A New Transdisciplinary Approach to Foster Soft Skills in Engineering

Using Critical Reading Micro-Workshops

Patricia Caratozzolo
Mechatronics Department, School of Engineering,
Tecnológico de Monterrey, campus Santa Fe
Ciudad de México, México
pcaratozzolo@itesm.mx

Álvaro Álvarez
Language Department, School of Social Sciences,
Tecnológico de Monterrey, campus Santa Fe
Ciudad de México, México
alvarez.delgado@itesm.mx

***Abstract*— International reports presented in recent years insist on the need to develop soft skills to a greater degree considering the future jobs required to address the Fourth Industrial Revolution. The biggest problem arises with two of those competences in particular: Critical Thinking and Creativity, given the difficulty of their enhancement using the logical-scientific approach traditionally used in engineering programs. That implies the need to consider disruptive innovations in teaching-learning approaches. In this study, research was conducted to verify the relationship between a mixed infusion-immersion implementation of an artistic-narrative approach and the development of these two soft skills. The results showed that, using the same stimulus path that metacognitive tools of the artistic process provoke, is a very efficient way to naturally develop soft skills in Generation Z students. Critical Reading MicroWorkshops were implemented into classroom activities involving a Critical Reading framework. The results obtained corroborate the significant influence that the new approach had to foster Critical Thinking and Creativity in engineering students.**

Keywords—Critical Thinking, Creativity, Educational Innovation, Soft Skills in Engineering.

I. INTRODUCTION

The importance of soft skills in engineering, especially Critical Thinking (CT) and Creativity, has been studied for many years by academic researchers. However, it has not been until very recently, since freshmen belong almost 100% to Generation Z, that the need has been seen to introduce innovative approaches so that these competences are developed in an effective and lasting way considering the particular characteristics of *Gen Z engineers* [1]. Both, employers and international accreditation agencies, are the most interested in these competences being formally considered in engineering programs. It can be considered that the year 2015 was the turning point in the reports on the need to include new cognitive and metacognitive tools to achieve the full development of soft skills in Gen Z engineers due to two fundamental factors: first, the strong consolidation of social networks that meant an unexpected difference in the way recent graduates see the world, think about private and public matters and become aware of themselves; and second, the exponential development of technological platforms that became accessible to them [2]. This explosion of resources -in social networks and information technologies- that was verified in all areas of life of Gen Z students forced, *by avalanche effect*, its uncontrolled incorporation into educational environments.

At that time, all kinds of implementations arose in the classroom: the gamification of courses, the incorporation of educational apps and videos, the practice of distance education, the use of mobile devices for communication, evaluation and delivery of tasks, the empirical acceptance of the information found on the Internet, the use of augmented reality and virtual reality programs, the use of simulators and virtual laboratories to perform laboratory practices and a long etcetera that became a rampant race in which the final objective seems to be which institution is more innovative [3]. This phenomenon was especially noticeable in engineering careers because it was logical that all technological implementations began in STEM (Science Technology Engineering Mathematics) programs [4].

When the weaknesses in the development of soft skills were detected, numerous studies appeared trying to apply and put into practice the developments made in the 90's about CT and its relationship with other soft skills [5]. Some of the studies try to develop these competences by infusing strategies in the classroom and others by incorporating more technological tools [6]. In all cases, the objective of these studies has been the development, via the traditional logical-scientific modality of thinking, of the CT *abilities*: inference, judgment, problem solving, identifying assumptions.

The reality is that technological tools do not produce learning *per se* [7]. Students do not learn from the apps, not from the videos, neither from Wikipedia nor from the platforms that transmit technical information to them. The only way to learn, in engineering or in any other career, occurs through a structured mental process.

With the support of NOVUS Grant, 2017-2018, TecLabs, Tecnologico de Monterrey, Mexico.

Our project consists in a transdisciplinary approach that incorporates those tools that effectively trigger the cognitive and metacognitive processes of learning. To do this we have resorted to a mixed approach -infusion/immersion- by adapting the three higher-order levels of Bloom's Taxonomy. We use a deliberative discussion-based andragogy and structured controversy approaches to design Critical Reading workshops.

The results obtained so far confirm our hypothesis that the development of CT *inherent qualities of temperament:* communication, collaboration, diversity, perspective taking, inter-related dialogue, open-mindedness and diverse perspective; instead of CT abilities, are what make creative and critical thinker engineers, that is to say, *engineers for peace*.

II. PEACE ENGINEERING

It is increasingly important that engineers fully develop the skills of CT and creativity, since the exercise of their profession requires that they comply with the ethical obligations declared by most international engineering associations. For example, the IEEE is its Code of Ethics [8] establishes, among other commitments:

"... to accept responsibility in making decisions consistent with the safety, health and welfare of the public… to disclose promptly factors that might endanger the environment... to avoid real or perceived conflicts of interest whenever possible… to improve the appropriate application and potential consequences of technology... "

Being in a position to fully comply with these commitments requires from future engineers a high degree of self-awareness and common sense that must be formally developed together with the technical and technological training they receive in college years. It is reasonable to think that the current students of engineering will be generating all the technological advances of the world by 2040, so it is essential to incorporate in engineering programs, as soon as possible, a specific soft skills training plan in order to comply with the requirements posed, for example, by the World Economic Forum, WEF, in its report The future of Jobs [9].

At the same time, the current globalization promotes the great mobility of engineers across all borders, so that today a large part of the workforce of any company is multicultural and diverse. Additionally, the Gen Z engineers do not feel strong roots neither for their companies nor for their countries, as it happened with the professionals of previous X and Y Generations, and most of them make frequent changes of company, city and even of country of residence [10]. Engineering is probably the most cosmopolitan career since the technology itself is universal and has no borders.

Bearing in mind all the above considerations, it is evident the need to develop those teaching-learning methods and strategies that prepare engineers as *ambassadors of peace* in the world. The strength, responsibility and influence of engineers is now more important than ever, so it is crucial their training not only in the professional but in all the skills and competencies for their personal and social development.

The incorporation of reflective practices through spaces for dialogue must be taken done throughout the engineer program and can be considered as part of the cognitive and metacognitive tools in all subjects. The objective of this new approach favors the establishment of a common language and develops the critical and reflective thinking of the future engineer who, in this way, achieves a better personal, social and professional development. Inherent dispositions for each soft skill, considered in this study to achieve better engineers for peace, are shown in Table 1.

TABLE 1. SOFT SKILLS FOR PEACE ENGINEERING

Soft Skill	Inherent disposition
Self-motivation	To be able to motivate oneself without the need of external influence factors.
Self-awareness	Be responsible for your own thoughts and behaviors.
Communication & Collaboration	Communicate effectively with active listening and constructive feedback.
Teamwork	The ability of an effective interaction work.
Perspective taking	Being able to understand different points of view with which you do not agree, without letting the disagreement interfere with one's reasoning.
Understanding of diversity	Consider the integration of gender, nationality, beliefs and experience.
Ethics	Be able to face ethical dilemmas in the professional field.

III. INFUSION TEAMS WITH GENERATION Z STUDENTS

Although Generation Z (digital natives born between 1995 and 2010) differs in many aspects of generation Y, especially in regard to learning styles, we have been able to verify that educational theories based on Cognitive Development by stages are still valid for both groups of students. In this way, we consider that the methods associated with the strengthening of skills and competences related to CT and Creativity can be designed taking advantage of the numerous studies and works carried out in the past by prestigious institutions [11].

In addition, Gen Z students arrive at college at varying levels of cognitive development and will continue to progress at varying levels dealing with their own learning. Not all students arrive at college with high levels of reflective and CT, and also some students will develop these skills later than others. Instructors would be well advised to keep in mind that

cognitive ability is a developmental process and students must go through a series of steps over a period of time before they are able to think critically and reflectively. In our work, we have adapted it to the special characteristics of the Gen Z students for the design of our methodology. It has been very useful for our research the information from various fields to profile Gen Z student characteristics, and the different ways to connect with them, with carefully designing of the MW activities.

IV. SOFT SKILLS AND MODALITIES OF THINKING

Jerome Bruner points out that there are two modalities of cognitive functioning and each of them offers characteristic ways of constructing reality and ordering experience [12]:

The logical-scientific modality tries to fulfill the ideal of a mathematical, formal system of description and explanation. It uses the categorization or conceptualization and the operations by which the categories are established, represented, idealized and related to each other in order to build a system. In general terms, the logical-scientific modality uses procedures to ensure verifiable references, and to verify empirical truth. This is the modality in which engineering students are trained at college. That is why the speech of engineering students is regulated by requirements of coherence and not contradiction. The field of engineering is defined not only by observable entities to which their basic statements refer, but also by the series of possible worlds that can be generated logically and verified against observable entities; that is, it is directed by hypothesis of principles.

The artistic-narrative modality looks for probably particular connections between two events and uses procedures to establish the likelihood, not the truth. The artistic-narrative modality is concerned with how we come to give meaning to experience, deals with human intentions and actions and the vicissitudes and consequences that mark its course. It tries to situate the events of experience in time and space. This type of modality is practiced by students of artistic and humanistic careers in college. Until now, educational theories have tried to avoid incorporating the artistic-narrative modality in engineering courses so as not to lose the rigor of the search for empirical truth. However, during our research we have found that attempts to ignore one of the modalities at the expense of the other inevitably lose the possibility of developing CT and Creativity. For the design of the cognitive tools of this study we consider the following definitions:

> *Critical Thinking* is using logic or reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems [13].
> *Creativity* is the ability to come up with unusual or clever ideas about a given topic or situation, and to produce work that is both novel, original and unexpected, and appropriate, useful and adaptive concerning task constrains [14].

We have adopted Lev Vygotsky's criterion according to which human mental activity depends, to achieve its full expression, to be linked to a set of cultural instruments [15]. We believe that the exercise of engineering can be greatly benefited if intuitions are transformed into a symbolic system of either natural language or some form of artificial language. We also understand that in order to ensure that engineering students develop at their maximum capacity the soft skills it is important to develop those cognitive tools that enrich both modalities of thought, the logical-scientific and the artistic-narrative.

V. METACOGNITIVE STRATEGIES

A. MicroWorkshops Dynamics

A MicroWorkshop (MW) is a very short discussion-based team activity designed to solve a problem, develop a plan, reach a decision or design a flow. To be effective, the MW must have certain characteristics that are listed in Table 2.

MW provide a way to create an intensive experience in a short amount of time and encourage the practice of innovative methods to develop soft skills. MW can help to create a common purpose among participants and an ideal opportunity to practice Interthinking strategies.

TABLE 2. MICROWORKSHOP CHARACTERISTICS

Short duration	Less than 45 minutes
Small Size Group	10-12 students
Punctual	Focused on one issue at a time.
Active	All participants have a chance to practice the technique under discussion.
Structured	All participants have formally defined roles.
Self-contained	It may end with handouts and suggestions for further implementation for those who are interested.

A MW of short duration is the best option as a mean of introducing a metacognitive tool with the main objective of developing synergy in creative groups integrated by Gen Z participants.

Group size is also important because with less than 10 participants there may not be enough opinions and ideas to create critical mass, and the rate of the Interthinking and Creativity process would not become self-sustaining [16]. With more than 12 participants, it would be very difficult for everyone to express their opinion, argue solidly and contribute with more than one intervention in a 45-minute period.

B. Critical Reading and Literature Debates

Starting from a somewhat elementary analogy, we can say that the brain is sort of a muscle that needs to be exercised in order to be "in shape" and, like any kind of muscle, if it is not trained, it will become atrophied, perhaps permanently. As it's been stated by Kieran Egan in [17], if ironic reading comprehension -something for what CT is essential- is not developed when someone is around 20 or 21 years old, it will be almost impossible to develop it later. Beside this, it has been proved, and sadly forgotten, that reading is perhaps the most powerful tool to instill and develop CT. Although there are some ways of reading: scanning reading, comprehension reading, critical reading and interpretation (a *must have* for the example explained in the next section), to name some of them, it is impossible to get the interpretation level without haven't practiced the previous levels, since a critical reader must be able to explain the structure of any text, why it is structured in a specific way and base on his/her personal position in the presence of the text, reading tools which must have been practiced by different levels, starting from comprehension reading [18].

A critical reader (understood here as that one who's able to figure out an ironic text) must read any text having in mind the next questions:

What's the source for this text?
How is exposed the information?
Which are the intentions and the goal from the author?
Which tone is used?
What kind of language is used?
What thesis is proposed by the author?
In which way are the arguments structured along the text?
Did my opinion change anyway?
Did I take a stance in front of the text?

As it can be easily seen, not each one of these questions is present in academic texts and to be more specific, the ironic speech, maybe the most powerful source for testing and developing CT, belongs particularly to literary genres. Here is the need to include fiction texts in the academic programs for engineering students; otherwise, these students will hardly develop their CT.

C. Metacognition and cognitive process

It is assumed that, throughout their college years, students acquire the ability to understand the texts they read, both critically and creatively. However, our preliminary studies have shown that a certain percentage of students, even in the last year of their career, still face difficulties in the comprehension of texts, and this represents an insuperable barrier to apply CT to the reading process [17].

Reading is a process of construction of meaning from a written text, but the understanding of a written text not only actively constructs the meaning from the words read but also incorporating personal experiences. That is, it is not enough to understand the literal meaning of the text, but to interpret what is read, including constructing images, identifying categories of information and elaborating opinions and interpretations about what the author wanted to say. It is evident that there are currently, two different problems related to the comprehension of texts and both are related to reading: the first is the reduction of vocabulary manifested by Gen Z students, which makes them unskilled readers, because they cannot overcome the lower level of the reading process due to focusing on the decoding of unknown words. The second problem is related to the level of cognitive development of students. Our methodology considers the cognitive characteristics of each of the four stages of Egan's educational development theory, which we have chosen to characterize Gen Z students: Mythic, Romantic, Philosophical and Ironic [17].

Metacognition, defined as *thinking about thinking*, is the knowledge concerning about the cognitive processes, products and everything related to them. Metacognitive knowledge consists of cognitive learning strategies which students can use to regulate the process of knowledge acquisition. Reading comprehension does not occur automatically. Successful comprehension depends not only on the cognitive effort but also on the metacognitive processing, which in turn depends on the development stage of the student. Due to the fact that in the same classroom students with different levels of cognitive development coexist, we have considered two fundamental concepts derived of Vygotsky's work, *Scaffolding and Zone of Proximal Development* [13]:

Scaffolding concept. It refers to an observed fact that when a teacher interacts with students with the intention of teaching them something, they tend to adapt the degree of help to the level of competence they perceive of themselves.

Zone of Proximal Development concept. The ZPD is the distance between the real development level of the students (determined by the independent solution of the problems) and, the level of potential development (determined by the solution of the problems with the teacher's guide or with the support of the classmates).

The example included in the next section describes, in succinct form, an activity developed with a group of students using the MicroWorkshop scheme and some strategies of metacognitive instruction to develop critical reading of non-academic texts, using both concepts: Scaffolding and ZPD.

VI. METHODOLOGY AND EXAMPLE

Participants

Participants were 162 undergraduate students of engineering programs in Tecnologico de Monterrey, campus Santa Fe. They joined the study voluntarily, and 125 of them took metacognitive instruction for three semesters. The other 37 students did not take any training at all.

Instrumentation

Three different types of instruments were used in this study. The first type was vocabulary tests, with multiple-choice and true or false questions. These tests were prepared exploring different topics: words with prefixes and suffixes, antonyms, synonyms and paronyms; adverbs forming from adjectives, homophones words, etc. The second type was a modified version of the rubrics presented in the Miniature Guide by Paul & Elder [14]. Finally, to assess how well students performed each outcome and considering that assessing the evidence for competencies as CT and Creativity usually involves subjective judgments concerning products or behaviors, we also use a third type of instrument, adapting an already-existing rubric, the VALUE Rubrics, from AAC&U, developed for the Essential Learning Outcomes of the Association of American Colleges and Universities [19]. We are currently working on improvements, because the number of samples that we have worked with may not yet be enough to extrapolate the results obtained with these last rubrics.

Procedure

The research methodology of the study was quantitative-experimental, the most appropriate to establish causal relationships between groups of variables. Experimental research allows to influence a variable and establish cause-effect relationships. The independent variable was our experimental variable or treatment and the dependent variable was our result or criterion, with which we achieved the effects observed in the study. The research hypothesis was that cross curricular incorporation of discussion-based activities such as MW, for the development of Critical Reading basic skill in curricular courses, leads to: greater CT (process skill), which will improve social & management skills (cross-functional skills) of engineering students. The comparison between groups was the fundamental element of this investigation, for which we worked with two groups: the one that received the treatment (*Experimental Group*) and the one that did not receive it (*Control Group*). Based on preliminary results obtained during the first year, we decided to use a third group to which a different treatment was applied (*Comparison Group*).

Design

The design chosen for the project was focused on the Experimental Research, Quantitative, Solomon type [20]. It was intended to control the possible interaction that could exist between the pre-test and the treatment. This design allowed the results to be generalized also for the subjects who had not receive the pre-test. Two groups received pre-test and two others did not; two groups received treatment and two others, did not. The measurement of the dependent variable in pre-test situation was done at the same time in the two groups, and the measurement of the dependent variable in post-test situation was done at the same time in the four groups. The assignment of the subjects to the groups was done randomly. The methodological design is explained in Fig. 1.

The students in the *Experimental Group* attended three MW of reading comprehension instruction each semester, during three consecutive semesters. The chosen texts were works of universal literature of different genres: novel, short story, plays, poetry and essay.

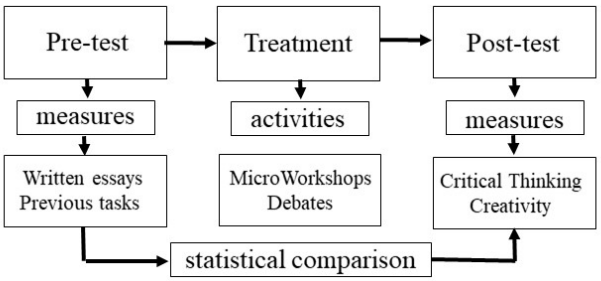

Fig. 1. Solomon four-group design

Example

The following is a description of the activity developed in one of those MW, dedicated to the Critical Reading of the satirical essay *A Modest Proposal,* by Jonathan Swift (1729). The literary analysis was based on [21]. The method requires a prior preparation of the students in the selected text: they perform a series of tasks, during the previous two weeks, that stimulate their individual reflection and then they write a brief essay about their experiences and opinions about that reading.

TABLE 3. EXPERIMENTAL GROUP ACTIVITIES

Week	Activity	Topic
#1	Individual/ preliminary	Brief background of the topic: Biography of Jonathan Swift and Historical Context of the political relationship between Ireland and England / Protestants and Roman Catholics. Research on the role of the *anonymous pamphleteering* used in the eighteenth and nineteenth centuries to articulate political ideologies and to attempt to shape public opinion.
#2	Individual/ preliminary	Reflection on satire, sarcasm and irony, as argumentation resources in an essay.
#3	MicroWorkshop	Discussion on concepts such as colonialism, greed, inhumanity, society, misanthropy and irrationality. Discussion about the role played by each of the characters in the text: the Proposer, Psalmanazar and the Pretender.

Because Critical Reading refers to a careful, active, reflective and analytic reading, the form to do that is questioning the content so, students are encouraged to considering some specific extra-questions, as follows:

What assumptions does the author make in terms of values, beliefs or knowledge?
What appeals does the author make? To reason (logos), to the emotions (pathos), or to our sense of trustworthy (ethos)?

During the MW session the instructor focus the student's attention on answering those questions, e.g., the group see the use of *logos* in the overwhelming amount of figures and statistics used by The Proposer to justify its proposal as if it were an economic strategy. Regarding the use of *pathos*, the group reflect on the purpose of Swift, when he uses phrases such as the one that initiates the text: "*It is a melancholy object to those who walk through this great town, …*". Finally, regarding the use of *ethos*, the group analyze the final paragraph of the text: *"I have not the least personal interest in endeavoring to promote this necessary work…"*

The inclusion of these type of activities into the classroom allowed the effective development of the ability to reflect and the practice of artistic-narrative thinking modality. In that way the group shared experiences orally, with presentations and discussions, and in written form, with essays and opinions, that is also a way of transforming the prevailing mode of teaching in the classroom, which is the monologist, by a dialogic mode in argumentative spaces.

The way in which the methodology was carried out, allowing the students to prepare for two weeks before each MW, met the scaffolding objective necessary for the highest percentage of students to work in a comfortable ZPD and obtain better results in the assessment rubrics used.

VII. CONCLUSIONS

The results obtained in the tests and exit surveys show that the exercise of Critical Thinking and Creativity in the classroom helped the engineering students to have enough resources to be in harmony with others and at the same time maintain their independence from criteria. The acquisition of these qualities of temperament are of great importance to counteract the excessive influence of social networks, which today is more powerful than ever.

In addition, we could verify that our method propitiated the development of certain personal attitudes that seemed fundamental for the development of engineers for peace:
Enthusiasm, to be involved with passion and to include personal interests so as not to feel "divided" between academy, workplace and life.
O*pen mentality,* to listen to all parties, pay attention without prejudice, avoid arrogance and admit alternatives, face unconscious fears and avoid defensive attitudes.
Intellectual responsibility, to ensure the integrity, coherence and harmony of the conclusions reached and the implications that the developed ideas could have had.

ACKNOWLEDGMENT

The authors would like to acknowledge the financial support of Writing Lab, TecLabs, Tecnologico de Monterrey, Mexico, in the production of this work.

REFERENCES

[1] Mohr, Kathleen AJ. "Understanding generation Z students to promote a contemporary learning environment." *Journal on Empowering Teaching Excellence* 1.1 (2017): 9.

[2] Seemiller, Corey, and Meghan Grace. *Generation Z goes to college*. John Wiley & Sons, 2016.

[3] Wang, Shiang-Kwei, et al. "Professional development to enhance teachers' practices in using information and communication technologies (ICTs) as cognitive tools: Lessons learned from a design-based research study." *Computers & Education* 79 (2014): 101-115.

[4] Gardenfors, Peter, and Petter Johansson, eds. *Cognition, education, and communication technology*. Routledge, 2014.

[5] Ennis, Robert H. "Critical thinking assessment." *Theory into practice* 32.3 (1993): 179-186.

[6] Bensley, D. Alan, and Rachel A. Spero. "Improving critical thinking skills and metacognitive monitoring through direct infusion." *Thinking Skills and Creativity* 12 (2014): 55-68.

[7] Jonassen, David H. "What are cognitive tools?." *Cognitive tools for learning*. Springer, Berlin, Heidelberg, 1992. 1-6.

[8] Code of Ethics from IEEE Policies, Section 7.8 - Professional Activities. http://www.ieee.org/policies

[9] World Economic Forum. "The future of jobs: Employment, skills and workforce strategy for the fourth industrial revolution." *World Economic Forum*. 2016.

[10] Weiler, Angela. "Information-seeking behavior in generation Y students: Motivation, critical thinking, and learning theory." *The Journal of Academic Librarianship* 31.1 (2005): 46-53.

[11] Moore, William S. "My mind exploded: Intellectual development as a critical framework for understanding and assessing collaborative learning." *Washington Center for Improving the Quality of Undergraduate Education* 20.04 (1995).

[12] Bruner, Jerome. *Realidad mental y mundos posibles*. Vol. 19962001. Barcelona: Gedisa, 1988.

[13] Paul, Richard, and Linda Elder. *The miniature guide to critical thinking: Concepts & tools*. Foundation Critical Thinking, 2001.

[14] Kaufman, James C., and Robert J. Sternberg, eds. *The Cambridge handbook of creativity*. Cambridge University Press, 2010.

[15] Vygotski, Lev Semenovich, Alex Kozulin, and Pedro Tosaus Abadía. *Pensamiento y lenguaje*. Barcelona: Paidós, 1995.

[16] Littleton, Karen, and Neil Mercer. *Interthinking: Putting talk to work*. Routledge, 2013.

[17] Egan, Kieran, and Sánchez Barberán. *Mentes educadas: cultura, instrumentos cognitivos y formas de comprensión*. 2000.

[18] Argudín, Yolanda, and María Luna. *Aprender a pensar leyendo bien: habilidades de lectura a nivel superior*. 2000.

[19] VALUE Rubrics. Association of American Colleges & Universities. https://www.aacu.org/value-rubrics. Writer's Handbook. Mill Valley, CA: University Science, 1989.

[20] Cohen, Louis, and Lawrence Manion. *Método de investigación educativa*. No. 37.012. La Muralla,, 1990.

[21] Preston, Oliver. "A Modest Proposal." *LitCharts.* LitCharts LLC, 21 Nov 2016. Web. 29 Sep 2018.