Perspectives on the use of Serious-Storytelling for Creative Thinking Awareness in Engineering

Patricia Caratozzolo
School of Engineering
campus Santa Fe
Tecnologico de Monterrey
Ciudad de Mexico, Mexico
pcaratozzolo@tec.mx

Alvaro Alvarez-Delgado
School of Social Sciences
campus Santa Fe
Tecnologico de Monterrey
Ciudad de Mexico, Mexico
alvarez.delgado@tec.mx

Samira Hosseini
Writing Lab, TecLabs
Vicerrectoria de Investigacion y
Transferencia de Tecnologia
Monterrey, Mexico
samira.hosseini@tec.mx

***Abstract*— This Research-to-Practice Full Paper discusses the use of the Serious-Storytelling approach for enhancing soft skills that are decisive for the development of new job opportunities for young engineers. Multifarious international organizations, in their recent reports, emphasize the need to include new cognitive tools for developing the soft skills that Gen Z engineers need due, on the one hand, to the strong consolidation of social media, which shows an unexpected difference in the way recent graduates view the world and define themselves; and on the other hand, to the exponential development of the technology that was made accessible to them. Serious-Storytelling cognitive tools were adapted for the design of critical reading and critical writing co-curricular activities and were included as active learning experiences in different engineering programs. The research was conducted based upon a 4-group Solomon methodology with a quantitative design. To assess creative thinking competencies, different evaluation instruments were used for PreTests and PostTest, including several fluency and originality tests, as well as storytelling articulateness ability tests and modified VALUE rubrics of the Association of American Colleges and Universities (AAC&U). The obtained results showed that the designed Serious-Storytelling approach promoted a better understanding of scientific concepts in engineering subjects, a higher capability to develop rising demand skill sets and a stronger creative thinking competence awareness.**

***Keywords*—** *Creative thinking, Serious-Storytelling, Soft skills in engineering, Educational Innovation, Higher Education.*

I. INTRODUCTION

With the arrival of Generation Z students in higher education, the need to introduce innovative and effective ways to develop critical thinking and creativity in this unique cohort is greatly reinforced. Generation Z students arrive at college having varying levels of communication skills and narrative habits –including texting and short messages in social-network platforms - that weaken the force of their argumentations, hinder their vocabulary acquisition, and fail to contribute to the development of their soft skills.

Both, the Organisation for Economic Co-operation and Development, OECD, in its *Future of Education and Skills 2030* document [1], and the World Economic Forum, WEF, in its *Towards a Reskilling Revolution* report [2], emphasize the need to include new cognitive tools for the complete development of soft skills that Generation Z students. The use of cutting-edge technologies as a learning tool has always played a leading role in engineering programs, however, for Generation Z students, technological tools are not synonymous with learning, but having easy instant access to abundant information [3]. The fact that they do not have to wait to obtain information from search engines does not mean that they know how to critically evaluate that information and its sources or that they are able to analyze it systematically and methodologically. The triggering question that prompted the authors to work on the present study was: How to include creative thinking in an engineering design process including higher order logical components? The answer to this paradigm seems to be related to recognizing the value of art and imagination in the process of generating scientific knowledge.

The original idea of extending the STEM (Science, Technology, Engineering, Mathematics) approach to integrate art and design consisted of developing Science, Technology, Engineering, *Art* and Mathematics in STEAM projects [4,5]. The results obtained showed that STEAM approaches certainly promoted a better understanding of scientific concepts in engineering matters [6]. The authors decided to give a *turn of the screw* to the problem and we considered merging the STEAM approach with the Serious-Storytelling approach, in order to achieve the joint development of both soft skills required in engineering: critical thinking and creative thinking. Some recent studies that refer to the use of the Serious-Storytelling approach to improve soft skills -in students of various higher education programs- were reviewed and analyzed in the present work, with the aim of adapting best practices and findings to the engineering programs [7,8,9,10].

Our project consisted of an interdisciplinary approach that incorporated those Serious-Storytelling tools that effectively trigger the cognitive and metacognitive processes of learning in a mixed infusion/immersion environment included as active learning experiences in different engineering programs [11] and had the objectives of: *(i)* developing, in future engineers, the soft skills required by employers; *(ii)* promoting a better understanding of scientific concepts in engineering subjects; and, *(iii)* developing a higher capability of communicative skills and stronger creative thinking competence awareness.

II. THEORETICAL FRAMEWORK FOR CREATIVE THINKING

Two of the conclusions of the last January 2020 WEF Meeting in Davos were: In the next two years -by 2022- 42% of core skills required to perform existing jobs are expected to change [12]. Although it's important to provide students with the digital skills necessary for the Fourth Industrial Revolution, a very important critical characteristic in learning content and experiences will be to define high-quality learning in the Fourth Industrial Revolution, the so-called “Education

With the support of NOVUS Grant, 2019-2020, TecLabs, Tecnologico de Monterrey, Mexico.

4.0" Innovation and creativity skills: including that content that fosters skills required for innovation, complex problem-solving, analytical thinking, creativity and systems analysis.

Creative thinking does not occur automatically but is a process that depends not only on the cognitive effort but also on the metacognitive processing, which in turn depends on the developmental stage of the student. Because in the same classroom, students with different levels of cognitive development coexist, we considered two fundamental concepts derived from Vygotsky's work, *Scaffolding* and *Zone of Proximal Development (ZPD)* [13]. The *scaffolding* refers to the observed fact that when a teacher interacts with students with the intention of teaching, they tend to adapt the degree of help to the level of competence they perceive in themselves. The *ZPD* is the gap between the real development level of the students and the level of potential development that could occur with the teacher's guidance or the support of the classmates.

The present work was based on the importance of the development of those cognitive and metacognitive skills that enable the use of language, verbal expressiveness, higher-order thinking skills as necessary components to enhance creativity in the educational field. Regarding the conceptual framework, the study was based on the Jerome Bruner's *theory of cognitive functioning* and John Dewey's *theory of the development of the mind* [14,15]. These theories deal with the ability of students to find meaning in works of art and to develop new technological products by converting imaginative concepts into a believable reality, and with the need to create active learning experiences in all academic courses through the exercise of aesthetic activities and their assessments.

There are two modalities of cognitive functioning of thought, and each of them offers characteristic ways of constructing reality and ordering experience: The *logical-scientific modality* tries to fulfill the ideal of a mathematical, formal system of description and explanation. The *narrative-artistic modality*, on the other hand, looks for connections between two events and uses procedures to establish the likelihood, not the truth. 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 flexible critical thinking and creativity [16]. Although shifting from logical to narrative thinking has been unfairly suppressed in engineering programs, recently published evidence showed that this type of change is best suited to enable engineers overcome two of the most pernicious personality traits: *cognitive fixation* and *premature closure* [17].

Different studies demonstrate the strong influence that the socio-cultural environment of students can have on the ability to develop creative thinking [18]. Basically these studies reinforce the idea about the influence of the social on reflective thinking and the development of creative process. In the field of reflective thinking, it is very difficult to counteract people's natural tendency to generate incorrect thinking, especially among Generation Z students for whom excessive exposure to the massive and passive visual entertainment in their daily lives, causes a continuous stunting of their criticality abilities, inexorably spreading to all other aspects of their lives, including academics [19].

Generation Z students have idols -Market, Theater, Tribe and Cavern, according Bacon's model- which are particular and different from those expressed by previous Generation Y (Millennials). Because students are part of a learning group, it is that shifting mode ability should be considered part of the creative process. Therefore, to strengthen the development of this individual skill, we considered that each student is immersed in a *Creative Model* in the style proposed by Csikszentmihalyi [20]. For the practical application of this model in the present study, some considerations were made as shown in Table 1, where a possible interpretation of the relationships between the *Idols Model* and the *Creative Model* is also explained.

Table 1. Models comparison

Idols Model		***Creativity Model***
Cavern	each engineering student	*PERSON*
Tribe	teachers, instructors, jury contests, publishers of scientific publications, synod, advisors.	*DOMAIN*
Market	areas of cutting-edge knowledge such as virtual reality, augmented reality, artificial intelligence, IoT, automated vehicles, etc.	*FIELD*
Theater	current trends such as sustainability, climate change, energy efficiency, social networks, circular economy, transactional energy, etc.	

We also noticed that it is not enough to just unravel the internal mental process of the students but it is necessary to analyze the process in the context of the classroom and the academy, to understand how creative thinking can be enriched and what possible reluctances are interspersed in the flow path. The model developed in the present study is outlined in Figure 1.

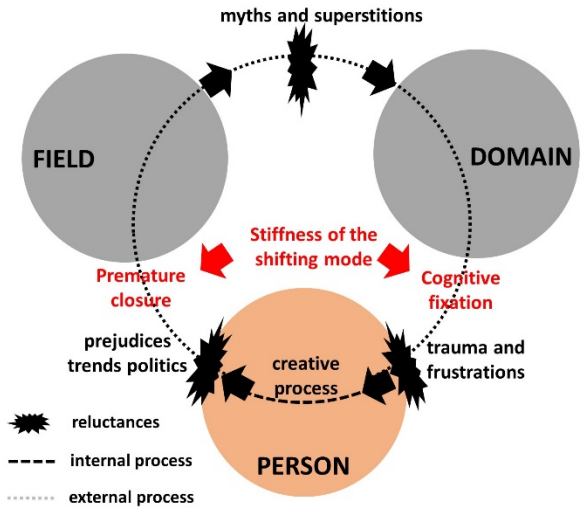

Fig. 1. Stiffness of the shifting mode

The model proposes that a person's creative process cannot be analyzed as if the individual were isolated but should be considered in relation to the environment in which he/she operates: that is, Person interacts with Domain and Field:

Field: It is what we usually call culture, a series of rules or symbolic knowledge shared by a particular society.

Person: who exercises a creative process and who wants to create a new Field or change it in order to show their ideas and products there.
Domain: which includes those individuals who act as gatekeepers who give access to the Field. Its function is to decide whether an idea or product of a Person should be included in the Field.

The scheme allows to distinguish the cognitive process, internal to the *Cavern;* the FLOW path, going from the Field to the Domain, and finally, the reluctances that any idea or new product must overcome to complete the creative process successfully. Two catalysts that students seem to require for the development of higher levels of creative potential are considered:

- Continuous exposure to diversified experiences helps to weaken the constraints (*Cognitive Fixation*) imposed by Domain.
- The experience of challenging experiences that help strengthen their ability to persevere in the face of obstacles (*Premature Closure*) that Field represents.

Creative thinking and the specificity of the domain [21]. An adaptation of the conceptual contribution of Ennis's on critical thinking was used considering that creative thinking, like critical thinking, is characterized by three principles:

- Background knowledge is essential for creative thinking in a given domain.
- Transfer of creative thinking between domains becomes possible when accompanied by an instruction for such transfer.
- Strong or even moderate specificity instruction is likely to be more effective than general creative thinking instructions in the form of subsequent add-ons.

Torrance framework [22]. Creativity is a complex and multivariate construct that involves not only cognitive but also perceptual and emotional processes. Any attempt to develop the creativity of a university student must be accompanied by the challenge of designing and obtaining valid instruments for its evaluation. Creative thinking refers to the production of:

- *Fluency*, or the production of a great and significative number of relevant ideas
- *Originality*, or the generation of unique, uncommon or unusual ideas in a given context
- *Flexibility*, or the incorporation of different perspectives and points of view and in different categories/spectra of thinking
- *Elaboration*, or the capacity to enhance the ideas by providing additional detail

It is very significant that creativity can be nurtured but cannot be directly measured. The only way to assess creativity is indirect through the assessment of those cognitive skills that are indicative of creative thinking. There are various theoretical models that explain the operationalization of the creative construct based on visual and verbal stimuli, and one of them is the famous Torrance Test of Creativity Thinking, TTCT, created in 1966. The TTCT is a tool that has been successfully applied in the last 50 years and even has multiple longitudinal studies that establish a high predictive validity.

It is important to note that we have not used the TTCT but we have designed the evaluation instruments used in this research based on it, since the characteristics developed by Torrance were ideal for the design of the experiences (*Treatment*) and our own evaluation tests (both *Pre-Tests* as *Post-Tests*) as it will be explained in the Assessment Tools Section.

III. SERIOUS-STORYTELLING TOOLS

Storytelling is considered a creative process *par* excellence and can be an ideal tool to strengthen resilience to ambiguity in engineering students, who are generally exposed to analytical thinking. That is why, for the design of the treatment to be applied in this study, specific Serious-Storytelling tools were considered to develop creative thinking and improve the ability to analyze and combine existing ideas and images through new disruptive and alternative solutions [23]. Serious-Storytelling's approach differs from non-academic storytelling in that it enables opinions and perspectives to be developed in contexts of scientific / technical application and uses narratives for a purpose beyond entertainment.

One of the best strategy for the incorporation of the activities -designed considering the actual cognitive stages of thinking of the students- was in the form of didactic interventions and an integrated infusion-immersion approach, by training in shifting mode of thinking experiences, carried on in ordinary courses of the engineering program [24]. Given that stories (understood as a chronological account of events) are a fundamental component of human memory and the basis for the most fundamental cognitive events, it is understandable that emotions and reflection are two of the fundamental aspects of storytelling. The addition of storytelling experiences to the learning process creates a personal relationship between the instructor and the audience and is also a powerful tool to engage students and form emotional connections to the topics under study. The essential components of storytelling can be divided into four elements:

Perspective. It is a subjective point of view and includes story features such as cognition and emotion.

Narrative. It is the actual content of the story and includes features such as *mimesis* and *diegesis*.

Interactivity. It is the essential interaction between the speaker and the audience and includes features such as engagement and decision.

Medium. It is the message and includes features such as content and forms.

Storytelling is also an ideal cognitive tool to include in Vygotsky's approach because it is based on active and collaborative learning and is produced through the knowledge and previous experience of students. The process of storytelling can be considered *mimesis* -artistic imitation- or visualization of real-world happenings, in a way that an engaged audience interacts with the narrative flow of a story and perceives the narrative as an emotional experience, in Dewey's theory style. In Serious-Storytelling systems, which are intended to be used as cognitive tools in the academic field, the notion of story progression is much more complex than in entertainment media, and can be said to be an abstract

artifact that makes let the story progress, instead of the characters, events, or a cause-effect relationship.

With respect to the academic framework, it is essential to understand that serious stories can be entertaining and fun, but their primary purpose is knowledge and value creation for a serious context matter [8]. In the case of Serious-Storytelling, the four components must be understood in such a way that the following features are achieved:

- Provision of real-world understanding
- Self-reflective and introspective context
- Intrinsic motivation
- Relation to a matter of importance, experience, knowledge and understanding
- Self-empowerment and personal advancement

IV. METHODOLOGY

Design. The design chosen for the project was the Experimental Research, Quantitative, 4-group Solomon type, as in Table 1.

TABLE 1. Solomon 4-group design

R	O1	X	O2
R	O3		O4
R		X	O5
R			O6

O indicates the measurement of the dependent variable before (O1) or after (O2) the treatment. X indicates the treatment or independent variable, while R indicates that the groups were chosen randomly. It is intended to control the possible interaction that may exist between the Pre-Test and the Treatment. This design will allow the results to be generalized also for the subjects who didn't receive the PreTest. The measurement of the dependent variable in the Pre-Test situation is done at the same time in the two groups, and the measurement of the dependent variable in the Post-Test situation is done at the same time in each semester. The assignment of the subjects to the groups is done randomly. Two of the three groups that will be used as Treatment groups (R O1 X O2) and of control with Pre-Test (R O3 ... O4) will be taken at random too. The third group will be taken as a Treatment group without Pre-Test (R ... ... O5). One group will be taken as a Treatment group (R O1 X O2), another group will be taken as a Treatment group without Pre-Test (R ... ... O5) and a third group as a control group without pre-test (R ... O6).

Group criteria:
EG-PreT-T: Experimental Group with *PreTest* and *Treatment*
EG-T: Experimental Group without *PreTest*, only *Treatment*
CG-PreT: Control Group with *PreTest*
CG: Control Group without *PreTest*

Participants. A total of ten different groups were involved over seven semesters (S1 to S7), from January 2016 to June 2019, as shown in Table 2. The research was conducted with a quantitative design and a sample of 182 undergraduate students of two engineering programs. Participants joined the study voluntarily and 119 of them underwent cognitive and metacognitive instruction for six semesters (experimental group, EG), while 63 students remained untrained (control group, CG). Participants who contributed to this study had an average age of 22 years by the end of the study, and were distributed in six different courses (the official ID of each course appears in parentheses) taught by the first author, as follows:

In the B.S Mechatronics Engineering program:
Applied Electronics (TE2033), and Actuators (MR2003).
In the B.S. Sustainable Development Engineering program: Capstone Project for Sustainable Development (DS2005), Energy Generation Systems (M2005), Energy Distribution Systems (TE3053), and Technologies for the Efficient use of Electricity (TE2042).

TABLE 2. Methodological data used in this study.

Group Type	Total sample	# group	Students per course	Course & Semester IDs
EG-PreTest-T	76	1	16	TE3053-S4
		2	20	DS2005-S5
		3	22	M2005-S3
		4	18	TE2042-S7
CG-PreTest	27	5	27	TE3053-S7
EG-T	43	6	8	TE2042-S1
		7	9	TE2042-S2
		8	26	TE2033-S7
CG	36	9	14	MR2003-S3
		10	22	TE3053-S6
	182			

Procedure. The research methodology of the study was quantitative-experimental to establish a correlation between groups of variables. 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 methodological design is schematically illustrated in Figure 2.

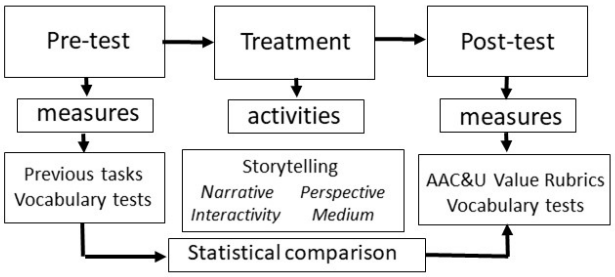

Fig. 2. Procedure design.

Instruments for data collection.
PreTest: Vocabulary tests, designed to establish the approximate lexicon of each student, compared to the Corpus of Contemporary American English, COCA, that contains 60,000 ranked words [25]; Creativity scale self-reports and lateral thinking ability checklists.

Treatment: Shifting mode activities and art experiences, sets of questions *based on* Figural & Verbal forms of the Torrance TTCT test, writing of essays.

PostTest: Fluency and Originality tests, and Rubrics *based on* the VALUE Rubric (Valid Assessment of Learning in Undergraduate Education Rubric) of the Association of American Colleges and Universities, AAC&U [26].

V. Assessment Tools

The use of cognitive tools for the development of the abilities of creative thinking must be complemented with the application of metacognitive tools in order to also influence the development of specific dispositions of temperament, that is, the exercise of reflection skills in engineering students [27]. The research hypothesis was that interdisciplinary incorporation of Serious-Storytelling-based activities for the development of creative thinking leads to the enhancement of the engineering students' intellectual engagement, intercultural knowledge and core soft skills required in the labor market. The desired abilities considered were [28]:

- The capacity to combine or synthesize existing ideas, images, or expertise in original ways
- The experience of thinking, reacting, and working in an imaginative way
- A high degree of innovation, divergent thinking, and risk taking

Previous studies carried out by the authors on the topic of storytelling showed that the inclusion of artistic spaces for reflection are also very appropriate to question the concept of utilitarianism and functionality in design, which prevails in spaces for scientific reflection [29]. The advantage of working with artistic spaces is that the fine art artifact is considered a non-utilitarian aesthetic object and has no functional purpose except to be intervened and to awaken in young people unexpected kinds of aesthetic judgments in addition to strengthen their curiosity, imagination and the formation of personal opinion.

For the proper development of the activities in the Serious-Storytelling framework, the creative experiences were selected in a way that allows observing whether students effectively develop creative thinking through the verification of compliance with four performance criteria that were included in the VALUE Rubric of Table 3; namely, a) Attentiveness towards different situations; b) Competencies acquisition (reflect, create, adapt or model); c) Perspective-taking, and d) Knowledge of cultural worldview frameworks. The cognitive tool chosen to develop the creativity *Elaboration* feature was related to expanding the background of meanings ready to be used in later intellectual enterprises.

All the PreTests were designed in such a way that the student could transfer as many words as possible from his/her passive language to his/her active language [30]. We considered understanding as *Active Language,* AL, that which is formed by the words that are used daily; and as *Passive Language,* PL, that which is formed by words that are understood when they are heard or read in context.

Language relates and organizes meanings at the same time that it selects and fixes them. Since meaning is inserted in the context of a situation and every word belongs to a statement, we can say that a statement is part of a narrative, description or process of higher reasoning. Bearing this in mind, we consider that it was particularly important to include in our project the exercise and practice of continuity and the ordering of meanings, which is what finally gives coherence to a discourse, whether oral or written. In our research, we found that the habits of sporadic and fragmentary discourse promoted by social networks exert a disintegrating intellectual influence. Language has the characteristic of being organized into levels, each of which provides constituents for the next higher level. Each level has its own order, but that order is controlled and modified by the level superior to it, so the structure of the language goes from the sounds of speech to the intentions of the speech and discourse. When formulating a certain expression, we select words and combine them depending upon the use we want to give to a statement. Selection and combination are the two most primitive acts of language. In the *selection*, the requirement to preserve or modify the meaning by substitution of words or expressions prevails. The rule of substitution should transcend the simple synonymy (to keep the reference as literal as possible) and even reach the metaphor (to create a climate change).

The vocabulary tests consist in proposing to the students the reading of short essays -high quality lexical texts- written by specialists, renowned writers and university professors. The selected texts contained less than 200 words. A list of words from each text was created, corresponding to the least frequently used 6%, and two different types of tests were designed to determine, respectively, whether or not the student can explain the meaning of the words (open response) and whether or not the student can distinguish the meaning of the word in a context. This was done with a multiple-choice question containing a stem that identifies the word, a set of four possible word definitions that contains a key that is the correct answer to the question, and three distractors that are plausible but incorrect.

VI. Example of Co-Curricular Activities

The paradox underlies all creative forces. The removal of the paradox creates balance, and balance would mean boredom and languor. Starting from the premise that paradox is what drives creativity and complexity, we can use that self-awareness to create a new type of storytelling. The *Higher-Order Thought*, *HOT*, theory of consciousness has been shown to provide satisfying explanations of the subjective experiences involved in a variety of personality traits, including *Cognitive Fixation* and *Premature Closure* [31].

A paradox is not a contradiction: If something is paradoxical, it has two apparently opposite characteristics that are expressed at the same time. The experience designed in this study consisted of providing the images, sounds, metaphors and relies on the role of listener-reader-spectator of the student, to make connections, fill in the gaps and do the hard work of stimulating thought and creativity.

The work of art should not have to explain anything, but, on the contrary, it is the listener-reader-spectator who should have the ability to read or see it or listen to it and get something out of it: a paradoxical story in a narrative. This is the balance between simplicity and complexity -creative tension- which has its greatest expression in the arts but should be able to be brought into the realms of design and complex engineering problem solving. The conscious paradox, which can be developed with serious storytelling, can then be applied in solving specific engineering issues.

The infusion-immersion approach used in this study considered the incorporation of artistic experiences -Art in STEAM- with a flexible agenda of 6 interventions per semester in the classroom (approximately 15 minutes each) in conjunction with the performance of activities outside the classroom that the students did individually (approximately 2 hours each).

TABLE 3. Example of the Rubric used as PostTest. (*This rubric was created using the Association of American Colleges and Universities (AAC&U) VALUE Rubrics) [26]*.

	Capstone 4	Milestones 3	2	Benchmark 1
Attentiveness towards different situations	Interprets intercultural experience from the perspectives of self and more than one worldview and demonstrates the ability to act in a supportive manner that recognizes the feelings of another cultural group.	Recognizes intellectual and emotional dimensions of more than one worldview and sometimes uses more than one worldview in interactions.	Identifies components of other cultural perspectives but responds in all situations with their own worldview.	Views the experience of others but does so through their own cultural worldview.
Acquiring competencies	Reflect: Evaluates creative process and product using domain-appropriate criteria.	Create: Creates an entirely new object, solution or idea that is appropriate to the domain.	Adapt: Successfully adapts an appropriate exemplar to his/her own specifications.	Model: Successfully reproduces an appropriate exemplar.
Perspective-taking	Evaluates and applies diverse perspectives to complex subjects within natural and human systems in the face of multiple and even conflicting cultural positions.	Synthesizes other perspectives (such as cultural, disciplinary, and ethical) when investigating subjects within natural and human systems.	Identifies and explains multiple perspectives (such as cultural, disciplinary, and ethical) when exploring subjects within natural and human systems.	Identifies multiple perspectives while maintaining a value preference for their own cultural positioning.
Knowledge of cultural worldview frameworks	Demonstrates sophisticated understanding of the complexity of elements important to members of another culture in relation to its history, values, or beliefs.	Demonstrates adequate understanding of the complexity of elements important to members of another culture in relation to its history, values, or beliefs.	Demonstrates partial understanding of the complexity of elements important to members of another culture in relation to its history, values, or beliefs.	Demonstrates surface understanding of the complexity of elements important to members of another culture in relation to its history, values, or beliefs.

Title of the Series of Activities: *The conscious paradox of storytelling with paintings*

The fifteen different images and illustrations used during our study were images of works by famous painters and artists. The experiences allowed students to get to know the work of great artists (not only painters but also photographers, sculptors, plastic artists, designers and architects) from different artistic movements and to write their own stories and anecdotes from their hobbies using the style of contemporary critics of art. With these images, a critical interpretation was made and analyzed using the answers of the students to five sets of questions (*based on* the components of Verbal TTCT [22]):

Five kind of questions	Asking questions about the picture
	Guessing causes of the action in the picture
	Guessing consequences immediate or long-term about the picture
	Just suppose hypotheses about on improbable situation
	Propose an improvement of the *denouement* that defies the natural tendency towards a premature closure

The designed Sets of Question seek to develop in students not only three of the 5norm-ref but also two traits of criterion-ref (*based on* the components of Figural TTCT [22]):

Three qualities of divergent thinking	Fluency
	Originality
	Elaboration
Two traits of creative strengths	Resistance to premature closure
	Ability to avoid cognitive fixation

This way of designing the Treatment allowed, firstly, to incorporate in a holistic way the concepts of Scaffolding and Zone of Proximal Development; and secondly, to offer students the essential spaces (combination of synchronous and asynchronous activities) to develop their own internal process "Person" interacting with the "Field" and the "Domain", as explained in the Framework Section of Theoretical Work in Creative Thinking.

Example of image. "Never morning wore to evening, but some heart did break" work painted by the English artist Walter Langley, in 1894 [32]. The title refers to some verses from a Lord Tennyson's poem:

> *That loss is common would not make*
> *My own less bitter, rather more:*
> *Too common! Never morning wore*
> *To evening, but some heart did break…*

Some of the questions posed to the students in the session were:

Give this image a title and tell what the story might be if the young woman were the protagonist.
If this scene were from a movie about a dystopian future, what do you think the situation would be?
Who are you in history?
Why are you there watching the scene?
What are your feelings to be there at that moment?
Without looking at the image (from what you remember) imagine that a year after seeing the women, you tell someone about the event and its long-term consequences.
How else would you tell the story if you had to lie about what happened?
Invent an alternative story, about what happens on the scene, where none of the women is the main protagonist.

Preliminary activity (infusion-immersion approach). All students were asked to read literary reviews and blogs on artistic appreciation from electronics magazines and museums; In addition, links to highly regarded pages were provided for them to take virtual tours, read essays of aesthetic judgments and watch video essays, all with the aim of soaking up the storytelling style, increasing their lexicon corpus and learning more about artistic concerns and social of the time and the country in which the suggested artists lived.

Example of review essay. "This Is This: The Manifold Masculinity of Michael Cimino's 'The Deer Hunter'. Review essay written by Jeremy Carr. Professor Carr teaches film studies at Arizona State University and writes for different publications as Cineaste, Senses of Cinema, Vague Visages, The Moving Image and Fandor [33]. A detailed study of the results of a vocabulary test based on the text of prof. Carr was included in the Findings and Results section.

Divergent thinking activity. Students were asked to search the Internet for information about the authors and their work. A discussion session was held where the students established a personal relationship with some of the pictures and some of the works. The group was divided into teams of 4 participants, and there was a role-play activity in which each team member was characterized as a friend or colleague of the author. The students recorded short interviews (with their cell phones) of the type that would be included in a video essay about the authors and their work.

Convergent thinking activity. Each student chose a work relating it to some experience of their own and then wrote a short story (using the style of art critics) based on the image. Students recounted this in a final session where each narrator shared their experience while projecting the chosen image.

VII. Findings and Results

In order to verify that the students of the experimental group and the control group had similar initial conditions of the lexicon, the results of the vocabulary PreTest in both groups were compared. The initial comparison between 182 students (119 students of the EG-PreT-T and 63 of the CG-PreT) where the PreTests were applied revealed no significant differences in their vocabulary background. However, the PostTest comparison of the vocabulary scores revealed that the EG-PreT-T group showed significantly higher improvement than the CG-PreT.

The PostTests on critical thinking, creative thinking and Intercultural Knowledge using AAC&U rubrics showed that the experimental group attained 37% improvement in comparison with the students of the control group in the upper "Capstone" level and a 35% decrement in the number of students who remained at the lowest "Benchmark" level of the rubric. These results are shown in Table 4.

TABLE 4. AAC&U Rubrics distribution for EG and CG

	Value Rubrics			
Groups	Capstone 4	Milestones 3	2	Benchmark 1
EG	22 %	35 %	23 %	20 %
CG	16 %	18 %	35 %	31 %
	+ 37 %	+ 94 %	- 34 %	**- 35 %**

Regarding the analysis of the distributions of the students according to the results obtained in the Post-Test, it could be observed that the shapes of the Gaussian bells had in the case of the Experimental group (EG) a left skewness and in the case of the Control Group (CG) a right skewness, as shown in the graphs of Figure 3.

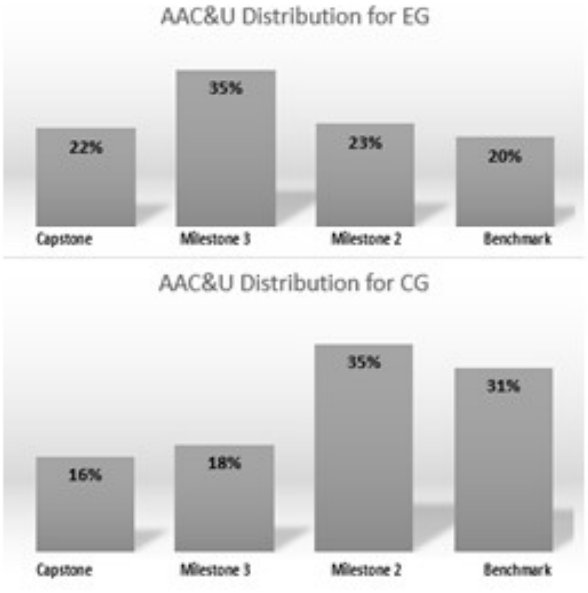

Fig. 3. AAC&U Distributions

Example of results of Post-Test. Table 5 shows ten words chosen in an example of vocabulary test (that corresponds to the essay presented in the previous section). In the first two columns ten selected words from the original essay are shown, along with the respective rank in the COCA.We consider a Position of Sentence (PoS) percentage to make the lists with nouns (N), verbs (V), adjectives (J) and adverbs (R).

TABLE 5. Comparison between the language from an essay and from student's essays

		Selected Essay Text [30]		Synonym chosen by the student	
#	PoS	word	Rank [25]	word	Rank [25]
1	N	**barbarity**	31,872	**brutality**	8,787
2	J	**fused**	30,451	**stuck**	9,703
3	N	**belligerence**	29,960	**aggression**	4,562
4	J	**manifold**	22,935	**diverse**	2,830
5	J	**sweltering**	19,303	**hot**	721
6	R	**perpetually**	13,516	**forever**	2,093
7	J	**majestic**	10,793	**magnificent**	5,556
8	V	**adhere**	6,609	**obey**	5,742
9	R	**profoundly**	6,577	**strongly**	2,398
10	V	**forge**	5,364	**build**	408

The last two columns show a selection of the words most chosen by students in their own essays. A succinct comparison allows to appreciate:

-For very high rank words (> 30,000), In the case of **barbarity** and **fused**, when students were required to describe the same image but using their own words, they chose the synonyms **brutality** and **stuck** on a lower rank: less than 10,000.

-For three of the words (**manifold**, **perpetually** and **profoundly**) the students chose synonyms for ranks between 2,000 and 3,000 (**diverse**, **forever** and **strongly**).

-For two of the words (**sweltering** and **forge**) the students chose synonyms of even less than the 1,000 rank (**hot** and **build**), which would correspond more to the spoken language than to the written one.

The PostTest showed that in the control group only 9% of the students had a real vocabulary mastery of the corpus with a rank greater than 20,000. This proportion rose to 22% in the case of students in the experimental group. Regarding the use of vocabulary in the lowest level of the range (less than 10,000), the control group showed that 32% of the students managed with written language in that range, while in the experimental group, this percentage was reduced at 25%.

Findings. The convergent stage of the activity present in the technique of Serious-Storytelling is the one that allows the assessment of the different performance criteria of the rubric; they were chosen based on three qualities of divergent thinking and two traits of creative strengths. It is noteworthy that it would not have been possible to apply a VALUE Rubric or obtain a correlation between the results of the PreTest and the PostTest if the activity had been limited only to entertainment storytelling.

The vocabulary tests identified the structural deficiencies in the reading and writing skills of engineering students that results in a lower level of disruptive reasoning and creative thinking. It has been possible to identify the teaching and learning strategies that encourage the development of effective communication skills in the students. Also, it has been possible to design specific, didactic activities for areas such as Mathematics, Physics, Sciences, Electronics and Computer Technologies that encourage the development of these skills across the engineering curricula.

Discussion on the creative thinking assessment: The rubrics were used with the intention of evaluating and discussing learning related to the students' interdisciplinary skills, not the grading. These rubrics allowed positioning the learning within a basic framework of expectations.

Discussion on the inclusion of Serious-Storytelling in engineering courses: The incorporation of artistic activities, such as those presented in this study, to develop soft skills in engineering courses is a proposal of educational innovation in response to compliance with the requirements of employers and accreditation agencies. This concept responds to the growing need to achieve integrated thinking in engineers. It is suggested that the incorporation of storytelling activities into the curricular courses be carried out by trained instructors and follow a sequential taxonomy of the type: creating, inventing, innovating, engineering, and controlling. It is precisely in the first two stages of the process (creating and inventing) where the development of artistic activities could help to free the modality of narrative thinking explained in previous sections.

Discussion about the language used to evaluate results: Because the project is based on the use of metacognitive Serious-Storytelling tools in students whose mother tongue is Spanish, all the assessment instruments were designed in that language.

VIII. Conclusions

As OECD and WEF have pointed, it is absolutely necessary, and even urgent, involve and instill engineering students in the development of soft skills, since 21st century engineers must be creative and critical enough to build values and judgments and even solve ill-defined problems to understand and remember conceptual information. The results of our study showed that Serious-Storytelling could be an effective cognitive tool to acquire creative thinking, that fosters the abilities and dispositions of temperament that are required by employers. Given the triggering question, regarding how to insert creative thinking in engineering, our proposal to use art and imagination (via the visual arts and the essay, in the activities presented in this study), is a viable option, since the students themselves recognize (in both academic course and training exit surveys) a significant increase in their communication abilities, language skills, as well as in cognitive and emotional empathy. Additionally, we could verify that our method propitiated the development of specific personal attitudes necessary for the future engineers of Generation Z: attentiveness towards different situations (empathy) and knowledge of global cultural frameworks (intercultural competence).

Acknowledgments

The authors would like to acknowledge the financial and the technical support of Writing Lab, TecLabs, Tecnologico de Monterrey, in the production of this work. The authors would like to acknowledge the financial support of Novus Grant with PEP no. PHHT090-19ZZ00008, TecLabs, Tecnologico de Monterrey, in the production of this work. The authors would like to acknowledge the students of the courses DS3005, M2003, MR2003, TE2033, TE2042 and TE3053, that so kindly and selflessly participated in this study.

REFERENCES

[1] Howells, K. "The future of education and skills: education 2030: the future we want.", 2018.

[2] World Economic Forum Boston Consulting Group (BCG). "Towards a reskilling revolution: a future of jobs for all." World Economic Forum, Geneva, Switzerland, 2018.

[3] Seemiller, C. and Grace, M. Generation Z goes to college. John Wiley & Sons; 2016.

[4] Yakman, G. Recognizing the "A" in STEAM Education. *Middle Ground*, *16*(1), 2012. p.15.

[5] Watson, A. D., & Watson, G. H. Transitioning STEM to STEAM: Reformation of engineering education. *Journal for Quality and Participation*, *36*(3), 2013. pp 1-5.

[6] Hayes, J. R. Cognitive processes in creativity. In *Handbook of creativity*. Springer, Boston, 1989, pp. 135-145.

[7] Nishioka, H. Analysing language development in a collaborative digital storytelling project: Sociocultural perspectives. *System*, *62*, 2016, pp. 39-52.

[8] Lugmayr, A., Sutinen, E., Suhonen, J., Sedano, C. I., Hlavacs, H., & Montero, C. S. Serious storytelling, a first definition and review. *Multimedia tools and applications*, *76*(14), 2017, pp. 15707-15733.

[9] Mistry, A. The art of storytelling: Cognition and action through stories. *International Journal of Arts & Sciences*, *9*(4), 2017, pp. 301.

[10] Helmut, H., & Moser, A. Story Templates, Serious-Storytelling to Support Learning. In *2018 IEEE 18th International Conference on Advanced Learning Technologies (ICALT), 2018,* pp. 405-407.

[11] Bensley, D. A., & Spero, R. A. Improving critical thinking skills and metacognitive monitoring through direct infusion. *Thinking Skills and Creativity*, *12*, 2014, pp. 55-68.

[12] World Economic Forum Boston Consulting Group (BCG). " Jobs of Tomorrow: Mapping Opportunity in the New Economy." World Economic Forum, Geneva, Switzerland, 2020.

[13] Vygotsky, L.S. Thought and language. MIT press; 2012.

[14] Bruner, J. S. Actual minds, possible worlds. Harvard University Press; 2009.

[15] Dewey, J. How we think: A restatement of the relation of reflective thinking to the educational process. *Lexington, MA: Heath*, *35*(64), 1933, pp. 690-698.

[16] Caratozzolo, Patricia, Alvaro Alvarez-Delgado, and Samira Hosseini. "Strengthening critical thinking in engineering students." *International Journal on Interactive Design and Manufacturing (IJIDeM)* 13, no. 3 (2019): 995-1012.

[17] McKay, A. and Karwowski, M. and Kaufman, J.C. "Measuring the muses: validating the Kaufman domains of creativity scale (K-DOCS)." *Psychology of Aesthetics, Creativity, and the Arts* 11, no. 2: 216, 2017.

[18] Simonton, D.K. Creativity: Cognitive, personal, developmental, and social aspects. *American psychologist*, *55*(1), 151, 2000.

[19] Caratozzolo, Patricia, and Álvaro Álvarez. "A new transdisciplinary approach to foster soft skills in Engineering: Using Critical Reading Micro-Workshops." In *2018 World Engineering Education Forum-Global Engineering Deans Council (WEEF-GEDC)*, pp. 1-6. IEEE, 2018.

[20] Csikszentmihalyi, M. *Flow and the psychology of discovery and invention*. New York: Harper Collins, 1996. Vol. 56, pp. 107.

[21] Ennis, R.H.. "Critical thinking and subject specificity: Clarification and needed research." *Educational researcher* 18.3, 1989, pp. 4-10.

[22] Kim, Kyung Hee. Can we trust creativity tests? A review of the Torrance Tests of Creative Thinking (TTCT). *Creativity research journal*, 2006, vol. 18, no 1, pp. 3-14.

[23] Pringle, A., Sowden, P.T., Deeley, C., and Sharma, S. Shifting between modes of thought: a domain-general creative thinking skill?. In *2016 KIE International Conference on Knowledge, Innovation and Enterprise, Berlin, Germany*, 2016, pp. 220-259.

[24] Caratozzolo, Patricia, Alvaro Alvarez-Delgado, and Samira Hosseini. "Fostering specific dispositions of Critical Thinking for student engagement in engineering." In *2019 IEEE Global Engineering Education Conference (EDUCON)*, pp. 221-226. IEEE, 2019.

[25] Corpus of Contemporary American English. COCA. https://corpus.byu.edu/coca/. Accessed 31 March 2020.

[26] Rhodes, T. *Assessing Outcomes and Improving Achievement: Tips and Tools for Using Rubrics*. Washington, DC: Association of American Colleges and Universities. 2014.

[27] Rawat, K. J., Qazi, W., and Hamid, S. Creativity and education. *Academic Research International*, 2012. *2*(2), p. 264.

[28] Allen, M. J. "Using Rubrics to Grade, Assess, and Improve Student Learning." *Strengthening Our Roots: Quality, Opportunity & Success Professional Development Day*, 2014. pp. 34-35.

[29] Caratozzolo, Patricia, Alvaro Alvarez-Delgado, and Samira Hosseini. "Metacognitive Awareness and Creative Thinking: the capacity to cope with uncertainty in engineering." In *2020 IEEE Global Engineering Education Conference (EDUCON)*, pp. 638-643. IEEE, 2020.

[30] Kurland D.: How the Language Really Works: The Fundamentals of Critical Reading and Effective Writing. http://www.criticalreading.com/critical_reading_thinking.htm Accessed March 2020

[31] Gennaro, R.. The consciousness paradox. *Consciousness, Concepts, and Higher-Order Thoughts, Cambridge*. 2012.

[32] Langley,W. "Never morning wore to evening, but some heart did break". https://artuk.org/discover/artworks/never-morning-wore-to-evening-but-some-heart-did-break-33805/search/keyword:never-morning-wore-to-evening-but-some-heart-did-break-3075841 Accessed April 2020

[33] Carr, J. This is this: The manifold masculinity of Michael Cimino's "The Deer Hunter". https://vaguevisages.com Accessed March 2020