relevant to succeeding in a programming subject and consequently in a computer degree [10-15]. In this regard, we conducted a pilot study to investigate students' mathematical skills upon entering a computer engineering degree. To achieve this, we realized an experiment where the ABI (a Portuguese acronym for Basic Informatic Skills) instrument [16] was used. The results obtained on each scale were analysed and correlated internally (all scales among them) and with the grades obtained in mathematical curricular units that we believe are more closely related, namely Algebra, Analysis, and Geometry.

We also correlated all those variables with a Diagnostic Test. Since 2013, in our institution (Coimbra Engineering Institute of the Polytechnic University of Coimbra), our team has developed a Diagnostic Test (DT) [17] to characterize the student's level of Mathematics syllabus, considered essential for the full integration of students in the Calculus Curricular Unit. This DT was constructed considering the Basic and Secondary Education program of the Country and the guidelines of SEFI, Mathematics for the European Engineer [18, 19]. Diagnostic Test's result provides useful information on the mathematical content that should be worked with the student at different levels.

Therefore, the next sections describe the methods applied to the experiment carried out, as well as the analysis and discussion of the results obtained. We end with some conclusions and pointers for future work.

II. Methods

The study is exploratory and aims to achieve the following objectives: analyze basic computer skills in a sample of 1st-year students at our institution; facilitate moments of reflection and self-discovery to empower students in acquiring skills demanded by the job market; enhance academic success among students in the field of information technology, with a particular emphasis on degrees in computer engineering; and develop a tailored response to address the academic needs of these students concerning computer skills.

A. Sample

The sample comprises young Portuguese students from a Computer Science degree of our institution, totalling 72 participants (Table 1). In defining our sample, we considered the following inclusion criteria: a) students following a degree in Computer Engineering or Computer Science; b) aged 18 or over; c) completion of the instrument; and d) no evident difficulties in understanding that would disrupt the proper completion of the used instrument. Consequently, the sample consisted of 63 young males (87.5%) and nine young females (12.5%), with an average/mean (M) age of 20.94 (SD (Standard Deviation) = 3.431). The age range in the total sample varied from a minimum of 18 years old to a maximum of 33 years old (Table 1).

TABLE 1 - DEMOGRAPHIC CHARACTERISTICS OF THE SAMPLE: AGE AND GENDER

	Total		Male		Female	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age	20.94	3.431	21.03	3.574	20.33	2.236
	N	*%*	*n*	*%*	*N*	*%*
Gender	72	100%	63	87.5%	9	12.5%

B. Statistical Procedures

In determining the appropriate tests for statistical analysis, we assessed the normality and homogeneity of the sample concerning gender. The null hypothesis, indicating that the sample follows a normal distribution with homogeneous variances, was rejected due to a significant imbalance between the number of female participants (n=9) and male participants (n=63). Consequently, we opt for conducting an analysis using descriptive statistics and non-parametric tests. Spearman's non-parametric correlation was employed to examine the correlation between variables.

C. Instrument

The ABI instrument is a self-response instrument which assesses the main skills underlying most tasks carried out in IT departments or computerized services. The instrument is adapted, validated and standardized for the Portuguese population and the technical manual includes several construct validity studies, such as correlation between tests; correlation between the items and the total of each test and other tests and factor analysis. We also carried out Cronbach analysis, which was entirely satisfactory. It comprises six scales assessing fundamental computer science skills. These scales include:

1. Verbal Aptitude (VA) scale: This scale measures the ability to understand ideas expressed through written and oral language.

2. Numerical Aptitude (NA) scale: This scale evaluates agility in understanding and manipulating mathematical concepts, relationships, and formulas.

3. Attention (A) scale: This scale assesses the ability to perform tasks requiring concentrated attention, perceptual rigor, resistance to monotony, and error detection.

4. Number Series (NS) scale: This scale examines the ability to follow a logical process.

5. Code (C) scale: This scale measures the programming code proficiency.

6. Diagram (D) scale: This scale evaluates the ability to analyze a problem and organize solutions in a series of logical steps.

Each scale includes items contributing to a raw score, later translated into an ordinal percentile scale (1 to 99). This scale indicates the subject's relative position compared to others in the same normative group (Figure 1). Norms for this study were based on subjects with a 12th-year educational background. The total score for each scale is derived from the sum of correctly answered items. A higher percentile level indicates more vital skills or aptitudes in the participant.

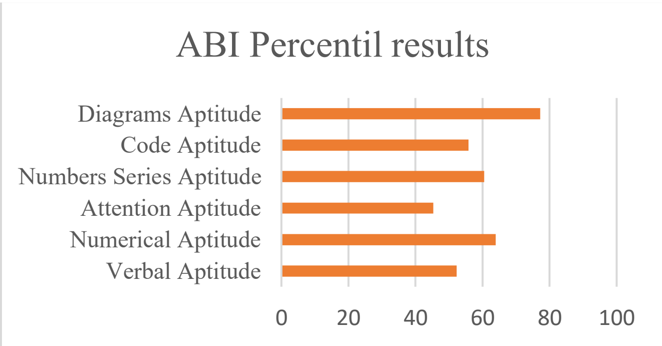

Fig1. Percentile results for each ABI scale

A reliability analysis was conducted to assess the instrument's internal consistency, using Cronbach's Alpha coefficient calculated across all ABI scales. The obtained value of 0.705 is considered reasonable.

For a more accurate analysis and interpretation of results, the percentile table, based on the Portuguese measurement of the ABI scale, was qualitatively grouped into the following categories:- Percentiles ranging from 0 to 5: Indicate a very low level in the skills assessed by the scale; - Percentiles ranging from 6 to 30: Reflect a low level of the skills assessed by the scale; - Percentiles ranging from 31 to 69: Represent an average level of the skills assessed by the scale; - Percentiles ranging from 70 to 94: Indicate a high level of skills assessed by the scale; - Percentiles ranging from 95 to 99: Reflect a very high level of skills assessed by the scale.

III. RESULT ANALYSIS

The results obtained from each scale in this study are presented next.

1. Verbal Aptitude (VA) scale: On the VA scale, we observed a minimum percentile of 1 and a maximum of 95. The sample demonstrates an average percentile level for verbal skills (M=52.25), indicating a moderate ability to

comprehend ideas expressed through written and oral language (Table 2). Figure 2 illustrates that only 3 (3%) students exhibit a very low level of verbal skills, while merely 4 (5%) students showcase a very high level. Additionally, 16 (22%) students obtained results at a low level of verbal skills, 25 (35%) at a medium level, and 25 (35%) at a high level of verbal aptitude. Spearman's correlation analysis was conducted to explore the relationship between age and verbal aptitude, revealing a weak positive correlation (r=0.07) with no statistical significance (p=0.561).

TABLE 2 - RESULTS ANALYSIS OF THE VERBAL APTITUDE SCALE ACCORDING TO GENDER (N = 72)

	Total		Male		Female	
	M	*SD*	*M*	*SD*	*M*	*SD*
Results	52.25	28.343	53.43	27.631	44.00	33.545

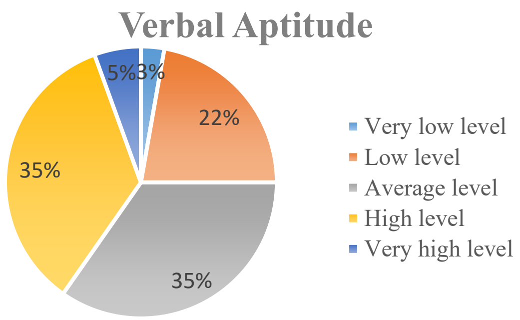

Fig. 2: Results by verbal aptitude level.

2. Numerical Aptitude (NA) scale: On the Numerical scale, the minimum percentile obtained was 1, and the maximum was 99. The sample exhibits an average percentile level for numerical skills (M=63.92), suggesting a moderate capacity for understanding and manipulating mathematical concepts, relationships, and formulas (Table 3). Notably, the female group demonstrates a high level of numerical skills (M=72.22), while the male group attains an average level of numerical skills (M=62.73). An analysis based on the level of numerical aptitude reveals that 1 (1%) student has a very low level of skills, 13 (18%) exhibit a low level, 19 (26%) demonstrate an average level, 30 (42%) showcase a high level, and 9 (13%) present a very high level of numerical skills (Figure 3). The Spearman's correlation coefficient between age and numerical aptitude was r = -0.141, indicating a weak negative correlation with no statistical significance (p=0.236).

TABLE 3 - RESULTS ANALYSIS OF THE NUMERICAL SERIES SCALE ACCORDING TO GENDER (N = 72)

	Total		Male		Female	
	M	*SD*	*M*	*SD*	*M*	*SD*
Results	63.92	26.41	62.73	27.549	72.22	14.814

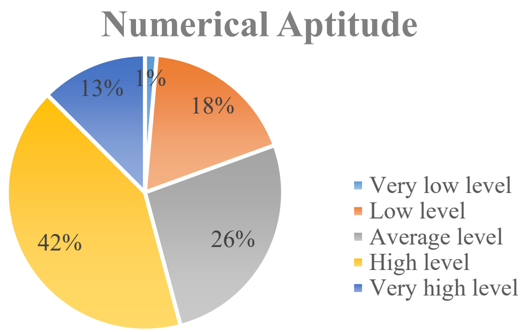

Fig. 3: Results by numerical aptitude level.

2. Attention (A) scale: On the Attention scale, the minimum percentile obtained was 5, and the maximum was 90. The sample demonstrates an average percentile level for attention (M=45.35), reflecting a moderate ability for concentrated attention involving a task that requires error detection in a model attempting to replicate program listings (Table 4). The female group average was 48.89, while the male group average was 44.84. Regarding attention levels, 2 (2%) student shows a very low capacity, 24 (33%) exhibit a low level, 31 (43%) demonstrate a medium level, and 16 (22%) present a high level of attention. Notably, no participant achieved a very high attention percentile on this scale (Figure 4). The Spearman's correlation coefficient between age and attention was r = 0.01, indicating a weak positive correlation with no statistical significance (p = 0.885).

TABLE 4 - RESULTS ANALYSIS OF THE ATTENTION SCALE ACCORDING TO GENDER (N = 72)

	Total		Male		Female	
	M	*SD*	*M*	*SD*	*M*	*SD*
Results	45.35	24.51	44.84	24.1	48.89	25.71

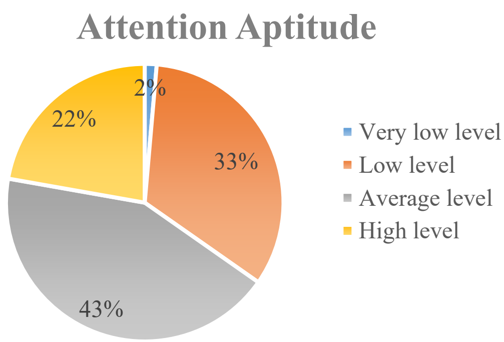

Fig. 4: Results by attention aptitude level.

4. Numbers Series (NS) scale: On the NS scale, the minimum percentile obtained was 4 and the maximum was 96. The sample exhibits a medium-level percentile for logical reasoning (M=60.50), representing an average ability to follow a logical process (Table 5). The male group averages 62.46, while the female group averages 46.78. Regarding percentile analysis, 1 (1%) student displayed a very low level of logical reasoning ability, 17 (24%) exhibited a low level,

15 (21%) demonstrated a medium level, 32 (44%) showed a high level of attention, and 7 (10%) participants showcased a very high level of logical reasoning ability (Figure 5). Spearman's correlation coefficient between age and attention was r = -0.067, indicating a weak negative correlation with no statistical significance (p=0.574).

TABLE 5 - RESULTS ANALYSIS OF THE NUMBER SERIES SCALE ACCORDING TO GENDER (N=72)

	Total		Male		Female	
	M	*SD*	*M*	*SD*	*M*	*SD*
Results	60,50	29,52	62,46	29,42	46,78	8,05

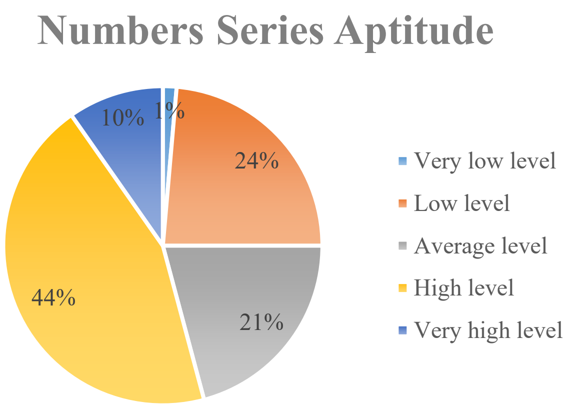

Fig. 5: Results by number series aptitude level.

5. Code (C) scale: In the Code scale, we observed that the minimum percentile obtained was 1, and the maximum was 96. The sample exhibits a medium-level percentile (M=55.83) for locating elements mixed with others and indicating the corresponding code, considering certain characteristics (Table 6). The male group averages 56.51, while the female group averages 51.11. Concerning the percentile analysis, 5 (7%) students displayed a very low level of aptitude for coding, 13 (18%) showed a low level, 21 (29%) demonstrated an average level, 29 (40%) presented a high level of attention, and 4 (6%) participants showcased a very high level (Figure 6). The Spearman's correlation coefficient between age and coding aptitude was r = 0.114, indicating a weak positive correlation with no statistical significance (p=0.340).

TABLE 6 - RESULTS ANALYSIS OF THE CODE SCALE ACCORDING TO GENDER (N = 72)

	Total		Male		Female	
	M	*SD*	*M*	*SD*	*M*	*SD*
Results	55.83	27.48	56.51	26.63	51.11	34.31

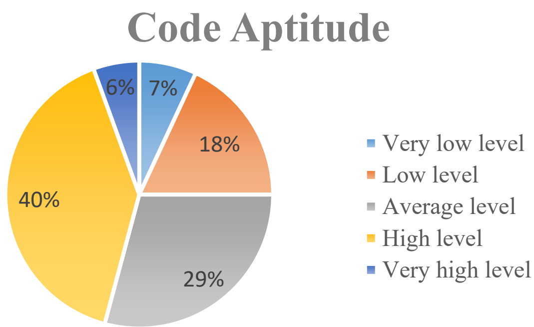

Fig. 6: Results by code aptitude level.

6. Diagrams (D) scale: On the Diagrams scale, we identified that the minimum percentile obtained was 2, and the maximum was 99. The sample demonstrates an average-level percentile for logical reasoning (M=77.19), signifying a good ability to follow a logical process (Table 7). The male group average was 77.84, while the female group average was 72.67. In terms of percentile analysis, we observed that 1 (1%) student exhibited a very low level of logical reasoning ability, 5 (6%) displayed a low level, 9 (12%) showed an average level, 46 (64%) presented a high level of attention, and 12 (17%) participants demonstrated a very high level of logical reasoning ability (Figure 7). Spearman's correlation coefficient between age and the ability to logically analyse a problem was r = -0.058, indicating a weak negative correlation with no statistical significance (p=0.626).

TABLE 7 - RESULTS ANALYSIS OF THE DIAGRAMS SCALE ACCORDING TO GENDER (N = 72)

	Total		Male		Female	
	M	*SD*	*M*	*SD*	*M*	*SD*
Results	77.19	21.15	77.84	20.06	72.67	28.72

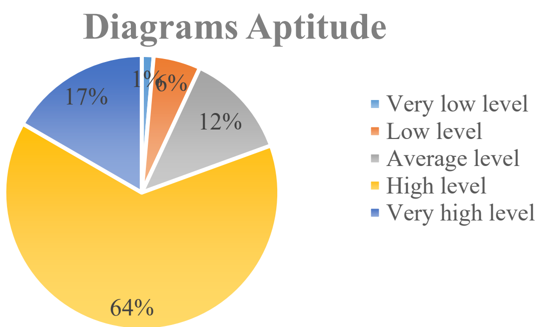

Fig. 7: Results by diagrams aptitude level.

IV. RESULTS DISCUSSION

In terms of verbal aptitude, the results suggest that the majority of students exhibit an average level of verbal aptitude, with few extremes (very low or very high). Additionally, there is no significant relationship between students' age and their performance in verbal skills, showing a very weak correlation between these variables.

Concerning numerical aptitude, the results indicate an average-high performance and a varied and asymmetrical distribution in the levels of numerical aptitude within the sample, with some difference between genders, though lacking statistical significance. Furthermore, based on the analyzed data, there is no statistically significant relationship between students' age and their numerical skills.

In the context of attention scale, the results point to average-low performance in the capacity for focused attention within the sample, with a slight discrepancy between genders. The majority of participants fall within the average level of attention, with few instances of very low or high performance. Additionally, according to the analyzed data, there is no significant relationship between students' age and their attention span.

Regarding the numbers series aptitude, the results suggest an average-high performance in logical reasoning ability within the sample, similar to the numerical aptitude, with a notable gender-based discrepancy. Most participants demonstrate a high level, with few cases of very low or high performance. However, based on the data analyzed, there is no significant relationship between students' age and their logical reasoning ability, nor between the gender variable and logical reasoning ability.

The results suggest an average performance in code scale within the sample, with a minor difference between genders. Most participants exhibit a high code aptitude, with some cases at extreme levels (very low/very high). Moreover, based on the statistical analysis conducted, there is no significant association between students' age and their coding ability.

Concerning the diagram scale, the results indicate an average performance in problem-solving related to diagrams/fluxograms within the sample, with a relatively small gender-based discrepancy. Most participants demonstrate high and very high levels of diagramming skill, with a small percentage at medium and low levels. Additionally, based on the statistical analysis performed, there is no significant association between students' age and their ability to reason logically with diagrams. However, no significant statistical correlation existed between the gender variable and any of the ABI scales.

Table 7 presents the correlations obtained among all the studied variables. Based on the correlations between the various assessed cognitive abilities, certain conclusions or trends can be discerned. Strong correlations between verbal skills (ABI_VER) and attention skills (ABI_ATT) and verbal skills (ABI_VER) and codification (ABI_COD) skills were found, suggesting that individuals with more developed verbal skills also possess better levels of codification (programming) and are more attentive (high levels on the attention).

TABLE 7 – CORRELATIONS BETWEEN PAIR OF VARIABLES

TD	1.000									
Alg.	.984**	1.000								
Anal.	.973**	.940**	1.000							
Geo.	.940**	.910**	.893**	1.000						
ABI_VER	.061	.085	.029	.091	1.000					
ABI_NUM	-.031	-.034	-.054	-.032	.194	1.000				
ABI_ATT	-.152	-.168	-.161	-.124	.406**	.483**	1.000			
ABI_SER	-.012	-.050	.006	-.065	-.029	.234*	.243*	1.000		
ABI_COD	-.109	-.131	-.093	-.154	.369**	.168	.499**	.430**	1.000	
ABI_DIAG	-.080	-.070	-.122	-.111	.141	.328**	.472**	.338**	348**	1.000
	TD	**Alg.**	**Anal.**	**Geo.**	**ABI_ VER**	**ABI_ NUM**	**ABI_ ATT**	**ABI_ SER**	**ABI_ COD**	**ABI_ DIAG**

Strong correlations between numerical skills (ABI_NUM) and attention skills (ABI_ATT) and numerical skills (ABI_NUM) and diagram skills (ABI_DIAG) were found. There is a moderate correlation between numerical skills (ABI_NUM) and numbers series skills (ABI_SER). This implies that individuals with strong numerical skills have better attention levels, more capacity to interpret diagrams, and tend to exhibit more capacity to interpret serial numbers. Although a positive tendency is noted between numerical skills and codification, but it lacks statistical significance.

All the other scales of ABI (Number Series, Code, and Diagram scales) are strongly correlated with each other. The Attention scale is correlated with all other scales of the instrument, highlighting the importance of concentration to succeed in tasks.

Concerning the participants' age, even though without statistical significance, weak negative correlations were found between age and numerical skills, age and number series and age and diagrams skills. Also, a positive tendency was verified between age and Verbal, attention and code scales, yet it lacks statistical significance. This suggests that age may not significantly influence computer ability skills among the study participants.

There were also strong correlations among all the mathematical subjects (Alg., Anal., Geo.) and the Diagnostic Test (TD). However, no correlation was found among any of the scales of ABI instrument with the mathematical subjects or the diagnostic test, suggesting that proficiency in these skills may not strongly predict performance in mathematics.

There are a few possible explanations for why the tests for the various mathematical topics did not show the expected correlations with the utilized instrument (ABI). The ABI instrument mainly assesses fundamental informatics skills, which might not be directly related to the particular cognitive capacities needed to succeed in math classes like geometry, algebra, and analysis. The skills required for solving mathematical problems may not closely overlap with the abilities evaluated by the ABI, such as coding or diagram interpretation. Even though, we consider that a wide range of cognitive skills, such as logical deduction, quantitative analysis, and abstract reasoning, are required in mathematical subjects, the ABI tool might not fully capture these complex abilities, which would prevent it from correlating with mathematical exams. Computer literacy and mathematics could constitute separate cognitive domains with their own requirements and learning paths. Although learning in one domain may be facilitated by proficiency in another, the correlation may not be significant enough to be observed using the study's measurements. Therefore, while many reports discussing the relationship or correlation between mathematical and programming abilities can be found in the literature, this study did not find evidence of such a relationship. Therefore, the search for instruments and solutions for both issues continue, and it will be the subject of future research.

V. CONCLUSIONS AND FUTURE DIRECTIONS

We believe solid mathematical preparation is essential to succeeding in an engineering degree program and career. Thus, this study's primary goal is to determine how well-versed students are in mathematics skills at the entrance of a computer engineering degree. To do this, we use the ABI instrument, which assesses the main skills underlying most tasks carried out in IT departments or computerized services. Although the instrument is adapted, validated and standardized for the Portuguese population the expected correlations with mathematical subjects were not found.

The study reveals moderate positive associations between numerical skills and verbal skills, attention, and diagram interpretation skills. However, statistical significance varies across these relationships. While numerical skills exhibit some correlation with sequential problem-solving skills and coding, these associations lack statistical robustness. Age doesn't seem to significantly impact numerical skills among participants. Strong correlations exist among mathematical subjects, and a Diagnostic Test specially prepared to determine gaps in these subjects, indicating their interrelatedness. Surprisingly, no correlation was found between basic computer skills, determined by the used instrument, and mathematical performance, suggesting other influential factors.

In summary, while numerical skills show associations with various cognitive abilities such as verbal skills, attention, code and diagram interpretation skills, the strength and significance of these associations vary. Additionally, the absence of correlations with the ABI scales and the used mathematical subjects implies that other factors may influence performance in mathematics beyond the ones necessary to succeed in a computer job determined by the used instrument. Several justifications can be offered for not finding the expected correlations between the used instrument (ABI) and the various mathematical subjects tests.

A variety of factors, including learning environments, teaching pedagogies, and educational backgrounds, can affect how cognitive skills develop and manifest. The observed correlations may not hold true if all of these contextual factors were not taken into account by the study. Therefore, in future studies, these factors will be taken in consideration. The study might have lacked sufficient statistical power to detect small or moderate correlations between the ABI instrument and mathematical subjects' tests. Larger sample sizes or more sensitive measures could have been necessary to reliably identify such relationships. It's possible that the study didn't have enough statistical power to identify weak or moderate correlations between the tests for mathematical subjects and the ABI instrument. To accurately identify such relationships, larger sample sizes or more sensitive measurements might be required in future research.

ACKNOWLEDGMENT

The authors would like to thank all students that participated in the study.

REFERENCES

[1] T. Jenkins, "On the difficulty of learning to program", Proceedigs of the 3rd Annu. LTSN_ICS Conf., Loughborough University, United Kingdom, August 2002, pp. 53-58.

[2] Yizhou Qian and James Lehman, "Students' misconceptions and other difficulties in introductory programming". ACM Transactions on Computing Education, vol. 18, no. 1, pp. 1–24, October 2017. doi: 10.1145/3077618. URL https://doi.org/10.1145/3077618.

[3] J. B. Bennedsen, M. E. Caspersen and M. Kölling, "Reflections on the Teaching of Programming: Methods and Implementations", New York, USA: Springer Publishing Company, Inc., 2008.

[4] E. Lahtinen, K. Ala-Mutka and H-M Järvinen, "A study of difficulties of novice programmers," Proceedings of the 10th Annual SIGCSE Conference on Innovation and Technology in Computer Science Education, Monte de Caparica, Portugal. ACM New York, NY, USA, pp. 14-18, 2005.

[5] C. Watson and F.W. Li, "Failure rates in introductory programming revisited", Proceedings of the 2014 Conference on innovation & technology in computer science education, Uppsala - Sweden, pp. 39-44, June 2004.

[6] Jens Bennedsen and Michael E Caspersen. Failure rates in introductory programming: 12 years later. ACM inroads, vol. 10, no. 2, pp. 30–36, 2019.

[7] Delsika Pramata Sari, R. Ati Sukmawati and Iskandar Zulkarnain,"The Relationship Between Mathematical Ability and Programming Ability of Computer Science Education Students", Proceedings of the 1st International Conference on Creativity, Innovation and Technology in Education (IC-CITE 2018), pp. 50-53, 2018

[8] A. Gomes and A. Mendes, "Learning to program - difficulties and solutions", Proceedings of International Conference on Engineering Education (ICEE 2007), Coimbra - Portugal, pp. 283-287, 2007.

[9] Baldwin Douglas, Henry M. Walker, and Peter B. Henderson, "The roles of mathematics in computer science", Acm Inroads vol. 4, no. 4 (2013), pp. 74-80.

[10] J. Bennedsen and M. E. Caspersen, "Abstraction ability as an indicator of success for learning object-oriented programming?" SIGCSE Bulletin inroads, vol. 38, no. 2, pp. 39-43, 2006.

[11] P. Byrne and G. Lyons, "The effect of student attributes on success in programming," SIGCSE Bulletin, vol. 33, no. 3, pp. 49-52, 2001.

[12] A. Gomes and A. J. Mendes, "A study on student's characteristics and programming learning," Proceedings of the World Conference on Educational Multimedia, Hypermedia and Telecommunications, Vienna, Austria. EDMEDIA'08, AACE, pp. 2895-2904, 2008.

[13] E. Tomai and C. Reilly, "The impact of math preparedness on introductory programming (CS1) success," Proceedings of the 45th ACM technical symposium on Computer Science Education (SIGCSE'14), Atlanta, Georgia, USA: ACM New York, NY, USA, pp. 711-711, 2014.

[14] Gomes, A., Ke, W., Marcelino, M. J., Im, S., Siu, S., and Mendes, A., "A Teacher's view about introductory programming teaching and learning – Portuguese and Macanese perspectives," Proceedings of 45th ASEE/IEEE Frontiers in Education 2017 (FIE'17). Indianápolis, Indiana, USA.

[15] Andrew Luxton-Reilly, Simon, Ibrahim Albluwi, Brett A. Becker, Michail Giannakos, Amruth N. Kumar, Linda Ott, James Paterson, Michael James Scott, Judy Sheard, and Claudia Szabo, "Introductory Programming: A Systematic Literature Review," Proceedings Companion of the 23rd Annual ACM Conference on Innovation and Technology in Computer Science Education (Larnaca, Cyprus) (ITiCSE 2018 Companion). Association for Computing Machinery, New York, NY, USA, 55–106. https://doi.org/10.1145/3293881.3295779

[16] De la Cruz, M. V., "Aptidões básicas para Informática. Manual Investigación y Publicaciones Psicologicas (2ª edição revista). Madrid: Tea Ediciones, 1992.

[17] M. Carr, C. Fidalgo, M.E. Bigotte de Almeida, J. Branco, V. Santos, E. Murphy and E. Ni Fhloinn, "Mathematics diagnostic test in engineering: An international comparison between Ireland and Portugal", European Journal of Engineering Education, vol. 40, no. 5, 546-556, 2014.

[18] M.E. Bigotte de Almeida, A. Gomes, J. R. Branco and T. Pessoa, "The influence of educational learning paths in academic success of mathematics in engineering undergraduate", Proceedings of the 2016 IEEE Frontiers in Education Conference Proceedings (FIE), Eire - USA, 1, 1-6, 2016 https://doi.ieeecomputersociety.org/10.1109/FIE.2016.7757453

[19] M.E. Bigotte de Almeida and V. Santos , "Strategies for supporting mathematics in engineering", Proceedings of the 12th annual International Conference of Education, Research and Innovation (ICERI2019), 11-13 November, 2019, Sevill