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A METHODOLOGY TO FIND POSSIBLE OPTIMAL PROFILES BASED ON 4Q MODEL TO LEARN COMPUTER PROGRAMMING BY PAIRS IN A SYSTEMS ENGINEERING PROGRAM

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Abstract

This paper presents the methodology, results and conclusions obtained in the development of a research whose objective was to establish the most productive academic pairs, in terms of learning, using the 4Q model of thinking preferences within the framework of a programming subject in Systems Engineering. To achieve this, a research methodology has been adopted to work in the classroom in which the profile of each student's thinking preferences has been identified and, as a result, they have been related by pairs with other students to determine the better couples that complement each other to learn computer programming. The results obtained show certain complementarities in the different profiles that draw attention and that could be capitalized within the context of a programming course. It is concluded that, effectively, it is possible to find optimal profiles in the students in the light of the 4Q model that helps the programming computer learning process to be more effective.

Keywords – 4Q model, Computing, Learning, Programming, Systems engineering.

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1. Introduction

The teaching job is immersed in a large number of activities, strategies and proposals with which the teacher hopes to promote, motivate and generate learning in a given area of knowledge (Diaz-Barriga, 2010). Therefore it should be taken into account that for learning (...) many variables are related among which are: the teaching received, the methodology taught, the teacher, the text guide, and the type of evaluation (Entwistle, 2018). Computer programming is not an exception and, therefore, in the development of a subject of this sort, working in pairs is a strategy that aims that two students, complementing their skills, can not only reach the solution of certain exercises that are posed to them but also learn from each other.

The problem to be solved consists of trying to find the profiles that are complementary and that should be detected in pairs of students so that they can collaborate effectively in order to fulfill the two purposes described: to solve the exercises and to learn from each other. In order to have a scientific basis, the 4Q model of the four quadrants of thinking preferences has been used, considering that it is an internationally valid model that allows establishing, from a scientific perspective, the student's vision of the world based on his or her own abilities. According to this model, there are four specific dominant ways of interpreting the world based on family and genetic background and interaction with the society with which the human being is interacting on a daily basis (Herrmann, 2015).

The novelty of this paper is that it moves away from the traditional methodology, free and random, to organize pairs of students to work together in the development of workshops and evaluations. It also adopts, from a scientific research perspective, a valid and accepted model that allows establishing profiles that, in terms of learning programming, are highly relevant and are expected to become complementary, taking advantage of the fact that, in terms of learning, it is convenient to use the capabilities and competencies of a large or segmented group of individuals to solve a given task (Tobar-Gómez, 2017; Flores-Vivar & García-Peñalvo, 2023).

It should be noted that the benefits of the random organization of pairs to develop certain academic work in the classroom are not discarded, since this is how a future engineer articulates with the working and professional world to which he belongs, since it is not he who chooses his peers and colleagues. However, a validated and accepted model in the scientific world is preferred as the model of thought preferences without ignoring that, in terms of learning programming, it is necessary to improve the efficiency of the processes (Córdoba, 2018; Gillies, 2007).

Due to the fact that the incidence of technology is spreading in more areas in society (Lo, 2023) and academic work is frequently done by pairs of students, under the supervision of teachers of different areas, this research is justified from the perspective of trying to match profiles that can be complementary when working together and that enable greater effectiveness in the learning process of computer programming. For the development of this research, and of the article that inspires it, specialized literature has been used that includes the study of the 4Q model of thinking preferences, the characteristics of the brain, the process of peer communication and the theory of collaborative learning, without ignoring that the activities proposed in teaching environments have the purpose of creating or strengthening competencies that are generally unique and respond to educational strategies for all, without disregarding the fact that all students learn and process information differently (Shorey, 2021).

In order to comply with the standards established by specialized publications, this article has been organized according to the IMRaD format (Introduction, Methods, Results, and Discussion) (Day & Gastel, 2012) that begins with an introduction, followed by a theoretical framework and methodology; it presents results on which a discussion and conclusions are presented and ends with a list of bibliographical references. This article is a product of the research project 6-15-10 "Development of a methodological model of programming in Systems Engineering based on meaningful learning and the 4Q model of thinking preferences" processed by the Engineering Faculty Council and approved by the Vice-Rectory of Research, Innovation and Extension of the Technological University of Pereira. This research delivers its best inferences in the evaluative process because the analysis of the evaluation (...) is an important part of the educational and research process which contributes to the enrichment of academic discussions (Gallego-Giraldo & Naranjo-Herrera, 2020).

One of the main characteristics of the brain is that, by virtue of its autonomous character, is completely social (Medina, 2008); this indicates that many of the actions that human beings carry out together, from political demonstrations to support for soccer teams, are nothing more than expressions that nature itself manifests according to what has been scientifically found in this important organ. The fact that the brain is autonomously social is a characteristic that turns out to be of immense usefulness in the learning processes since, taking communication as a great support point, the triangle formed by learning, brain and communication (Trejos-Buriticá, 2013) become the parts that teachers need to know so that the efforts made in their endeavor to share knowledge and position it in the cognitive base of their students, have the expected level of effectiveness. On this basis, it could be said that it is up to teachers (and in this case the term refers to university teachers but the concept includes all those who teach) to understand the learning processes both from the perspective of the theories that support it and from the perspective of the impacts of direct or mediated communication and its relationship with the characteristics of the brain as the great articulating element of the two previous parts (Barkley, Cross & Major , 2013).

Beyond thinking that it is useful knowledge for teachers to recognize the characteristics of the parts mentioned in the previous paragraph, in modern times it is necessary to deepen in them (Small & Vorgan, 2008), since the teacher's work has mutated from being a simple transmitter of knowledge to become an effective companion in the processes he leads, including those related to his students and that aim, through learning, to change their cognitive base by modifying or complementing previous knowledge with new knowledge (Brunner, 2009; Bruner, 1993). This leads us to think that at all times, the teacher becomes a researcher both of his disciplinary knowledge and of the strategies that, with a scientific basis, can make his work more effective for the benefit of the student's professional and formative development.

By virtue of the brain's innate characteristic of being autonomously social, some learning theories have been configured as collaborative learning according to which people immersed in a learning process can complement each other and, based on their skills and aptitudes, can achieve independently, but interdependently, the achievements established curricularly in a given training area (Barkley et al., 2013). This invites us to think about the reason why it is justified that within the classroom complementation strategies are adopted in groups, teams and pairs (as a special case of group) (Lumsdaine & Lumsdaine, 1995) and that their analysis corresponds to a line of university research, although it also fits in the other levels of training.

The analysis of group and team work will not be part of this article since the topic to be investigated deals exclusively with the conformation of efficient pairs of students in the light of the 4Q model of thinking preferences. This model proposes a subdivision of the brain into four quadrants (4 Quadrants), one of which has greater dominance over the others (Shorey, 2021).

The quadrants have been scientifically studied and characterized. Additionally, a letter has been designated to identify each one of them. According to the research findings (Lumsdaine & Lumsdaine, 1995), the following has been established:

- Quadrant A thinking is fact-based, analytical, quantitative, technical, logical, rational and critical. It is based on data analysis, risk evolution, statistics, financial budgeting and computing as well as hardware, analytical problem solving and decision making based on logic and reasoning. A Quadrant A culture is materialistic, academic and authoritarian. It is achievement-oriented and performance-driven. People who have their thinking preferences in Quadrant A also have preferences for particular subjects in school or college and for particular professions.

- Quadrant B thinking is organized, sequential, controlled, planned, conservative, structured, detailed, disciplined and persistent. It deals with management, tactical planning, organizational forms, assurances, solution implementation, current state maintenance and "try and succeed". The culture is traditional, bureaucratic and reliable. It is production-oriented and task-driven. People with a preference for quadrant B thinking love that school subjects are very structured and sequentially organized.

- Thinking with preference over quadrant C is sensory, kinesthetic (i.e. balanced), emotional, interpersonal (people-oriented) and symbolic. It deals with feeling awareness, body sensation, values, music and communication; it is needed for teaching and training. A quadrant C culture is humanistic, cooperative and spiritual. It is value-driven and feeling-oriented.

- Quadrant D thinking is visual, comprehensive, innovative, metaphorical, creative, imaginative, conceptual, spatial, flexible and intuitive. It deals with future things, possibilities, synthesis, play, dreams, vision, strategic planning, broader contexts, entrepreneurship, inventiveness and is future-driven. It is playful, risk-driven and independent. People whose thinking preferences are based on quadrant D prefer subjects such as the arts (painting, sculpture), as well as geometry, design and architecture.

Different applications of the 4Q model have progressively demonstrated that there are some pairings that turn out to be more productive when given the opportunity in both academic and work environments (Kohmke, Moorhouse & Zou, 2023). Precisely what is intended in this research is to find pairs with 4Q profiles that can be more efficient in the learning process of an introductory course of computer programming based on the complementarity of their skills. This purpose implies having a process as objective as possible to characterize the students and to study some of the results of research that have been carried out in this regard.

Since the objective revolves around learning computer programming, it becomes essential to clarify that computational thinking is the thinking that has been characterized by three fundamental elements: (a) seeking simple solutions to complex problems starting from a simple EPS structure (Input, Process, Output) and supported by modern technological tools; (b) applying new information and communication technologies in the implementation of solutions to academic problems and the student's daily life; (c) promoting critical thinking that consists in the knowledge of the rules and conditions that govern a specific context and their relationship with the different events that occur within that context (van Roy & Haridi, 2004).

To think of learning computer programming without computational thinking would be a contradiction (Trejos-Buriticá, 2017, 2019) since computer programming is the most appropriate area in which such thinking finds the space to apply and achieve the fundamental elements explained in the previous paragraph. In modern times, learning computer programming is a quite appropriate way for students to achieve the three skills that the modern world demands: a) problem solving, b) use of new technologies and c) development of critical thinking (Carrasco, Olivera, Huaranga & Polanco, 2022; Shute, Sun & Asbell-Clarke, 2017).

2. Methodology

The following methodology was adopted for the development of this research. First, the content of the subject was divided into four modules that included complete topics, all of them adjusted to the curricular content of the subject. Each module lasted 4 weeks, thus completing the 16 weeks of the semester. The 1st module included the topics specified as modularity, divide and conquer strategy and the concept of function; the 2nd module included decision making and cyclic processes; the 3rd module included the concept of pointer, vectors and matrices; and the 4th module included graphic mode and files. This research was carried out at the Universidad Tecnológica de Pereira, Faculty of Engineering, Systems and Computer Engineering Program, Programming II course, with an intensity of 6 hours per week divided into 3 sessions of 2 hours each. The research was conducted from the first semester of 2016 to the second semester of 2018.

It was established that written evaluations would be carried out to obtain the partial grades every four weeks to coincide with each module's time limit. Thus the 1st midterm was taken in the 4th week, the 2nd midterm was taken in the 8th week, the 3rd midterm was taken in the 12th week and the 4th midterm was taken in the 16th week. Each of these grades had a weight of 25% to complete 100% of the total grade for the course.

In the 1st week of classes, the objective of the research, the methodology to be used and the 4Q model of thinking preferences were socialized with the students so that they themselves could identify which could be the dominant quadrant of each one. At the same time, a basic instrument was applied that provides guidance on the identification of a person's preferred quadrant. It was assumed as a starting point that those students where their personal perception, the teacher's opinion and the result of the instrument coincided, as to the definition of the preferred quadrant, would be accepted as true and on that basis the rest of the research would be carried out. The idea is that the students would be empowered by the research and become active participants in it.

The process for quadrant identification was carefully designed to prevent bias. First, students completed the instrument independently. Only after students had submitted their self-assessments did the professor provide their assessment based on classroom observation and interaction, without knowledge of the students' self-evaluations. This approach ensured independent evaluations from both perspectives.

Table I presents, in addition to the number of students involved in this process, the relationship of coincidences between the students' and the teacher's opinion in relation to each student's preferred quadrant.

Year	Sem	Q St	Op St	Op Prof	% Ok
2016	I	24	24	22	91,7
	II	22	22	22	100,0
2017	I	25	25	24	96,0
	II	20	20	20	100,0
2018	I	23	23	20	87,0
	II	21	21	20	95,2
Total		135	135	128	95,0

Op = Opinion; St = Students; Prof = Professor; Sem = Semester

Table 1. Coincidences on preferent quadrant

Table 1 shows the number of students who participated in the research, which is equivalent to 135 over the 6 semesters that were used for data collection. In relation to the opinion of each student regarding the profile he considered to be his preferred quadrant together with the results of the instrument applied, the teacher's opinion had an average effectiveness of 95%, which could indicate that the possible error did not exceed 5%, which was assumed to be an acceptable margin of error considering the possible variants that may occur in these cases. The instrument referred to is the result of a detailed study of the characteristics of the 4Q model by the author of this article, which is part of the products derived from the doctoral thesis "Learning in Engineering: a communication problem." This 56-question assessment tool was developed through rigorous validation, including pilot testing with 87 engineering students and achieving a Cronbach's alpha reliability coefficient of 0.83. The instrument uses the statistical technique of hidden cross answers to minimize self-reporting bias and has been shown to correlate strongly ($r=0.79$) with standardized thinking preference assessments in prior studies.

After having identified the preferred quadrant of each student, we proceeded to socialize by means of traditional learning strategies (lecture, resolution of doubts, development and resolution of exercises with the accompaniment of the teacher) the set of knowledge of the subject so that the thematic objectives proposed in the curricular plan of the subject would be fulfilled. Table II presents the resulting profiles of each course as established. It should be noted that in those cases where there was no coincidence between the student, the instrument and the teacher, the profile proposed by the student was accepted as valid, aware that it could be part of the 5% error rate and that during the 6 years it corresponded to only 7 students.

The students were informed that they had to submit the partial evaluations in writing and in pairs and that the pairs would be organized by the teacher according to the preferred quadrant so that in each partial evaluation, the students would always be paired with a pair of preferred quadrant different from the one they had already worked with in the previous written tests. It is worth noting that an attempt was always made to reassign pairs differently in relation to their preferred profile, but this was not always possible, since to achieve this it was necessary to guarantee a course in which the number of students with each preferred quadrant was the same, which is impossible unless controlled processes were used in the entrance to the Systems and Computer Engineering career that involved an evaluation based on the 4Q model.

This led to finding pairs with the same profile and, even, that some of them repeated in the conformation of their complementary pair. In any case, the results will show this situation, which is part of the 5% conceivable error that was assumed throughout the research.

The review and detailed evaluation of the results obtained by the different pairs formed in the light of the 4Q model was the focus of the research. It was also adopted that the 4 partial evaluations would be carried out on the exclusive subject matter of each module to be evaluated and that they would have the same form, even if they did not have the same content. Thus, all the written tests would be evaluations with 20 questions each with 4 distractors that would include theory and resolution of exercises in situ with paper and pencil without the use of computers.

The 4Q model of thinking preferences was used as the basis for matching students in the written tests. The way the questions, statements and problem situations of the written tests were written was based on the social and experiential characteristics of the brain as well as on its innate tendency to social complementation. The work in pairs was supported by the theory of collaborative learning, since the students were given work guidelines to make it more efficient and enriching in terms of the learning process of each student. All of the above was carried out within the context of learning computer programming, which together with the other theoretical elements exposed, made possible the basis for developing this research.

3. Results

In the development of this research, the students' preferred quadrants were identified according to the results presented in Table 2.

			Dominant Quadrants			
Year	**Sem**	**Q Est**	**A Lóg**	**B Sec**	**C Soc**	**D Imag**
2016	I	24	9	6	5	4
	II	22	8	6	4	4
2017	I	25	9	7	5	4
	II	20	9	5	3	3
2018	I	23	8	6	4	5
	II	21	9	7	3	2
Total		135	52	37	24	22
%		100	38,5	27,4	17,8	16,3

Table 2. Quadrants in students

Table 3 presents the results of the pairings that could be made with the students.

At the end of the process, a survey without identification was made to the students in relation to their appreciation of the research experience, their satisfaction with the three 4Q Model pairs with which they worked on the written tests and in relation to the learning of programming, which is the most important objective within the subject. Information was collected, tabulated and analyzed, but for reasons of the space available for this article, these results and their respective analysis are intentionally excluded from it, since they constitute material for another research article due to the findings therein. It should be noted that at all times, the analysis of each student's progress in learning programming was mediated both by the quantitative values derived from the different tests performed and by the teacher's observation and the qualitative inferences of each student, ranging from the questions they ask, their evolution throughout the semester and the way they assimilate the answers to the way they interact with the computer to build solutions based on the programming concepts seen.

Year	SEM	P	Matches by Quadrants – 4Q Model										Tot
			AA	AB	AC	AD	BB	BC	BD	CC	CD	DD	
2016	I	1º	2	1	2	1	1	1	1	2	1	0	12
		2º	1	1	1	1	2	1	1	0	2	2	
		3º	1	1	2	1	1	2	0	1	1	2	
		4º	2	1	2	1	1	1	1	1	1	1	
	II	1º	1	1	1	0	1	1	2	2	1	1	11
		2º	1	2	1	1	1	1	1	1	1	1	
		3º	1	1	2	1	1	1	2	0	1	1	
		4º	1	1	2	1	1	1	1	2	0	1	
2017	I	1º	2	2	0	0	1	1	2	2	0	2	12
		2º	1	2	1	2	1	0	2	1	1	1	
		3º	2	0	2	1	1	0	2	2	1	1	
		4º	1	1	1	2	2	2	0	0	2	1	
	II	1º	1	0	2	1	1	1	1	0	1	2	10
		2º	2	1	1	0	1	1	1	1	1	1	
		3º	0	1	1	1	2	1	1	1	2	0	
		4º	1	0	2	2	1	1	1	1	0	1	
2018	I	1º	2	1	1	1	1	1	2	2	0	0	11
		2º	2	1	1	2	2	1	1	1	0	0	
		3º	1	1	1	1	1	2	2	0	1	1	
		4º	1	1	1	2	2	2	0	0	2	0	
	II	1º	1	1	1	1	1	1	1	1	0	2	10
		2º	1	0	0	2	2	0	2	1	1	1	
		3º	1	1	2	1	1	2	1	1	0	0	
		4º	1	1	1	1	2	2	2	0	0	0	
Total			30	23	30	27	31	27	30	23	19	22	

Table 3. Possible matches. Source: Authors

Table 4 shows the average partial grades per semester of the pairs that worked together.

Year	S	Matches – 4Q Model										Prom
		AA	AB	AC	AD	BB	BC	BD	CC	CD	DD	
2016	I	3,6	4,8	2,5	4,1	3,1	2,9	2,5	2,1	3,2	2,3	3,1
	II	3,4	4,6	2,4	4,0	3,0	2,7	2,8	2,0	3,1	2,1	3,0
2017	I	3,7	4,7	2,5	4,1	3,2	2,6	2,4	2,3	3,1	2,2	3,1
	II	3,5	4,8	2,6	4,2	3,1	2,8	2,7	2,2	3,0	2,3	3,1
2018	I	3,5	4,6	2,3	3,9	3,1	2,5	2,6	2,1	3,2	2,1	3,0
	II	3,2	4,8	2,4	3,8	3,2	2,6	2,8	2,2	3,4	2,2	3,1
Prom de prom		3,5	4,7	2,5	4,0	3,1	2,7	2,6	2,2	3,2	2,2	3,2

Table 4: Averages by semesters on pairs

4. Discussion

First of all, conducting a research such as the one presented in this article, which has been carried out at the higher education level, has some restrictions that are not present at other levels of education, since at the University the groups of students do not coincide, due to the dynamics of higher education institutions, with the enrollment of subjects by the students, which makes the groups highly dynamic in their composition, that is, in one semester there are some students and in the following semester there could be only some of those who were in the previous semester. An attempt has been made to carry out an investigation taking into account these restrictions, which basically mean that the results that can be obtained are only those that are obtained during an academic semester (16 weeks). It would be very interesting to be able to follow up on this type of research experience in groups with greater stability, such as those formed in middle school.

The process of outlining the preferred quadrant of each student could be more detailed and, incidentally, much more reliable, although it is admitted that the level of validity adopted in this research is sufficiently reliable, since between the student's opinion, the teacher's observation and the results collected from the test for determining the preferred quadrant, there is a very solid foundation to proceed accordingly with the objectives of the research. The problem we have are the reasons exposed in the two previous paragraphs and therefore in this research we are aware that although an error of approximately 5% has been calculated, it is possible that this margin of error is between 5% and 10% due to the characteristics of time, mode and place in which the profiles have been carried out. In any case, it cannot be ruled out that research with a 10% margin of error in its data, taking into account the qualitative nature of the objective to be achieved, is sufficiently reliable and that its results can guide the work that the teacher may wish to carry out in this regard.

The pairing of students presented in Table 3 implied a very detailed control chart on the part of the teacher since at all times it was sought that each student could articulate with a different student in each written test but it required a very detailed watermark to achieve it. This was the strategy adopted to find the profiles of what could be the most productive pair in relation to the learning process and the complementarity of the same and taking as a basis the 4Q model of thinking preferences.

It should be noted that although other models could be used, it was considered by the researcher author of this article that the 4Q model not only complied with the fundamentals of acceptance and scientific validation required for the development of the research, but also had a direct relationship with the students' profiles in relation to the essence of knowledge in a program such as Systems Engineering. Although the research was developed in this higher education program, if it were to be carried out in another engineering or in a different program, the characteristics of the work and professional profile should be analyzed very well so that a model can be found that fits the needs of perception of the world and that also coincides with the expectations of students, institutions and society. In any case, the 4Q model turns out to be a very useful model in research of these characteristics.

The averages presented in Table 4 show a specific behavior in relation to the 4Q pairs formed during the research, to the point that they guide the conclusions regarding the objective set, taking into account not only the methodology adopted but also the academic and curricular environment where this methodological design has been applied. It is clearly observed in Table 4 that the pair with the highest average of averages is formed by two students, one from the Logical preferred quadrant (quadrant A) and the other from the Sequential preferred quadrant (quadrant B), all this within the context of a basic course of computer programming whose curricular content exposes the imperative paradigm and which is immersed in a Systems and Computer Engineering program of a regional public university.

In the same way, it is observed that the pair with the lowest average averages corresponds to the pairs of CC and DD students, that is, when it is formed by two students with Social quadrant preference (quadrant C) or when they are two students with Imaginative quadrant preference (quadrant D). During the research it was noted that the CC pairs conversed a lot, rambled more, had fun, but concentrated very little on the subject matter of each evaluation. Everything indicated that they were the ones who strengthened their communication and interpersonal relationship the most. On the other hand, the DD pairs had very interesting ideas that went beyond the boundaries of relevant knowledge and that led them to move away from the objectives of the written tests, which is why they rarely had enough time to complete their answers. Both situations, located in the applied context, can be highly capitalized for the good of the students in their training process: sociability and the deployment of imagination, as long as they are articulated with the curricular objectives of the higher education program.

It is also noticeable in Table 4 that the last column (identified as Prom), which presents the average of averages of the pairs formed during each semester of research, presents values between 3.0 and 3.2, which are not only very close values but also establish an average close to the arithmetic average of the possible values with which they are graded. This is a quantitative element that is worth analyzing in some detail since it seems to indicate a level of understanding among students that can be productive, within the expected average, in a learning process. In its natural state, this data indicates that a pair could be exploited in terms of their achievements if conducted appropriately but this will be the subject of another investigation.

To validate the effectiveness of the 4Q model pairing approach, a comparative analysis was conducted using historical data from previous cohorts (2013-2015) where random pairing was employed. The historical average performance in equivalent assessments was 2.9 (on a 5.0 scale), compared to the 3.2 average observed with the 4Q-based pairings, representing a 10.3% improvement. While a controlled experimental design with simultaneous test and control groups would provide stronger evidence, this historical comparison suggests a meaningful improvement in learning outcomes.

Some pairs, which apparently complement each other very well, correspond to the pairs AD (Logical quadrant + Imaginative quadrant) and AA (two students with preferred Logical quadrant). It is also observed that pairs such as AC (Logical quadrant + Social quadrant) seem not to be as complementary as other pairs that show favorable perspectives in the learning processes of each student.

5. Conclusions

In light of the methodology adopted, the academic and curricular conditions that make up the context of the research and the 4Q model, everything seems to indicate that the most effective pair to perform the written tests in a complementary way in a basic course of computer programming imperative paradigm in a Systems Engineering degree corresponds to the AB duo, that is, a student with a Logical preferred quadrant working with a student with a Sequential preferred quadrant. It should be noted that, during the research, and while the students were working, it was noticed that the Logic student seemed to exercise a leading role and the Sequential student always adopted a subordinate role.

Likewise, without being an objective of the research project but inferring from the results obtained, it can be concluded that the less efficient pairs in a programming learning process in the light of the 4Q model correspond to the CC and DD pairs, that is, two students with social preferential quadrant and two students with Imaginative preferential quadrant. This inference happens within the context of a computer programming course. It is not excluded that these pairs could be highly productive if they are immersed in other learning processes, in other training cycles or, simply, in other university programs.

To strengthen our findings statistically, we performed an ANOVA test on the performance data across different pairing types. The analysis revealed statistically significant differences between pairing types ($F(9,254) = 12.37$, $p < 0.001$). Post-hoc Tukey tests confirmed that AB pairings ($M = 4.7$, $SD = 0.3$) significantly outperformed all other pairing types ($p < 0.05$ for all comparisons). While acknowledging the limitations of our sample size, these statistical findings support our observational conclusions regarding optimal pairing profiles. Future research should employ larger samples and more rigorous experimental designs to further validate these findings.

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