Fostering Digital Literacy through Active Learning in Engineering Education

Patricia Caratozzolo
Tecnologico de Monterrey
Ciudad de Mexico, Mexico
pcaratozzolo@tec.mx

Alvaro Alvarez-Delgado
Tecnologico de Monterrey
Ciudad de Mexico, Mexico
alvarez.delgado@tec.mx

Gabriela Sirkis
Universidad del CEMA
Buenos Aires, Argentina
gsirkis@ucema.edu.ar

***Abstract*— This Research-to-Practice Full Paper discusses the use of the active learning approach to enhance the 21st century skills that are critical to developing new job opportunities for young engineers. The soft skills required in the Fourth Industrial Revolution make the traditional mode of logical-scientific thinking insufficient for the degree of innovation and disruption required in future jobs. In the field of higher engineering education, the situation was doubly challenging: Generation Z students' cognitive skills had to be improved in terms of digital literacy and cutting-edge technological tools had to be quickly incorporated. This work is a study on the effectiveness of the didactic approach of Active Learning in STEAM (Science, Technology, Engineering, Art and Mathematics) and the innovative ways of empowering students to develop digital literacy skills, among them: photo-visual ability, reproduction ability, branching ability, real-time critical thinking ability and, the most important of this study, socio-emotional ability. The opportunities and challenges that the study addressed were related to accessibility, inclusion, and self-paced learning. The research was carried out with a mixed experimental methodology in a sample of 352 engineering students, who were evaluated with different types of instruments to know the level of acquisition of soft skills related to digital literacy. To evaluate these skills, different assessing instruments were used for pre-tests and post-tests, including: vocabulary level, lateral thinking ability, fluency and originality; as well as story-articulation skill tests and modified VALUE rubrics from the Association of American Colleges and Universities (AAC&U). The results obtained showed that the active learning approach promoted a better understanding of scientific concepts in engineering subjects, a greater ability to develop digital communication skills, and a greater awareness of creative thinking skill.**

Keywords—Educational innovation, higher education, soft skills in engineering, Education 4.0, STEAM.

I. Introduction

Strategies that promote active learning are those that not only encourage students to creatively construct knowledge and understanding but also to think critically about what they are doing. This approach is mainly focused on the development of students' abilities and therefore requires that the teaching-learning process flow in a complex cognitive taxonomy that supports a higher-order thinking modality. The advent of the Fourth Industrial Revolution, 4IR, and its educational expression, Education 4.0, implied the incorporation of some characteristics that allowed students to also develop high levels of dexterity in the use of cutting-edge technological tools [1].

The academy was strengthened in the 2018-2019 period with numerous publications that developed theoretical frameworks and adapted cognitive theories to the implementation of Education 4.0 to in- person teaching environments, social coexistence on university campuses, professional practice in industries and companies and finally the international experience of students with various agreements to study abroad. With the arrival of the COVID-19 crisis and the restrictions on domestic and international mobility, quarantines, curfews and social distancing, all higher-level educational institutions (HEI) had to adapt their teaching platforms so that all courses of its programs will transform to a fully online mode (synchronous or asynchronous) and then to a flexible blended mode, depending on the situation of the pandemic in each country [2].

The very state of maturity of the 4IR at the beginning of 2020 (thanks to the educational plans towards 2030) made many technological tools available almost immediately and that meant that many institutions did not require too much preparation to continue with their courses, except for the purchase of educational platforms, the adaptation of subject syllabi and the training of teachers and students. However, the biggest challenge in those months has been and continues to be how to incorporate technological tools correctly in virtual environments to fulfill the characteristics of the active learning approach [3] .

The authors worked on this study, for three years, with Generation Z engineering students, with the objective of redesigning the teaching-learning process with an approach based on the Anderson & Krathwohl Taxonomy of Learning [4]. Since the first semester of 2020 and, due to the COVID-19 crisis, some adjustments were added to the approach: *(i)* the courses were completely online; *(ii)* andragogic didactics allowed the development of soft skills from the theoretical framework of Education 4.0; *(iii)* virtual and technological

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tools - dosed and responsibly - were incorporated as enablers of metacognitive awareness.

II. Theoretical Framework

It is particularly significant that recent studies of higher education emphasize the need for instructors and students to develop a wide range of cognitive, social and emotional competencies, called 21st Century Skills [5]. These competencies make up a modern form of literacy, the digital literacy, which is critical for training, learning, upskilling and reskilling with digital technologies in today's virtual education environments.

Education in the Fourth Industrial Revolution can be identified with four skills and four learning characteristics of high-quality learning, the Education 4.0 Framework [6], as shown in Table 1.

TABLE 1. Skills and learning characteristics of the Education 4.0 Framework

Learning Skills
Global citizenship Innovation and creativity Technology Interpersonal
Learning Characteristics
Personalized and self-paced Accessible and inclusive Collaborative Student-driven

The original idea of extending the STEM approach to integrate socio-emotional skills was to develop science, technology, engineering, art and mathematics in STEAM projects [7][8]. Recent studies have shown that STEAM approaches certainly promote a better understanding of scientific concepts in engineering [9][10]. A graphical way of understanding creativity in criticality process is to imagine it as a three-dimensional space, a kind of multi-level tiered yard: in one direction are the stages of the Cognitive Process Dimension, which consists of the six levels of the Bloom's Taxonomy (Remember, Understand, Apply, Analyze, Evaluate and Create); in the other direction are the stages of the Knowledge Dimension, which consists of the four levels of the Anderson & Krathwohl's (A&K) two-dimensional Taxonomy (Factual, Conceptual, Procedural and Metacognitive) [11]. Figure 1 shows an interpretation of this tiered yard where joint progress in both dimensions means not only a cognitive effort but also intrinsic motivation and intellectual engagement to be able to climb each terrace and reach the upper levels in both dimensions. The sketch is based on the model created by Rex Heer [12].

Education 4.0 is changing the way today's young students will live, work and interact during their careers in the future, therefore, technological advances should act as enablers in the reinterpretation of cognitive theories and teaching techniques for the development of criticality [13].

Our challenge as educators is how to employ innovative, virtual and technological tools that boost creativity and challenge students to solve complex problems using unexpected solutions; appealing to the extensive use of their digital literacy skills, briefly explained in Table 2.

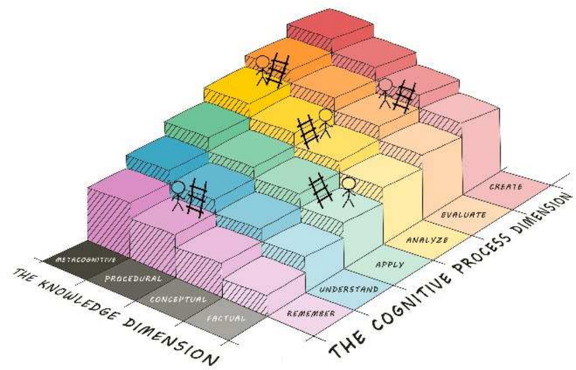

Figure 1. The multi-level tiered yard model for A&K's Taxonomy.

There is a difference between teaching students to have information at their disposal, commonly called the Knowing-That, in face-to-face environments, and teaching them to discover what to do with that information, called the Knowing-How, in fully online environments, to reach reasonable and justified conclusions [11]. The continuous exercise on the metacognitive vector of the tiered yard is what facilitates the students the ability to reason critically. Therefore, this model is opposed to the traditional approach of advancing only in the first three vectors of the dimension of knowledge (Factual-Conceptual-Procedural) towards the highest stages of Bloom's Taxonomy, which is known as domain specificity of subjects [12].

TABLE 2. Digital Literacy Skills and their Inherent dispositions.

Photo-visual
To be able to "read" and understand instructions and messages that are presented in a visual-graphical form.
Reproduction
To be able to create new meanings and interpretations by combining preexisting fragments of information in any form of media including text, graphics and even sounds.
Branching
To be able to have a good spatial-multidimensional sense of orientation while navigating hyperspace seeking information to construct knowledge.
Information
To be able to assess information effectively, by sorting out subjective, biased or even false information.
Socio-emotional
To be able to share emotions in digital communication, to identify deception in chat rooms, to have a mature self-awareness in virtual collaboration teams.
Real-time
To be able to effectively process simultaneous stimuli executing different tasks and rapidly change the angle of view and perspective of the environment.

Active Learning (AL) is an approach to andragogy that has been successfully incorporated into engineering curricula because it engages students with leadership and commitment by creating personalized experiences in the learning process of each subject of study [14] . The present study had the specific objective of designing these experiences to attract the interest of students in giving a practical meaning to education, through the development of the following transversal competences: leadership and social influence; Emotional intelligence; Reasoning, problem solving and ideation; and Analysis and evaluation of the system. Some of the essential conditions to promote effective AL experiences in the classroom were: learning experiences should include activities of reflection, critical analysis and synthesis and be structured in a way that promotes decision making and student responsibility for results; the experiences must involve all participants not only intellectually but also emotionally and socially; the experience should promote students' self-awareness, empathy with their peers and a greater knowledge of the environment and other cultures.

III. Methodology

A. Research Design

The methodology chosen for the project was the experimental research, mixed methodology (qualitative-quantitative) with a Solomon 4-group design [15]. It was intended to control the possible interaction that could exist between the pre-tests and the treatment, therefore, this design allowed the results to be generalized also for the subjects who had not receive the pre-tests. Two groups have received pre-test while other two have not. Likewise, two groups have received treatment while other two have not. The measurement of the dependent variable in pre-test situation was asynchronously performed among the two groups, and the measurement of the dependent variable in post-test situation was asynchronously performed among the four groups.

B. Learning Experiences

Generation Z students differ in many ways from previous generation students, known as Millennials, especially when it comes to learning styles. However, most early studies have shown that educational theories based on Cognitive Development by stages are still valid for both populations of students [16]. One particular aspect that remains briefly addressed in the literature is that Generation Z students arrive at university with different levels of cognitive development and abilities in creativity and criticality. It is for this reason that the teaching process to be developed in an active learning environment must take into account three aspects:

(i) the level of cognitive maturation that each student has when entering the courses (so that learning is personalized and self-paced);

(ii) the level of intellectual engagement and expectations of each student (for learning to be collaborative and student-driven) and finally,

(iii) the cognitive bias that the main characteristics of Generation Z students represent (Preference for performing passive visual activities; Comfort in reading only predigested texts; Suffering from a strong lack of concentration; Inability to perform intrinsically motivated cognitive efforts; Prevalence of social life developed in virtual social networks; Quasi-totality of their written expression in texting language) [17][18]. Recent studies, related to the establishment of safe and healthy socio-emotional environments in the HEI classroom, show the great importance that the dispositions inherent to interpersonal awareness represent for the implementation of the active learning approach in face-to-face settings [19].

During 2020, and due to the COVID-19 crisis, the analysis of these provisions has been resumed, but adapting them to remote and virtual education environments. The incorporation of reflective practices through spaces for dialogue (both in face-to-face and fully online environments) should be carried out throughout the engineering program as an example of cognitive and metacognitive tools using the technological platforms that are best adapted to each subject.

The objective of this approach favors the establishment of a common language (written, oral, digital and visual) and develops, on the one hand, the skills declared in the Education 4.0 framework, and on the other hand, the skills of digital literacy required by current workplaces. The best strategy for the incorporation of the learning experiences was in the form of didactic interventions and integrated infusion-immersion approach in curricular courses of the engineering program [20]. The activities were designed considering the actual cognitive stages of thinking of the students (according to Kieran Egan's theory [21]), and incorporated analysis sessions. Specific metacognitive tools were considered to develop digital literacy skills and to enhance the capacity for analysis and combination of existing ideas and images through new disruptive and alternative. The treatment included some of the following activities/digital literacy skills to develop:

- Dialogue Seminars, held after hours and outside the classroom, in spaces with adequate furniture of the Learning Commons (Branching).
- Supervised Questioning Session with a leader instructor to stimulate the recall of knowledge and sharpen understanding of concepts acquired in previous sessions (Information)
- Challenge-based learning with experts in industry facilities and technology companies (Reproduction).
- Training of students in the operation of the cockpit console of the radio station, training in the use and production of audio with portable equipment for recording in the classroom and outdoors (Real-time).
- Participation of students in radio programs and podcasts produced by teachers to develop oral communication skills (Socio-emotional).
- Student participation in contests and competitions of an artistic nature (Photo-Visual)

The following data sheet describes one of the experiences, out of a total of 24 different treatments, developed during the 6 semesters. Details on the resources, metacognitive tools, justifications, learning objectives and a brief description of the procedures are provided.

Artistic Experience: The conscious paradox of storytelling with paintings.

Resource Example: "Never morning wore to evening, but some heart did break" work painted by the English artist Walter Langley, in 1894.

Digital Literacy Skill addressed: Photo-Visual

Intervention Procedure: Students critically interpreted the image and wrote their own stories and anecdotes of their hobbies using the style of today's art critics. Student responses to five sets of questions (based on the Verbal Form B of the Torrance TTCT test [22]) were analyzed: 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.

Metacognitive tools from the fields of Arts	Asking and answering questions about artworks using *Art Crit Cards* is making meaningful connections between what we see and what we experience. When we tell or write (through debates, dialogue seminars, opinion blogs) what we experienced and felt when we observed an artifact, we build an understanding of the object and articulate in language what otherwise remain only muddled, fragmented and disconnected.
Cognitive tools from the STEM fields	Engineering reasoning requires to settle questions in order to solve complex problems. It is imperative that engineering students take the time to ask these questions clearly and precisely but also express them in different ways to clarify their meaning and scope. Being able to divide a question into sub-questions to understand and encompass all possible answers, including those untested and potentially risky, embracing divergent perspectives.

C. Participants

A total of twelve different groups were involved over six semesters (S1 to S6), from August 2018 to June 2021. The research was conducted with a sample of 352 students that joined the study voluntarily, 152 of them during 2018-2019 in face-to-face learning settings, and other 200 of then, during 2020/2021, in fully online learning settings. The experimental group -220 students- underwent cognitive and metacognitive instruction, while 132 students remained untrained in the control group. Of the 220 students of the experimental group, 124 received pre-test and treatment and 96 students received only treatment. Of the 132 students in the control group, 74 received the pre-test and the remaining 58 students did not. Participants who contributed to this study had an average age of 22 years by the end of each semester and were distributed in four different courses of the B.S. Sustainable Development Engineering program and the B.S Mechatronics Engineering program. The group criteria used in this study were the following:

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*

D. Instrumentation

Data Collection in Pre-Test and Post-Test. Different types of instruments were considered for the study; Some pre-tests and post-tests for data collection and research were: questionnaires, interviews, surveys, observation lists, rubrics and other tools to handle parametric data statistical; Reading comprehension tests, designed to determine the level of cognitive maturity of students; a modified version of the tests and rubrics presented by Paul & Elder [23]; and finally, to assess how well students performed each outcome and considering that assessing the evidence for competencies as critical thinking and creativity typically involves subjective judgments concerning products or behaviors, an already-existing rubric was used, the VALUE Rubrics, from AAC&U, developed for the Essential Learning Outcomes of the Association of American Colleges and Universities [24]. PreTests are important to know the level of cognitive maturity of students. In this study, Egan's taxonomy was used to place students on the levels: mythical, romantic, philosophical, and ironic. It is important to emphasize that the PreTest does not have a diagnostic function in terms of domain-specific knowledge level. The PreTest are also used to know the level of development that students have in: Creativity and seven other skills and transversal graduation competencies: Teamwork; Self-awareness; Transfer; Criticality; Knowledge of Cultural Frameworks; Broad Perspective; and Taking Risks.

IV. Discussions, Findings and Results

Preliminary Findings. During the first two years of the study, diagnostic studies were carried out on 68 students to determine approximately the cognitive maturity, the level of development of the soft skills required in the framework of Education 4.0 and the mastery level of digital literacy skills, upon enrollment in 8 face-to-face groups. In 2020, these studies were repeated in 56 students, enrolled in 4 online groups. The previous analysis of the results obtained in the years 2018-2019 revealed that the situation addressed in the teaching-learning process involved: *(i)* deficiencies in the capacity for argumentation due, on the one hand, to the reduced lexical corpus and, on the other, part, to the limited capacity for critical thinking; and *(ii)* insecurity in effective communication (oral and written) due to the difficulty of maintaining discursive coherence. During 2020, and due to the fact that all the courses were taught in the fully online mode, the findings showed, additionally, greater difficulty in developing the soft skills specific to digital literacy (defined in the previous sections).

Results and findings related with pre-tests. In order to verify that the students of the experimental group and the control group had similar initial conditions of soft skills development, the results of diagnostic pre-tests in both groups were compared. Initial comparison between 124 students (65 students of the EG-PreT-T and 59 of the CG-PreT), revealed no significant differences in their skills background, as shown in Figure 2.

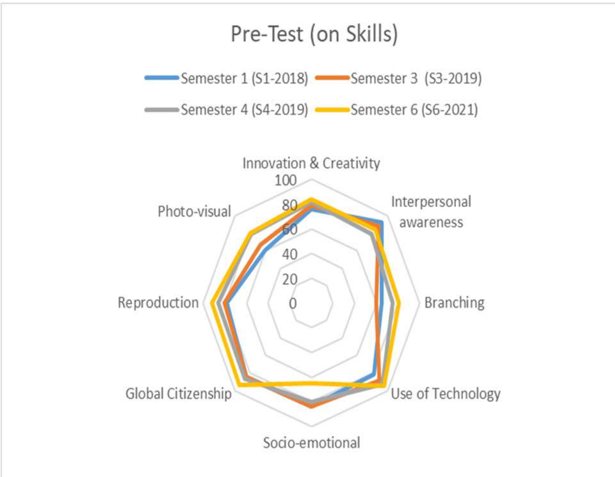

Figure 2. Pre-Test skills levels measured in semesters S1, S3, S4 and S6.

The finding of relevance that we can report from the pre-tests is the strong impact of social-emotional skills, noted in students in semester S6 (February-June 2021), presumably due to disappointment and frustration when starting a semester under strict measures of confinement and social distancing caused by the second wave of COVID-19.

Discussion on the skills Assessment. Figure 3 shows the impact of the AL experiences in experimental group. It can be seen that there is a strong correlation between the grades that the students obtained in final scores with the evaluation in the post-tests of skills.

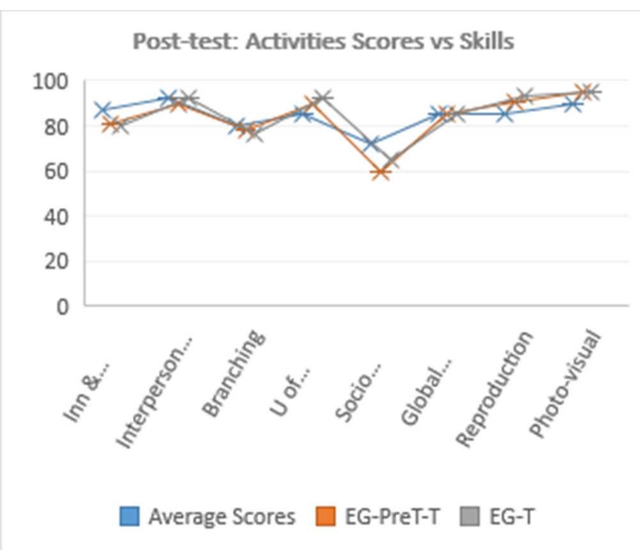

Figure 3. Correlation between final scores and post-Tests assessment.

The skills showed in figure 3 were: four Education 4.0 skills (Global citizenship, Innovation and creativity, Use of technology and Interpersonal awareness) and four digital literacy skills (Photo-visual, Reproduction, Branching, Socio-emotional).

Results related with the soft skills assessment in post-tests. Valid Assessment of Learning in Undergraduate Education, VALUE, rubrics were used with the intention of evaluating and discussing learning related to the students' interdisciplinary and digital literacy skills, not the grading [25][26]. These rubrics allowed positioning the learning within a basic framework of expectations. The post-tests on digital skills using AAC&U rubrics showed that the experimental group attained 37% improvement over the students of the control group in the upper "Capstone" level and a 35% decrease in the number of students at the lowest "Benchmark" level of the rubric. The results were similar for both students in the experimental group who underwent the pretest and those who did not pretest. The exercise of activities in small groups was highly beneficial, so that our methodology can be considered a successful, especially in fully online environments. These results are shown in Table 3.

TABLE 3. AAC&U Rubrics distribution for the Experimental Group (EG) and the Control Group (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 %**

Results and findings related with post-tests. To determine the actual relationship between intellectual engagement and critical thinking's specific dispositions, we computed the Pearson coefficient to verify the possible correlation between the results obtained in both post-tests, the Paul and Elder Framework and AAC&U Value rubrics. Also, the determination coefficient R^2 value was computed to find the percentage of the total variation in the AAC&U Value Rubrics results that can be explained by the linear relationship between them and the Paul and Elder Framework results. In all cases (consider that the present study uses social data), the strength of the correlation according to Evans' criteria ($0.6 < r < 0.79$, $36\% < R2 < 64\%$) can be considered strongly positive [27]. Overall, two significant findings can be highlighted:

First, the EG Pearson coefficient 0.6794 can be considered strongly positive, evidenced by the fact that 46% of the students that received the treatment showed this correlation. In contrast, the Pearson coefficient of -0.2353, with $R^2 = 5.5\%$, shows that the results obtained in the post-tests by the CG students have a very weak correlation. Second, students who received the treatment achieved results consistent with more robust intellectual engagement and a higher level of skills development: +26% and +35%, respectively, compared with the CG students.

Conclusions

Seeing that 21st-century engineers must be creative and sufficiently critical in their values and judgments to solve even ill-defined problems, it is necessary and urgent to develop soft-skills competencies in engineering students. The present work was a study on the effectiveness of the active learning approach in engineering courses and the innovative ways of empowering students to develop digital literacy skills. The use of rubrics allowed to obtain conclusive results since it revealed the importance of a correct diagnosis of the development of soft skills to promote the formation of metacognitive awareness, and the great impact of the design and implementation of adequate cognitive tools to achieve high quality results in the learning process. The results of our study showed that the creativity in criticality approach can be an effective cognitive tool within the Education 4.0 framework.

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References

[1] D. Jelonek, T. Nitkiewicz, and P. Koomsap, "Soft Skills of Engineers in View of Industry 4.0 Challenges," *Conf. Qual. Prod. Improv. – CQPI*, vol. 2, no. 1, pp. 107–116, Oct. 2020, doi: 10.2478/cqpi-2020-0013.

[2] J. Crawford, "COVID-19: 20 countries' higher education intra-period digital pedagogy responses," *J. Appl. Learn.*, vol. 3, no. 1, 2020, doi: 10.37074/jalt.2020.3.1.7.

[3] World Economic Forum Boston Consulting Group, "Insight Report Challenges and Opportunities in the Post-COVID-19 World," 2020. [Online]. Available: www.weforum.org.

[4] P. Caratozzolo and A. Alvarez-Delgado, "A new transdisciplinary approach to foster soft skills in engineering : Using critical reading micro-workshops," 2018, doi: 10.1109/WEEF-GEDC.2018.8629775.

[5] V. Silber-Varod, Y. Eshet-Alkalai, and N. Geri, "Tracing research trends of 21st-century learning skills," *Br. J. Educ. Technol.*, vol. 50, no. 6, pp. 3099–3118, Nov. 2019, doi: 10.1111/bjet.12753.

[6] World Economic Forum, "Schools of the future: Defining new models of education for the fourth industrial revolution," *World Econ. Forum*, no. January, pp. 1–33, 2020, [Online]. Available: www.weforum.org.

[7] M. E. Madden *et al.*, "Rethinking STEM education: An interdisciplinary STEAM curriculum," in *Procedia Computer Science*, Jan. 2013, vol. 20, pp. 541–546, doi: 10.1016/j.procs.2013.09.316.

[8] P. Caratozzolo, A. Alvarez-Delgado, and S. Hosseini, "Metacognitive awareness and creative thinking: The capacity to cope with uncertainty in engineering," in *IEEE Global Engineering Education Conference, EDUCON*, 2020, vol. 2020-April, doi: 10.1109/EDUCON45650.2020.9125135.

[9] C. Liao, "From Interdisciplinary to Transdisciplinary: An Arts-Integrated Approach to STEAM Education," *Art Educ.*, vol. 69, no. 6, pp. 44–49, 2016, doi: 10.1080/00043125.2016.1224873.

[10] T. Costantino, "STEAM by another name: Transdisciplinary practice in art and design education," *Arts Educ. Policy Rev.*, vol. 119, no. 2, pp. 100–106, Apr. 2018, doi: 10.1080/10632913.2017.1292973.

[11] P. Caratozzolo, A. Alvarez-Delgado, and S. Hosseini, "Creativity in Criticality: tools for Generation Z students in STEM," in *2021 IEEE Global Engineering Education Conference (EDUCON)*, Apr. 2021, pp. 591–598, doi: 10.1109/EDUCON46332.2021.9454110.

[12] R. Heer, "A model of learning objectives—based on A taxonomy for learning, teaching, and assessing: a revision of Bloom's taxonomy of educational objectives." 2012.

[13] Y. Eshet-Alkalai, "Thinking in the Digital Era: A Revised Model for Digital Literacy," *Issues Informing Sci. Inf. Technol.*, vol. 9, pp. 267–276, 2012, doi: 10.28945/1621.

[14] M. Hernández-de-Menéndez, A. Vallejo Guevara, J. C. Tudón Martínez, D. Hernández Alcántara, and R. Morales-Menendez, "Active learning in engineering education. A review of fundamentals, best practices and experiences," *Int. J. Interact. Des. Manuf.*, vol. 13, no. 3, pp. 909–922, Sep. 2019, doi: 10.1007/s12008-019-00557-8.

[15] C. Dawson, "Introduction to Research Methods 5th Edition: A Practical Guide for Anyone Undertaking a Research Project," 2019.

[16] E. J. Cilliers, "The challenge of teaching Generation Z. PEOPLE," *Int.J.Soc.Sci.*, vol. 3, pp. 188–198, 2017.

[17] T. Smith and T. W. Cawthon, "Generation Z Goes to College," *Coll. Student Aff. J.*, vol. 35, no. 1, pp. 101–102, 2017, doi: 10.1353/csj.2017.0008.

[18] M. Hernandez-De-Menendez, C. A. Escobar Díaz, and R. Morales-Menendez, "Educational experiences with Generation Z," *Int. J. Interact. Des. Manuf.*, vol. 14, pp. 847–859, 2020, doi: 10.1007/s12008-020-00674-9.

[19] L. R. Lattuca, D. B. Knight, H. K. Ro, and B. J. Novoselich, "Supporting the Development of Engineers' Interdisciplinary Competence," *J. Eng. Educ.*, vol. 106, no. 1, pp. 71–97, 2017, doi: 10.1002/jee.20155.

[20] D. Alan Bensley and R. A. Spero, "Improving critical thinking skills and metacognitive monitoring through direct infusion," *Think. Ski. Creat.*, vol. 12, pp. 55–68, 2014.

[21] K. Egan, "Developing Creativity and Imagination by Accumulating Lots of Useless Knowledge," in *Creative Dimensions of Teaching and Learning in the 21st Century*, SensePublishers, 2017, pp. 37–45.

[22] M. A. Runco and S. Acar, "Divergent Thinking as an Indicator of Creative Potential," *Creativity Research Journal*, vol. 24, no. 1. Taylor & Francis Group , pp. 66–75, Jan. 2012, doi: 10.1080/10400419.2012.652929.

[23] R. H. Ennis, "Critical Thinking Across the Curriculum: A Vision," *Topoi*, vol. 37, no. 1, pp. 165–184, 2018, doi: 10.1007/s11245-016-9401-4.

[24] M. J. Allen, "Using Rubrics to Grade, Assess, and Improve Student Learning," *Strength. Our Roots Qual. Oppor. Success Prof. Dev. Day Miami-Dade Coll.*, pp. 1–82, 2014.

[25] M. Lai, Emily R; Viering, "Assessing 21 st Century Skills : Integrating Research Findings National Council on Measurement in Education," no. April, pp. 1–67, 2012.

[26] T. Rhodes, *Assessing Outcomes and Improving Achievement: Tips and Tools for Using Rubrics | Association of American Colleges & Universities*. 2010.

[27] L. Cohen, L. Manion, and K. Morrison, *Research Methods in Education*. Routledge, 2002.