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Motivation for Critical Thinking: A Comparison of Students from Engineering and other Majors in Chile

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Abstract*– Motivation for critical thinking (MCT) is a crucial factor to be developed during the university stage. However, the employed teaching methods do not necessarily promote this development. Although some university mission statements promote knowledge through, for example, critical thinking courses for all majors, it may not confirm if this mission must be improved or has been reached. In this research, the Critical Thinking Motivation Scale was applied to 474 undergraduate students from engineering and other three faculties at a Chilean university campus to evaluate the expectancy and value components (attainment, cost, interest, and utility) that are employed to measure MCT, and to perform a comparison of these components between engineering and other faculty students. The results of the statistical analyses reveal that similarities exist in MCT when comparing engineering with the other faculty students. Additionally, low values were assigned to the expectancy and cost components by all surveyed students, which implies that the university policy that promotes this motivation should be generalized transversally for all students from the four faculties with a particular strengthening of these scale components.

Keywords*-- motivation, critical thinking, undergraduate students, higher education, cognition.

I. Introduction

Higher education institutions assign significant importance to the students' involvement in critical social problems of the population. Through education, these institutions provide students with relevant knowledge to develop strategies and solve problems [1, 2]. Numerous investigations have generated and delivered up-to-date knowledge to face different problems that may occur in professional work. However, students can solve these problems when they have learned the required knowledge and acquired the cognitive skills to enhance the appropriate decision-making processes, allowing them to face the challenges and to solve complex problems. One way to achieve these superior cognitive skills in future professionals is by applying various thinking strategies [3, 4] during their training and fostering the development of critical thinking. These strategies are the base for a good understanding of the necessary components required in the decision-making process, in which students propose solutions to complex problems. The development of these skills must be anchored in the evidence for making informed decisions while considering the context and identifying various intervening factors [5]. Critical thinking is a relevant competence that students should develop to successfully fulfill their learning and personal growth during their university and professional lives [6, 7].

The set of rules and intellectual tools designed to think better are known as "Critical Thinking". Given that all human beings think, but many do not perform it correctly, the use of the required rules is a prerequisite to achieve the appropriate outcomes [8]. Its importance is essential because human beings think all the time, consequently, thinking in the best way is crucial in all areas of our lives, especially in a debate of ideas. However, despite having a simple definition in concrete terms, this type of thinking is complicated since it implies the development of different cognitive skills for an individual. One of the first exhibitors of the concept is "reasonable and reflective thinking that focuses on deciding what to believe or what to do" [9]. The complexity of this type of thinking is also linked to other aspects such as "criteria that can be essential such as freedom, autonomy, sovereignty, and truth, among others. Critical thinking implies being sensitized, as well as contrasting a social, political, ethical, and personal reality" [10], which is why this concept is given by two fundamental concepts: "The first indicates a relationship with skills, that is, with the mastery of certain procedural knowledge to achieve "correct reasoning" [11]. On the other hand, there is motivation, which is essential to develop critical thinking [12, 13]. In other words, one of the best tools to deal with the exponential amount of information, including false arguments appearing nowadays, is developing critical thinking.

According to [9], it is crucial to note that metacognitive skills alone are not sufficient to enable a person to develop critical thinking. If the human being does not have the disposition or motivation to think critically, then the development of critical thinking will not take place. Likewise, having the willingness is not enough since if a person is willing and motivated to think critically, but does not comprehend how to accomplish it, again, the process will not occur.

We must clarify that we understand motivation as "each person's internal process that reflects the established interaction between the individual and the world. Motivation defines the subject's behaviors towards a purpose, an objective, or a goal that human beings consider necessary and desirable" [14]. The complex cognitive function, motivation, is a required step to the development of critical thinking. Accordingly, motivation plays a fundamental role in the process of developing and applying critical thinking. Additionally, the individual's actions "would depend on the expectancy that the person has to carry out a task in a satisfactory way and, on the value assigned to the task of thinking critically." [9]. Finally, [15] state that individuals with

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strong motivation for achievement tend to have high self-efficacy and high performance, which are essential behaviors for the development of critical thinking. Additionally, [16] states that expectancy refers to people's beliefs about their ability to influence events that affect their lives. This core belief is the foundation of human motivation, performance, and emotional well-being.

Motivation for critical thinking (MPC, for its acronym in Spanish) has been defined as "a set of cognitive skills that analyzes and evaluates data obtained from reality, verifying its validity, consistency, and veracity" [17]. There are few studies that specifically address MPC [15, 18-22] since the vast majority study the impact of critical thinking skills on specific dependent variables [23].

Studies have shown the specific components that better determine the use of MPC, such as expectancy and value components [18, 19]. Based on these components, our research question is focused on determining the MPC of undergraduate students from the Engineering faculty and other three faculties at a Chilean university campus, and similarities or differences in the MPC between Engineering and other faculty students. This study seeks to benefit the university and the students since the identification of the descended components may orient the necessary improvements in the curricula and the teachers' practices in each faculty. The development and implementation of the academic activities is a requirement to confirm that an institution provides students with the necessary and essential tools to develop the appropriate MPC.

II. Material and Method

The design is a cross-sectional study conducted in the students´ classrooms during the second semester of 2019. The study was carried out according to the Helsinki declaration, accordingly, the study was approved by an institutional review board (IRB) committee.

A. *Participants*

Undergraduate students from the Engineering faculty and other three faculties (Economics and Business, Rehabilitation Sciences, and Nursing) were invited to participate in this study by completing a survey during regular class periods in the fourth semester in their curricula. A written informed consent was given to the students prior to their participation.

B. *Instrument*

The participants responded an online questionnaire that has two main parts: 1) demographic and academic information that includes gender, age, and current academic year in the undergraduate program, and 2) a test on MPC based on a validated expectancy/value model proposed by [18]. Figure 1 shows the components of motivation with respect to critical thinking that is measured by Critical Thinking Motivational Scale (EMPC). This figure illustrates that the value component consists of four subcomponents (attainment, utility, cost, and interest). EMPC has 19 closed items with a 6-point Likert-type scale ranging from 1 (totally disagree) to 6 (totally agree), and the highest score for each component/subcomponent is 6 points. While the value component is the mean of the four subcomponents, MPC is computed by the square root of the multiplication of the expectancy and value components (√(expectancy×value)), as in [19].

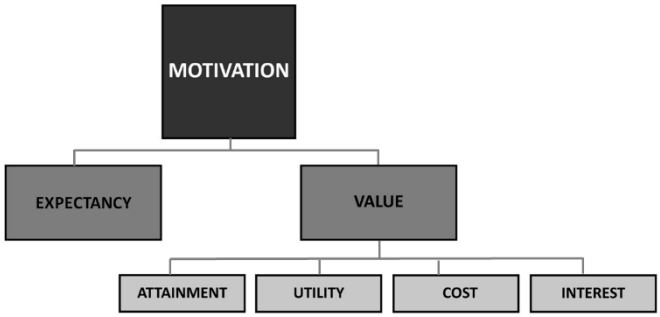


Fig 1. Critical Thinking Motivational Scale (EMPC) (adapted from Valenzuela et al., 2011)

TABLE 1
CRITICAL THINKING MOTIVATIONAL SCALE (EMPC)

Component	Items
Expectancy	
	When it comes to reasoning correctly, I am better than the majority of my classmates I am able to understand everything related to thinking rigorously I am capable of learning to think rigorously I am capable of learning to think correctly better than the majority of my classmates
Value	
Attainment subcomponent	It is important for me to learn to think correctly It is important for me to be good at thinking It is important for me to use my intellectual skills correctly It is important for me to be good at solving problems
Utility subcomponent	Thinking critically will help me become a good professional Thinking critically will be useful for my future Thinking critically is useful in everyday life Thinking critically is useful for other subjects and courses
Interest subcomponent	I like to think properly before deciding on something I like to learn things that will improve my way of thinking I like thinking critically I like to think rigorously
Cost subcomponent	If I have a problem that requires critical thinking, I am willing to sacrifice time from other activities I am willing to sacrifice time and effort to improve my way of thinking It is worth spending time and effort to acquire and use critical thinking

Note: adapted from Valenzuela et al., (2011)

TABLE 2
DEMOGRAPHIC CHARACTERISTICS OF THE SAMPLE

Variable		Faculty		
	Engineering N_{Eng}=127	Economics and Business N_{EcoBus}=104	Nursing N_{Nur}=66	Rehabilitation Sciences N_{RehSci}=177
Sex				
Female	21 (17%)	37 (36%)	56 (85%)	129 (73%)
Male	106 (83%)	67 (64%)	10 (15%)	48 (27%)
Age				
18	2 (2%)	0 (0%)	0 (0%)	1 (1%)
19	26 (20%)	11 (11%)	12 (18%)	29 (16%)
20	16 (13%)	14 (13%)	19 (29%)	53 (30%)
21	21 (17%)	19 (18%)	20 (20%)	34 (19%)
≥ 22	62 (49%)	60 (58%)	15 (23%)	60 (34%)
Academic semester				
4th semester	59 (46.5%)	48 (46.2%)	63 (95.5%)	101 (57.1%)
5th semester	1 (0.8%)	13 (12.5%)	0 (0.0%)	4 (2.3%)
Other	6 (4.7%)	43 (41%)	3 (4.5%)	72 (40.7%)

The participants responded to each item based on a series of statements related to the components of MPC (see Table 1). In this study, the scale has high reliability and validity (Kaiser-Meyer-Olkin test, KMO: 0.902 & 0.887) with the MPC components having satisfactory reliability and validity: expectancy (α= 0.774), and subcomponents attainment (α= 0.770), cost (α= 0.775), utility (α= 0.790), and interest (α= 0.724).

C. Procedure and data collection

The authorities of each faculty were informed and approved this research. The teachers responsible for each class were contacted to coordinate the time and classroom location prior to conducting the survey. The students voluntarily accepted to participate in the survey and responded to an online questionnaire with their smartphones. The average total response time of the questionnaire was approximately 30 minutes. Note that the collected data is only available to the research team members.

D. Statistical analysis

All data were collected in Excel files, and then exported and analyzed using STATA software. The survey results are expressed as median, interquartile ranges (IQR), and whiskers in boxplot diagrams for the components/subcomponents per faculty. In addition, the Kolmogorov-Smirnov test was employed to analyze the normality of the components. If the Kolmogorov-Smirnov test was statistically significant, then the nonparametric Kruskal-Wallis test (H statistic) was employed to study the significant differences in the scoring of the components among the four faculties. Subsequently, a post-hoc analysis was performed using the Mann-Whitney U test with Bonferroni correction to determine significant pairwise differences for those components/subcomponents that have statistically significant H statistic values. If the Kolmogorov-Smirnov test was not statistically significant, then one-way Analysis of Variance (ANOVA) was performed to examine the significant differences between the MPC components of the four faculties. The significance level is set at 0.05.

III. RESULTS

A. Participants

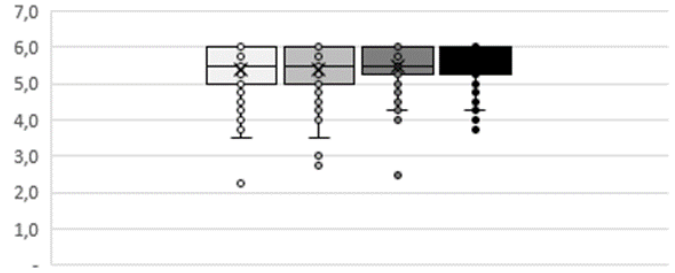
The initial sample comprised 482 students. Eight students decided not to participate in the study or did not complete the questionnaire. Therefore, the final sample was comprised by 474 students, with average age of 21.26 years old (SD= 1.58) of both sexes (51.2% women). The sample included 127 students from the Engineering faculty, and the remaining 347 belonged to the Economics and Business (n=104), Rehabilitation Sciences (n=177), and Nursing (n=66) faculties. Additional demographic characteristics of the sample are depicted in Table 2. All students signed the informed consent prior to their participation.

B. Critical Thinking Motivation Scale (EMPC)

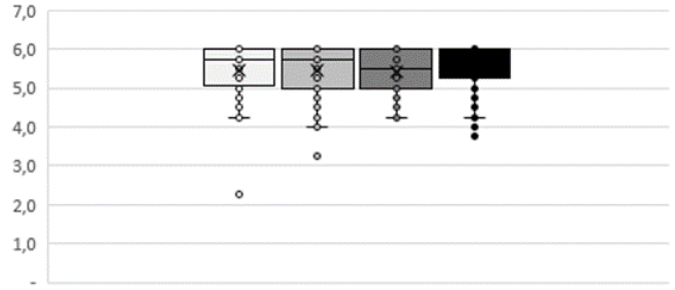
The boxplot diagrams in Figures 2 and 3 present the median, IQR, and minimum and maximum values for the MPC components for each faculty. In these figures, the white, light gray, dark gray, and black colors represent the Economics and Business, Engineering, Nursing and Rehabilitation Sciences faculties, respectively. Figure 2 presents the distribution for each of the four subcomponents that comprise the value component per faculty. Overall, the participants tend to score the utility, interest, and attainment subcomponents with similarly high values between 5 and 6, as observed in Figures 2a), 2b), and 2c), respectively, and lower values were assigned to the cost subcomponent, as shown in Figure 2d). These figures suggest that the participants tend to agree more with the items that measure the utility, interest, and attainment subcomponents than the cost subcomponent. Additionally, very similar results are obtained for the utility and attainment subcomponents between Engineering and Economics and Business faculties, as shown Figures 2a) and 2b), respectively. For the interest subcomponent, the IQR for the faculties of Engineering and Rehabilitation Sciences are larger than the other two faculties, and the faculty of Rehabilitation Sciences presents a slightly lower median than the other three faculties (See Figure 2c). Regarding the cost subcomponent in Figure 2d), the results for this subcomponent show similar medians between the Engineering and Nursing faculties, and the latter presents a larger IQR than the other faculties. Note that although the boxplots of the cost subcomponent in Figure 2d) suggest that most of the surveyed students report values ranging between 4

and nearly 6, this subcomponent presents the lowest results among all subcomponents.

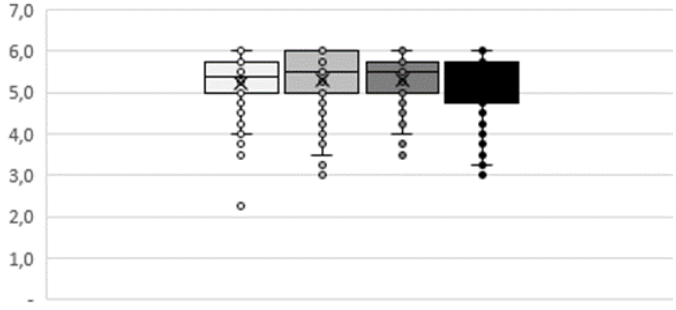
For the value component, which comprises the four subcomponents (utility, interest, attainment, and cost), Figure 3a) shows that similar median values are obtained for the four faculties, and slightly larger IQR for the faculty of Engineering and Nursing. Differences are more apparent with the expectancy component among the four faculties, as presented in Figure 3b). Lower median score values between 4 and 5 were obtained for all faculties with the expectancy component than with any other component. Approximately 50% of the participants from the faculty of Rehabilitation Sciences present expectancy values between approximately 4 and 5, and a larger range between the upper and lower whiskers than other faculties. Finally, Figure 3c) shows that the faculties of Economics and Business, and Engineering present very similar medians and a larger IQR of the scores for the MPC component for the Engineering faculty. Lower median score values of MPC (less than 5) are observed for the faculties of Rehabilitation Sciences and Nursing.



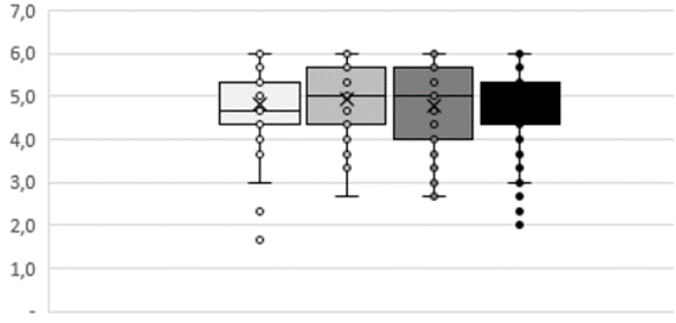
a) Utility subcomponent



b) Attainment subcomponent



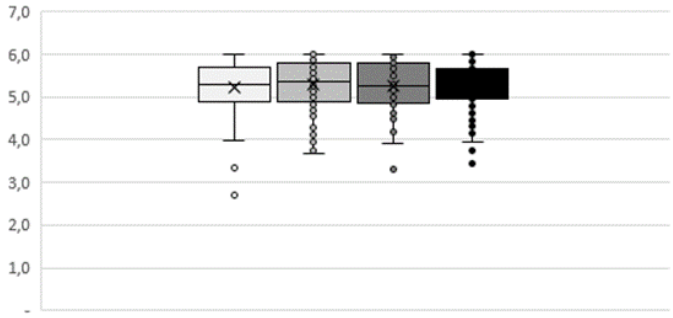
c) Interest subcomponent



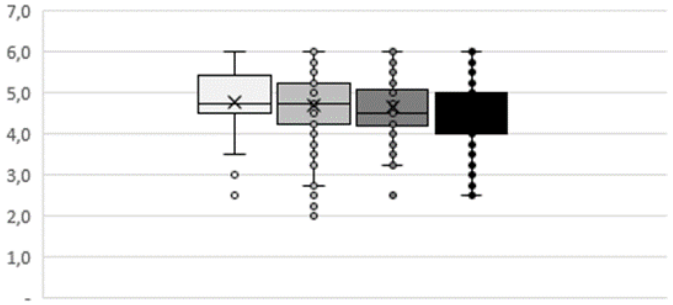
d) Cost subcomponent

Fig 2. Boxplot diagrams for each subcomponent of the value component per faculty Thus, each letter represents a value subcomponent: a) Attainment, b) Utility, c) Interest, and d) Cost, while colors represent the faculties included in this study, white: Economics and Business; light grey: Engineering; dark grey: Nursing, and black: Rehabilitation Sciences.

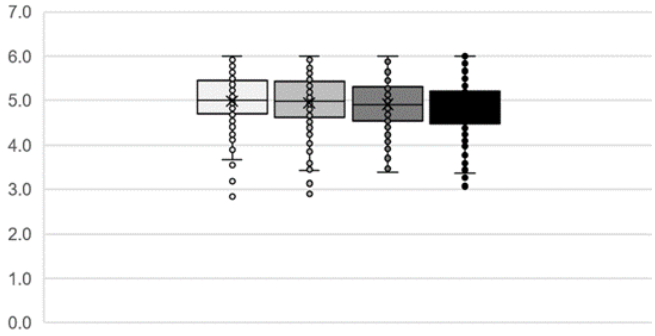
The Kolmogorov Smirnov test was employed to test the normality of each component. Table 3 presents the normality test results, suggesting that all components are not normally distributed due to the statistical significance, except for the MPC component. Thus, the parametric one-way ANOVA test is used for MPC, while the nonparametric Kruskal-Wallis test is employed for the expectancy and value components.



a) Value component



b) Expectancy component



c) MPC component

Fig 3. Boxplot diagrams for the MPC component per faculty. The colors represent the faculties included in this study, white: Economics and Business; light grey: Engineering; dark grey: Nursing, and black: Rehabilitation Sciences.

TABLE 3
KOLMOGOROV SMIRNOV TEST RESULTS FOR EACH MPC COMPONENT

Component	Faculty			
	Economics and Business	Engineering	Nursing	Rehabilitation Sciences
Subcomponents				
Utility	0.351*	0.338*	0.402*	0.408*
Attainment	0.367*	0.390*	0.349*	0.405*
Interest	0.302*	0.319*	0.336*	0.274*
Cost	0.256*	0.252*	0.244*	0.297*
Components				
Value	0.261*	0.290*	0.277*	0.279*
Expectancy	0.284*	0.299*	0.253*	0.222*
MPC	0.114	0.107	0.084	0.071

The results of the nonparametric Kruskal-Wallis test reveal that no significant differences for the value components (i.e., utility, attainment, interest, and cost) were found among the four faculties, as shown in Table 4. However, the results in this table suggest that at least one faculty is dominant over the other faculties for the expectancy component due to the statistical significance. Thus, this component is further investigated by constructing pairwise comparisons with the post-hoc Mann-Whitney U test.

The results of the post-hoc Mann-Whitney U test suggest significant differences in the expectancy component between the faculties of Economics and Business, and Rehabilitation Sciences [U (NEcoBus= 104, NRehSci= 177) = 6644.5, z = -3.8908, p = 0.0001) and also among the faculties of Rehabilitation Sciences and Engineering (U (NRehSci= 177, NEng= 127) = 9206.5, z = -2.6889, p = 0.0071]. No significant differences are observed among other pairs of faculties for the expectancy component.

TABLE 4
KRUSKAL-WALLIS TEST RESULTS FOR EACH MPC COMPONENT AND SUBCOMPONENT

Subcomponent and component	H (*df*, *N*)	*p*
Subcomponents		
Utility	3.326 (3, 474)	0.3441
Attainment	1.539 (3, 474)	0.6733
Interest	1.957 (3, 474)	0.5813
Cost	1.250 (3, 474)	0.7409
Components		
Value	1.136 (3, 474)	0.7684
Expectancy	16.860 (3, 474)	0.0008

TABLE 5
ONE-WAY ANOVA TEST RESULTS FOR THE MPC COMPONENT

	Sum of Squares	*Df*	Mean Square	*F*	Sig.	Critical value for *F*
Between groups	2.393	3	0.798	2.026	0.109	2.624
Within groups	185.041	470	0.394			
Total	187.434	473				

The results of the one-way ANOVA analysis of the MPC component did not show significant differences between the faculties (See Table 5). In other words, the participants from the four faculties did not differ significantly in their responses related to this component.

IV. DISCUSSION

The main goal of this study was to determine and compare the MPC in a group of university students in their fourth semester of their curricula from the faculties of Engineering and other three faculties (Economics and Business, Rehabilitation Sciences, and Nursing) at a campus of a private university in Chile. Overall, the MPC component presented similar results and no statistically significant differences between the students of the four participating faculties. When analyzing the value and expectancy components independently, no differences were observed in the value component, whereas differences were perceived between the Engineering and Rehabilitation Sciences faculties regarding the expectancy component (i.e., competence that a person perceives to perform a task adequately or think critically). In addition, we identified a hierarchy in the value subcomponents across the entire studied population from highest to lowest: utility, interest, attainment, and cost subcomponents.

Due to the statistical significance results for the expectancy component shown in Table 4 ($p<0.05$), we performed the post-hoc Mann-Whitney U test and identified that significant differences exist between students from the faculties of Economics and Business, and Rehabilitation Sciences, and

between the faculties of Rehabilitation Sciences and Engineering. This means that students from these faculties have different expectations on the ability to think critically. One explanation for these results could be that the metacognitive strategies used in the classroom in a transversal way in this academic institution, concurring with the procedures that facilitate information processing at the cognitive level. According to [24], "These strategies select and regulate the cognitive processes, where students must show interest in the subject, that is, an internal motivation towards it, since it requires planning and conscious use of these strategies, which facilitate academic performance".

Additionally, we must remember that MPC is declared in the higher education institution's mission and inserted in the curricula as a subject on critical thinking, and that this subject is transversal to all students at this university. The interest and utility subcomponents reflect the "critical cultivation of knowledge" approach, as they indicate how useful and important is to think critically. These subcomponents are relevant to the total student population investigated, while agreeing with the university's mission.

The above result is consistent with a study conducted by [25] carried out with 185 high school students in Chile, in which a positive and significant relationship was found between metacognition and MPC. This link is relevant since it reinforces the idea that it is necessary to motivate students to think deeply and elaborately, and one mean to achieve this is by allowing them to find the usefulness in the topics they must learn and questioning the traditional ways on how this knowledge has been used and taught [25].

In our study, the cost subcomponent (i.e., how much effort it would take to carry out this activity) and the expectancy component were significantly lower for students from all faculties. Similarly, as in the research by [19], both the cost subcomponent and especially the expectancy component have been determined as the lowest for all students from the School of Nursing. This finding could be explained by the fact that students may still be in the transition between their basic and university training stages, as they are in the second year of their undergraduate program and that, at this stage, students may not be mature enough to be responsible and manage the learning process. The value of critical thinking is not in question, but they are not willing to assume the cost of what it implies to motivate themselves to think critically, and they also believe that they do not have the capability to think critically [19]. Students are mostly willing to invest in developing critical thinking if they perceive a direct relationship between MPC and their academic performance. Therefore, the students would be willing to try to think critically if they perceive a high degree of control over their academic achievement [24]. In another study, [26] argues that Mexican students who enter the university do not have the ideal basis for this competence. This barrier prevents them from performing efficiently in their classes and from achieving good quality learning, in order to become competent professionals.

The development of critical thinking involves relevant processes in academic terms and the training of students. As stated by [27], the mission of education should enable students to acquire intellectual autonomy by using superior order strategies such as metacognition that are involved in subjects on critical thinking, rather than offering students an enormous amount of knowledge related to various specialized fields. As [28] argues that training students to think critically should focus not only on academic content but also on daily life problems, which is an objective of major importance for both the educational system and society. To develop critical thinking in students is to enforce both direct and indirect reflection of their thinking. The integral formation of the students should perceive the emergence or increase of their capacity to improve society and themselves. In fact, in this sense, a relationship between the formation of critical thinking and research begins to be appreciated.

Finally, as referred to by [16], the motivational processes favor the use of in-depth learning strategies that in turn favor academic performance, considering the role of the teacher. Thus, the importance of using teaching strategies that support the development of students' autonomy is highlighted to increase their interest and especially motivation [24]. Similarly, [19] highlight the importance of MPC regarding training teachers to emphasize the motivational components during the student's education at the university, and thus, enforcing MPC in the classroom. Teachers with the appropriate training in MPC should exceed the discourse that students should be motivated. Teachers should develop, establish, and implement practical strategies that motivate students to think critically, for example, through strengthening the use of problem-based learning, which is an essential result of this research [29]. Therefore, teachers have the duty to challenge students to be motivated to think critically, since, although the students in this study do understand that it is essential, useful, and enjoyable to motivate themselves to think critically, they do not feel capable and do not present a desire to work in the development this skill in-depth. This skill will be relevant for the students' work performance in the future as professionals in all areas.

The limitation of this study is that the sample represents four faculties of a campus from a private university in Chile. The research outcomes were obtained for a specific sample. Accordingly, the results may not be generalized to the whole student body at the analyzed university, nor to the population of undergraduate students in Chile or other countries.

V. Conclusions

The outcomes of this work will help researchers and the studied Chilean higher education institution to identify the strengths and weaknesses of students regarding their MPC. Overall, our results reveal that the students possess similar MPC, implying that incentive policies for MPC should be generalized for all the students from the four analyzed faculties within the institution. Thus, priority should be given to strengthen the most deficient aspects of MPC, particularly, on

how much effort it would take the students to think critically (cost component) and the feeling of competence that the students need to think critically (expectancy component). Future research should include more in-depth comprehension of the differences in expectancy component between the facilities (e.g., Engineering and Rehabilitation Sciences).

The understanding of the perception of MPC in the Engineering and other three analyzed faculties at a private university provides a global vision of this ability and detects the deficiency and the need of reinforcing the necessary components and/or subcomponents of critical thinking for the future professionals regardless of the work area. Thus, despite critical thinking being a skill that is usually taught and developed through all courses in a curriculum, we recommend implementing a critical thinking course and ensuring that the academic components are a pillar to facilitate and enhance the learning in the curriculum of other courses. Additionally, all teachers should generate instances that support students to develop more deeply the ability to think critically and motivate themselves to do so. Finally, it is relevant to consider the means for stimulating personal exploration of each student to think critically by significantly reinforcing the expectancy component and the cost subcomponent. This ability should be reinforced at all levels (both in this university and in other higher institutions globally), so that students become better critical thinkers.

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