Universidad 2020
12do Congreso Internacional de Educación Superior
LA HABANA, CUBA
DEL 10 AL 14 DE FEBRERO DE 2020
"La Universidad y la Agenda 2030 para el desarrollo sostenible"

TOWARDS THE USE OF LIBERAL ARTS TO REINFORCE KEY NOTIONS IN UNDERGRADUATE ENGINEERING CURRICULA

Jorge Torres Gómez[1], Antonio Rodríguez-Hidalgo[2], Carmen Peláez-Moreno[3], Yannelys Virginia Jerez Naranjo[4]

[1]Department of Digital Signal Processing, Chemnitz University of Technologies (TUC), Germany,
[2, 3]Department of Signal Theory and Communications, Universidad Carlos III de Madrid (UC3M), Spain,
[4]Direction of Information Technologies, Havana University of Technologies "José Antonio Echeverría"(CUJAE), La Habana, Cuba
[1]jtorres151184@gmail.com, [2]arodriguez@tsc.uc3m.es, [3]carmen@tsc.uc3m.es,
[4]yanny@tesla.cujae.edu.cu

ABSTRACT
In general, curriculum design for undergraduate students on engineering covers hard topics of specific disciplines typically related to mathematics and physics where they learn the basics of theory and practice. In this direction, a variety of skills concerning the analysis and implementation of analytic formulations are typically conducted in classrooms to assess the specifics of engineering branches. However, further improvement in the effectiveness of teaching may be gained through a multisensorial approach by means of liberal arts. Through the development of art and literacy skills on curriculum design, the fundamentals of engineering may be reached from a qualitative perspective in contrast with the analytic-only standpoint from common curriculum designs. Based on previous scientific evidence, we postulate that this increases the internalization and comprehension of pregnant concepts. This paper surveys reported ideas to develop the engineering teaching process including arts and literacy perspectives. In addition, a sample of exercises are proposed and discussed for the application of these ideas to a particular subject, multimedia coding theory, as part of the curriculum of Telecommunications Engineering undergraduate students in Universidad Carlos III de Madrid.

KEYWORDS: Engineering Curriculum, Critical Thinking, Liberal Arts, Multisensorial teaching.

1 INTRODUCTION

Liberal art education is commonly related to social sciences disciplines, while mathematics and physics are typically addressed in pure sciences and engineering programs. Consequently, a division of schools is historically addressed to separate arts from science into two different cultures (Snow, 2013). The mixture of both schools supports a variety of benefits to consider. A better education on both branches will empower students with a more complete understanding of convergence, meaning, and usage of technologies, which is still a pending subject (Klein & Balmer, 2007). According to (Klein, Traver, Raucci, & Jones, 2009; L. L. Bucciarelli & Drew, 2015), educational skills related to the art of reading, writing, communicating, as well as the appreciation of fine arts could contribute to the increasingly needed capacities of better critical thinking and creativity.

In addition, a transition from STEM (Science, Technology, Engineering and Maths) to STEAM (Science, Technology, Engineering, Arts and Maths) is advocated by several authors to break down the distinction between disciplines traditionally seen as "creative" like the arts or music, and STEM disciplines traditionally seen as more rigid or logical-mathematical (Henriksen, 2014; Catterall, 2017; Liao, 2016; Oner, Nite, Capraro, & Capraro, 2016; Radziwill, Benton, & Moellers, 2015). Moreover, this could be a way to reduce the gender gap existing in STEM and improve motivation (Salim, 2012; Dasgupta & Stout, 2014), which according to (Instituto Nacional de Estadística, 2017) showed a percentage of 30.4% male and 13.1% female graduates in Spain during 2017.

The application of arts concepts into science or engineering academic programs is an answer to the needs to stimulate induction instead of just deduction (Shuster, 2008). The production, discovery or invention of new and novel solutions, is supported by the inductive experience of appreciating a work of art. On the other hand, deduction processes (which are commonly addressed in typical courses) stimulate the particular application of a general theory in the context of engineering. The stimulation of both approaches, inductive and deductive, brings powerful skills to create better solutions.

Nowadays, most engineering programs lack an effective integration of both cultures which prevents a better awareness of the current world's problems. Including arts and their corresponding inductive processes into engineering programs turns into a real challenge. To illustrate these efforts, mixed academic programs are pursued by providing courses not only related to technology but to the appreciation of art. Some of these approaches allow engineering students to choose subjects offered by different departments to promote an interdisciplinary dialogue between arts and engineering (Klein & Balmer, 2007). Others motivate students to take part in cultural activities, such as museum visits or concerts, as in (*Pasaporte cultural | UC3M*, n.d.), or even offer them the possibility to participate in academic projects coached by professors both from social sciences and STEM departments (L. Bucciarelli & Drew, 2018). In addition, other programs integrate arts and animation in teaching computer programming to increase student´s motivation in learning (Jawad, Tout, Abualkibash, & Xie, 2018). For instance, through the use of emoticoding, the integration of algebra, geometry, music, and 3D art seems to improve student learning (Barmpoutis, 2018). Another example stands for web-designers, who smartly combine technology, arts and psychology to attract the attention of potential customers of their webpages (Fengmei & Zhang, 2013). Finally, as (Abu, Hassan, & Sahib, 2001) explain, abstract mathematical objects and concepts can be turned into another form of visual art using mathematical animations, which are perceived as a more tangible experience that can potentially improve and enrich their understanding.

Our current research is part of an ongoing teaching innovation project whose goal is to improve the understanding of engineering concepts using arts as the motor core of a more complex process, which should eventually lead to graduates that not only propose solutions to the professional challenges they face, but that are also critical about their environment and the consequences derived from technology. We ambitiously intend to *reinforce the understanding of key concepts* by promoting the *appreciation and creation* of small pieces of art.

In this first approach, different engineering topics will be taught from a subjective standpoint. The tools used to attain such purpose will be the elaboration of narrative excerpts and their auditory representation by means of well-known musical scales. Students shall be motivated to write their own thoughts and opinions about the topic at stake, and their textual contribution shall be used as the media where later on such concepts are tested. We see this work as a small addition in the education of the students of telecommunication engineering, since our contributions are mainly focused on the core concepts belonging to such academic program. However, we consider it a little stone that could be inspirational for colleagues teaching similar or different concepts, and which should help to educate better and well-rounded engineering professionals.

The rest of this paper is organized as follows: Section 2 introduces the methodology we used for attaining the previous goal. Section 3 is an outline of the academic course on Multimedia Information Coding for Communications, where these proposals will be assessed. Finally, we include a discussion in Section 5 and some concluding remarks in Section 6.

2 METHODOLOGY

As it has become apparent in the previous section, the introduction of *arts* and *critical thinking* into subjects of an engineering curriculum is beneficial for the development of more creative and socially-aware engineers. However, this is a challenging enterprise mainly because the materials and resources need to be developed *ad hoc*. Some general principles, applicable to any subject, need to be observed during this process. We have identified the following steps:

1. A small set of *key* or *core* concepts to be apprehended throughout the term the subject is being taught, need to be identified. These should be the main concepts that the students would need to retrieve from their memory in their future professional life when they face new unforeseeable challenges. Therefore, the goal of the instructors is to find ways of reinforcing the *pregnancy* of these concepts.
2. Original and suggestive *connections* between the previous *key or core concepts* and *arts* need to be found. This is a creative process that supports the motivational ability of the connection where elements of surprise and originality should be sought.
3. A set of *activities* to explore the previous *connections* need to be designed. A requisite of these activities is that they promote *critical thinking* and *creativity*, that is, the application of mechanistic rules and closed solutions should be avoided. In addition, we consider that these activities are partially aligned with the multimedia learning theory proposed by (Mayer, 2002), since our students shall learn concepts using not only verbal or written content, but also more visually and auditory rewarding ideas, which might help them to learn more deeply.
4. An assessment procedure tailored for the evaluation of the degree of understanding of the *core concepts* needs to be found.

In this paper, we are concerned with the steps 1–3, leaving step 4 as future work.

3 DESCRIPTION OF THE ACADEMIC COURSE

To illustrate the previous methodology we set out to apply the steps defined in Section 2 to the subject of "Multimedia Information Coding for Communications (CIMC)" in the curriculum of the four-year Bachelor degree on Mobile and Space Communications Engineering, taught in Universidad Carlos III de Madrid. The main goal of the course is to provide understanding of coding and compression techniques for digital media related to speech, audio, image, and video in order to reduce, as much as possible, their storage needs or equivalently their bitrate of transmission.

The course comprises 11 lectures, 5 seminars and 8 labs of 2 hours-duration each. The program addresses common codes and techniques based both on the statistics or entropy of the source (Huffman, Arithmetic, Golomb-Rice, Lampel-Ziv) and the perception of audio, images, and video (perceptual coding) to represent and transmit data. In addition, the evolution of the standards is presented to provide elements of discussion of the coding performance on nowadays applications. For instance, MP3 for audio compression, JPEG for image, and H.26X or the MPEG family for video. In lab sessions, students solve problems to code information through programming using Matlab software.

The program surveys the following six topics:

1. **Fundamentals of the digitalization of multimedia information**: This topic provides a quick review of the fundamentals of analog to digital conversion; the representation by sequences, matrix and time-varying matrix of audio, image, and video, respectively; as well as an overview of the fundamentals to compress information. The students are already familiar with these concepts, and this works as a introductory chapter.

2. **Speech Coding**: This topic establishes the mechanism of human speech production to introduce coding technologies. In this direction, vocoder, hybrid and waveform technologies are studied to enable efficient speech transmission over communication channels such as cellular systems.
3. **Audio Coding**: This chapter covers a broader representation of sound in comparison to speech. Additional codes and a first survey on the related standards are lectured. Besides, the concept of perceptual coding is explained based on a model of human hearing and associated psycho-acoustical phenomena.
4. **Image Coding**: This topic includes the analysis of two dimensional data in contrast with the previous two sections, where audio and speech were considered. Two-dimensional transforms are presented to apply coding in a different domain to reduce storage. The mixed solution of transformation and entropy coding is presented by using block diagrams together with the evolution of standards.
5. **Video Coding**: This topic introduces how redundancy is reduced in video throughout a reasonable processing of the evolution of its frames. Video formats, general coding as well as related standards, are illustrated in this section.
6. **Transmission of multimedia information**: This final topic covers the requirements for universal access to multimedia. Technologies and strategies are presented to provide access by means of illustrative approaches conducted by standards as well as the evolution of networks.

All the topics above deal with the digital representation of multimedia information. In this regard, multimedia may represent a data source with some specific characteristics or patterns that can be exploited for compression purposes. For instance, the speech recording of a *tenor* voice has major differences in comparison to a *bass* one. The fundamental frequency of the first is higher than the second's. A similar distinction can be observed in audio signals, since classic music presents different timbres and rhythms compared to jazz or soul music. Images, on the other hand, show huge differences in color and patterns depending of the age or art movement of their creation: paintings from the *baroque* period contrast strongly with *cubism* artwork. To illustrate this, a frame by *El Bosco* (see Fig. 1a), “The Garden of Delights”) will be more difficult to compress than a frame of Picasso (see Fig. 1b), “Blue Guitar”) provided the variety of color, intensities, and patterns that *El Bosco* uses in comparison with *Picasso* and the current state of the art in image compression. In the case of a video sequence, some films present less time-varying frame reproduction than others. For instance "Out of Africa" movie (*Official Trailer (Universal Pictures) | Out Of Africa | SceneScreen*, 1985) reproduces frames with less time-varying colors and movements on the scene than the exhibited concerts of Freddy Mercury on "Bohemian Rhapsody" movie (*Bohemian Rhapsody | Official Trailer [HD] | 20th Century FOX*, 2019). The variety of different locations and scenes change color and objects distribution between frames.

Based on these differences, coding techniques may exploit the dissimilarities of media sources to have a better performance in terms of data storage –size or rate of transmission versus quality of reproduction-. This connection between the media source and the coding performance –either in terms of the rate of compression or the quality (or distortion) of the outcome– is mediated by the concept of *redundancy* or *amount of information as measured by the entropy*. Due to the importance of these ideas traversing all the topics of the subject, they will be chosen as the *core concepts* to be identified in the first step of the methodology we defined previously in Section 2.

4 A PROPOSAL OF ACTIVITIES ON ENGINEERING CONCEPTS AND ART

The appreciation of art may produce a better understanding of coding concepts and applications. In this direction, the program follows two approaches. A first approach is to illustrate, on lectures and seminars, the differences in coding performance by appreciating some representative pieces of art. This leads to the introduction, from a subjective perspective, of the quantitative measurements of coding performance. On a second approach, students will be tasked to try to produce art based on the concepts

and fundamentals of coding. In this course, students become part of an active process which in turn will demand the comprehension of the basic theory of coding and how text, sounds and images are processed.
As we mentioned in Section 3, the different coding-technique fundamentals relay on Shannon's theory of information (Proakis & Salehi, 2004). In this theory, a metric to describe source-information is given by the entropy value. Codes try to achieve this value by conforming a binary sequence to get closer to the source entropy value as near as possible. In this direction, the reduction of redundancy plays a major role.
Having identified *entropy* and *redundancy* as *core concepts* (step 1) we now need to find *suggestive connections* (step 2) between them and some modality of art, and develop *open and creative* activities to make these connections apparent. To this end we present these two first exercises designed to teach, by the production of the students' own text and sound, the subjective interpretation of these two concepts. Future research on this ongoing topic is to devise additional exercises to illustrate these concepts also with images and video.

Exercise 1: Compressing the concept of Entropy

This exercise is related to the concept of entropy. The role of the students will consist in producing their own pieces of text, preferably related with their understanding of entropy. Our starting hypothesis is that they will need to study and understand the concept, as if they were trying to explain it to a colleague. The whole process of writing, by itself, shall make the students focus deeply on the task at hand, and should lead them to develop a critical thinking on the following two concerns: first, they shall become aware about whether they really understand the concept at stake or not, and secondly, in an idealistic scenario they should be capable of questioning themselves about the usefulness of the theoretical concept of entropy. The text devised by the students should reflect the following ideas:

1. Introduce themselves by the full name, academic grade, and subject.
2. Explain the concept of *Entropy* in not less than 15 words. The preferred length should be a couple of paragraphs.
3. Explain the applications of *Entropy* in not less than 15 words. The preferred length should be a couple of paragraphs.
4. Introduce their ideas about what coding is, or what they though it was before they started to learn about it.

Once their excerpts are written, they are asked to read them and record them into a raw audio file. Notice that semantically speaking, the informational content of both text and audio is the same, since both formats include the same textual data although in totally different modalities. From both sources they shall compute the following:

a) The entropy of the written script.
b) The entropy of the recorded speech.
c) To establish a comparison and discussion based on results in items a) and b).

Needless to be said, students will receive the tools necessary to perform such computations. What we expect them to understand is not only the concept. During the discussion, we expect them to give their opinion about which of these two formats seems to be more useful and comprehensible for them.
In the second part of this exercise, students must produce a new text reflecting the same content with fewer words. Notice that this is a procedure of compression itself, since students remove what they think is irrelevant or less informational in the texts that they produced. Then, students must record their own readings and solve again items above from a) to c). Based on these metrics, students must derive conclusions by comparing results from the first and second scripts. This whole procedure shall make them meditate about the usefulness of this process: whether the concept is understandable or not after removing some of the irrelevant text, whether a person unrelated to engineering shall be capable of understanding it before and after removing redundant information, and also to question to what extent uninformative data can be removed before the concept becomes incomprehensible.

Exercise 2: Listening to Redundancy

This exercise proposes to produce sound from a given written script. This is commonly referred to as Sonification (Degara, Hunt, & Hermann, 2015) with applications not only on text-to-sound but also on images-to-sound and vice versa. This exercise will focus on the production of sound from a written script to have a subjective measure of *redundancy*, another *core concept* of coding theory.

Redundancy is related to multiple replicas of a given attribute. In general, the repetition of a given attribute does not bring an additional definition of the object of study. In terms of a written text, this represents the redundancy of letters and words that may be dropped without losing message meaning. In terms of sound, this may be reflected by listening to a repeated (constant) musical chord in accordance with the repetition of the text attribute. On the other hand, in case that a given text presents too many attributes, with a similar repetition, then there is less redundancy on each attribute. In such a case, produced music should sound much more chaotic.

In this exercise, the general idea is to have a larger amplitude-varying sound in accordance with increased redundancy. Larger amplitude on the produced sound will be linked to a repeated attribute on the text, while less amplitude will be associated to the fewer appearances of a given attribute.

Based on this interpretation, the exercise demands to produce a written script by explaining the psycho-acoustic principle. This principle is introduced on Topic 2 “Audio Coding” for perceptual coding techniques. The script must reflect the following aspects (in not less than 15 words per item):

1. Introduction to psycho-acoustic principles.
2. Constituent elements of psycho-acoustic principles.
3. Absolute threshold of hearing.
4. Time masking.
5. Frequency masking

The exercise demands to save the text and load it using MatLab, then to obtain the histogram of the typed letters of the alphabet as depicted in Figure 2 a). These histogram bars will be the attributes used to convert text into sound. The amplitude of each bar on the histogram will modify the amplitude of a musical wave that will be composed by superposing the pentatonic-scale chords “C, G, D, A, E” during 0.5 seconds. By means of this procedure, each bar must be played one after another to reproduce the corresponding sound of the histogram, considering that each letter will be assigned one of the notes of the pentatonic scale. Since we have 29 characters (26 if we remove punctuation and spacing marks), each note will have between 5 and 6 letters from the alphabet. Notice that each letter will affect directly to the magnitude of the sound it represents in the scale, which for complete words shall modulate chords with different acoustic nuances. Note that the pentatonic scale was selected because of its simplicity, since any combination of the notes produces a chord that is consider harmonious by a regular listener.

On a second part of this exercise students must reduce redundancy by randomly erasing ¼ of the most repeated letters “A”, “E”. This random erasure of symbols is similar to the effects of perceptual coding to compress data that students are addressing on this topic. By erasing these extra redundant letters, it is expected to still understand text meaning, which is something to be assessed by each student. Based on the histogram from the reduced (compressed) text (see Figure 2b)), students must produce the new related sound.

By comparing graphs in Figure 2 a) and b), the compressed text in Figure 2 b) exhibits a more homogeneous amplitude-distribution than the graph in a). In the case of Figure 2 b), sound most produce similar amplitude-chords on each time-interval. This will be perceived as a less time-varying sound in comparison to the reproduced sound from graph 2 a).

5 DISCUSSION

By means of above proposed exercises, we expect to arouse the interest of our students about liberal arts both in an active and passive way. Actively, writing and recording their own ideas, where we expect them to express their concerns and proposals about the topics under analysis. Passively, giving them illustrative examples of how different pieces of art get coded depending on their redundancy, no matter whether they are auditory, visual or textual.

For instance, students will employ narrative techniques to produce their own scripts in case of Exercise 1, or they will adjust it so the sound has better sonority or acoustic properties in the case of Exercise 2. A similar intention will be conducted on future exercises.

The assistant professor will be in charge of introducing some basic concepts and intuitions about narrative, from both a theoretical and practical perspective, and will also motivate students to discuss the core concepts. For Exercise 1, students will reflect their understanding of the concept of Entropy without the support of any mathematical formula, which as we explained previously shall give them a broad idea about their comprehension about the topic. They should also become critical about the concept itself and its usefulness, which shall be verified posteriorly once that they actively remove some irrelevant content from their own excerpts of text. They will be able to check that their text remains understandable, but at the same time their length and Entropy change.

Exercise 2 reflects the concept of redundancy in terms of sound perception. Students may have a feeling of redundancy when they try to understand their own text after randomly erasing the most repeated letters. In this regard, redundancy is sketched by that part of the object that may be removed without losing the main description. Besides, provided redundancy is related to the repetition of a given pattern. The appearance of such patterns may be identified with a time-varying amplitude perception of musical chords, that is, without identifying a "homogeneous sound" in time. This may bring a perception of redundancy by hearing.

In addition, there are a variety of techniques to produce sounds from written texts or images interrelating them considering different attributes. For example, converting text into sounds can be performed using quite a variety of auditory features such as the pitch, amplitude, frequency and tempo, which might produce different sonorities. In this regard, the assistant teacher may promote a discussion about the redundant perception of different musical rhythms, i.e., What is more redundant, classical music from Bach or the flamenco guitar from Paco de Lucía? What sound attribute will be more useful to model and reduce redundancy? Is there some correlation between redundancy and something as subjective as the quality of music? [1] Additionally, the assistant teacher may introduce some basic concepts about music. For instance, to understand something as the pentatonic scale from Exercise 2 it is necessary to give some background notions about octaves, semitones, tones, etc. to have a better understanding of the posed objective.

Inspired in the two previous exercises we intend to include an additional task in future works, where students will be in charge of recording a video where they give their intuition about the topics explained in the classrooms. We expect them to act as some sort of presenters, which will make them to confront unusual situations such as acting and presenting some concepts in front of a camera and/or in front of a room full of people. To illustrate, the production of videos is becoming part of academic current development. Some academic engineering programs motivate their students to show and record the development of their projects using videos. These are the cases of "Human inspired telecommunication system" (*Human Inspired Telecommunication System - AP-S Antenna Design Challenge*, n.d.) and embedded system projects (*NUS EE4214 Project sem 1 0910: GRP 1 - I warrior lite*, n.d.) related to embedded systems by undergraduate programs on engineering studies. Additionally, most popular papers on scientific research are also developing video media files (Rappaport et al., 2013) to improve the understanding of their contributions and to motivate further study. Furthermore, animated tutorials produced by students represent also a reported method to support the comprehension of specific topics for teaching (Sklyarov & Skliarova, 2005).

[1] Note that these issues will drive a discussion even among specialists in the subject since the connections we are trying to evoke here are by no means, straightforward. Essentially, the proposed exercises are deliberately underdefined to allow students to have a chance to provide (and discuss) their own definitions about how should redundancy be defined for music, for example.

6 CONCLUSIONS

Ongoing research tries to introduce liberal arts to improve the teaching process of abstract concepts of engineering. Making a reasonable use of writing and sonification techniques, in this work we introduce two exercises that interconnect the attributes of text and audio with the active usage of liberal art concepts. We consider that these two will reinforce the understanding of key concepts not only by their analytical definition, but also by the 'feelings' or 'vibe' they convey. Future directions that we want to explore with this research are the devising of new solutions to cover the topics of Image and Video coding, as well as the transmission of multimedia information. During the second stage of our research we intend to have closer contact with other academic-departments and groups of research, hopefully from the areas of social sciences and arts. Our motivation is to get some hints about the concerns that researchers and teachers of such areas have, and how the knowledge that they have can be more broadly transmitted to future graduates of engineering. Their contributions are quite valuable, and shall provide new ideas to improve the way we teach, but could also motivate them to teach some interesting technological aspects to their own students. Our final goal, although quite ambitious, is clear: to produce more enlightened and cultured graduates.

ACKNOWLEDGMENTS

Current research is part of the 17th Call to Support Experiences on Innovative Teaching, Universidad Carlos III de Madrid, Spain, 2019-2020. This project gathers together to member professors from Universidad de Alcalá de Henares (UAH), Spain, Havana University of Technologies "José Antonio Echeverría" (CUJAE), Cuba and Chemnitz University of Technologies (TUC), Germany.

References

Abu, N. A., Hassan, M. D., & Sahib, S. (2001, October). Mathematical animations: The art of teaching. In *31st Annual Frontiers in Education Conference. Impact on Engineering and Science Education. Conference Proceedings (Cat. No.01ch37193)* (Vol. 3, pp. S1C–10). doi: 10.1109/FIE.2001.963987

Barmpoutis, A. (2018, March). Integrating algebra, geometry, music, 3d art, and technology using emoticoding. In *2018 IEEE Integrated STEM Education Conference (ISEC)* (pp. 30–33). doi: 10.1109/ISECon.2018.8340500

Bohemian Rhapsody | Official Trailer [HD] | 20th Century FOX. (2019). Retrieved 2019-11-07, from https://www.youtube.com/watch?v=mP0VHJYFOAU

Bucciarelli, L., & Drew, D. E. (2018, April). Breaking Boundaries with Liberal Studies in Engineering..

Bucciarelli, L. L., & Drew, D. E. (2015, September). Liberal studies in engineering – a design plan. *Engineering Studies*, *7*(2-3), 103–122. Retrieved 2019-04-13, from https://doi.org/10.1080/19378629.2015.1077253 doi: 10.1080/19378629.2015.1077253

Catterall, L. (2017). A Brief History of STEM and STEAM from an Inadvertent Insider. *STEAM*. doi: 10.5642/steam.20170301.05

Dasgupta, N., & Stout, J. G. (2014). Girls and Women in Science, Technology, Engineering, and Mathematics. *Policy Insights from the Behavioral and Brain Sciences*. doi: 10.1177/2372732214549471

Degara, N., Hunt, A., & Hermann, T. (2015, January). Interactive Sonification [Guest editors' introduction]. *IEEE MultiMedia*, *22*(1), 20–23. doi: 10.1109/MMUL.2015.8

Fengmei, Q., & Zhang, X. (2013, December). Construct a curriculum system of high vocational education combined technology with arts to implement the cultivation of innovative talents of web-designer. In *2013 2nd International Symposium on Instrumentation and Measurement, Sensor Network and Automation (IMSNA)* (pp. 83–88). doi: 10.1109/IMSNA.2013.6742823

Henriksen, D. (2014). Full STEAM Ahead: Creativity in Excellent STEM Teaching Practices. *STEAM*. doi: 10.5642/steam.20140102.15

Human Inspired Telecommunication System - AP-S Antenna Design Challenge. (n.d.). Retrieved 2019-10-28, from https://www.youtube.com/watch?v=5y80gYJJ1Wo

Instituto Nacional de Estadística. (2017). *Mujeres y hombres en España.* https://www.ine.es/ss/Satellite?L=es_ES&c=INESeccion_C&cid=1259925481712&p=1254735110672&pagename=ProductosYServicios%2FPYSLayout&param1=PYSDetalle&param3=1259924822888.

Jawad, H. M., Tout, S., Abualkibash, M., & Xie, Y. (2018, May). Integrating Art and Animation in Teaching Computer Programming for High School Students Experimental Study. In *2018 IEEE International Conference on Electro/Information Technology (EIT)* (pp. 0311–0317). doi: 10.1109/EIT.2018.8500178

Klein, J. D., & Balmer, R. (2007). Engineering, Liberal Arts, and Technological Literacy in Higher Education. *IEEE Technology and Society Magazine*, *26*(4), 23–28. doi: 10.1109/MTS.2007.911066

Klein, J. D., Traver, C., Raucci, S., & Jones, S. A. (2009, October). Special session - inventive courses: Blending engineering and the liberal arts. In *2009 39th IEEE Frontiers in Education Conference* (pp. 1–2). doi: 10.1109/FIE.2009.5350505

Liao, C. (2016). From Interdisciplinary to Transdisciplinary: An Arts-Integrated Approach to STEAM Education. *Art Education*. doi: 10.1080/00043125.2016.1224873

Mayer, R. E. (2002). Multimedia learning. In (Vol. 41, p. 85 - 139). Academic Press.

NUS EE4214 Project sem 1 0910: GRP 1 - I warrior lite. (n.d.). Retrieved 2019-10-28, from https://www.youtube.com/watch?v=DZwu8xj3BNc

Official Trailer (Universal Pictures) | Out Of Africa | SceneScreen. (1985). Retrieved 2019-11-07, from https://www.youtube.com/watch?v=5RrEv9-ks2Y

Oner, A., Nite, S., Capraro, R., & Capraro, M. (2016). From STEM to STEAM: Students' Beliefs About the Use of Their Creativity. *STEAM*. doi: 10.5642/steam.20160202.06

Pasaporte cultural | UC3m. (n.d.). Retrieved 2019-10-25, from https://www.uc3m.es/ss/Satellite/Cultura/es/TextoMixta/1371230632607/

Proakis, J. G., & Salehi, M. (2004). *Fundamentals of Communication Systems* (1edition ed.). Upper Saddle River, N.J: Pearson.

Radziwill, N., Benton, M., & Moellers, C. (2015). From STEM to STEAM: Reframing What it Means to Learn. *STEAM*. doi: 10.5642/steam.20150201.3

Rappaport, T. S., Sun, S., Mayzus, R., Zhao, H., Azar, Y., Wang, K., ... Gutierrez, F. (2013). Millimeter Wave Mobile Communications for 5G Cellular: It Will Work! *IEEE Access*, *1*, 335-349. doi: 10.1109/ACCESS.2013.2260813

Salim, N. (2012). The "IT" Girls: Inspiring girls in science, technology, engineering, art, and math [Pipelining: Attractive programs for women]. *IEEE Women in Engineering Magazine*. doi: 10.1109/MWIE.2012.2215263

Shuster, M. D. (2008, August). The arts and engineering [Focus on Education]. *IEEE Control Systems Magazine*, *28*(4), 96–98. doi: 10.1109/MCS.2008.924881

Sklyarov, V., & Skliarova, I. (2005, May). Teaching Reconfigurable Systems: Methods, Tools, Tutorials, and Projects. *IEEE Transactions on Education*, *48*(2), 290–300. Retrieved 2019-10-25, from http://ieeexplore.ieee.org/document/1427879/ doi: 10.1109/TE.2004.842909

Snow, C. P. (2013). *The Two Cultures and the Scientific Revolution*. Mansfield Center, CT: Martino Fine Books.

Appendix

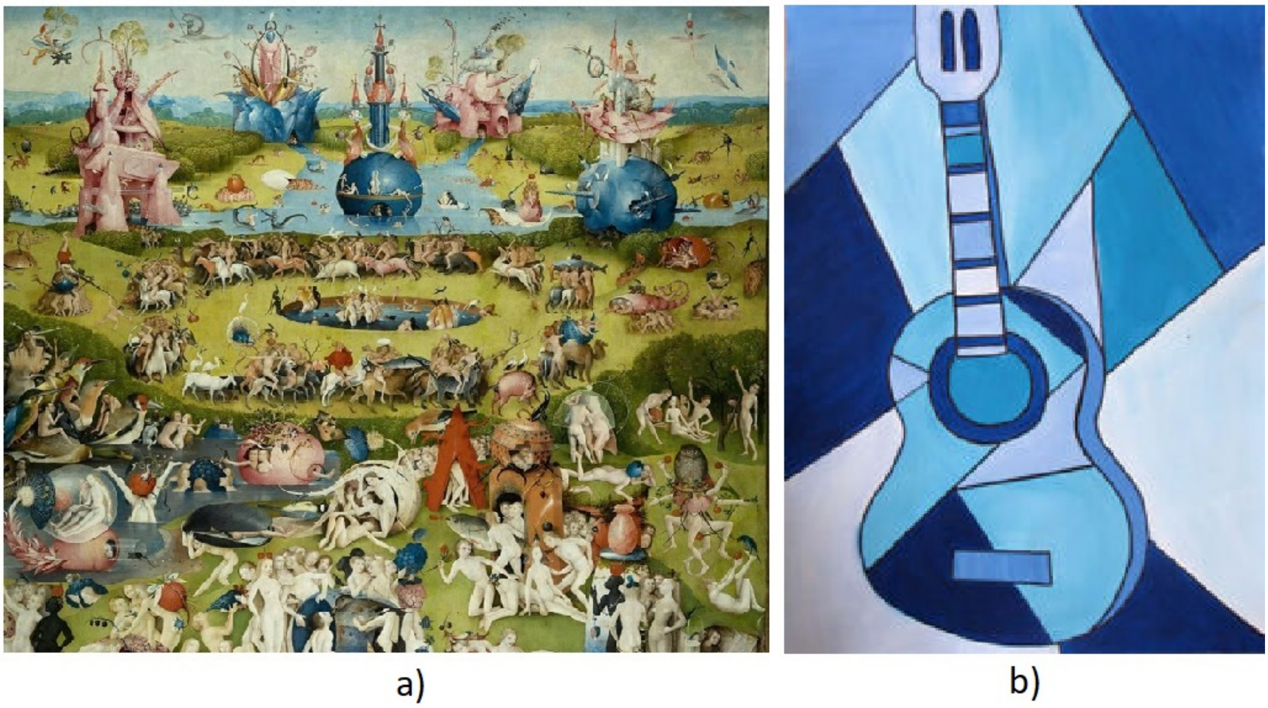

Figure 1: Illustrative example of paints complexity. a) El Bosco, “The Garden of Delights”. b) Picasso, “Blue Guitar”.

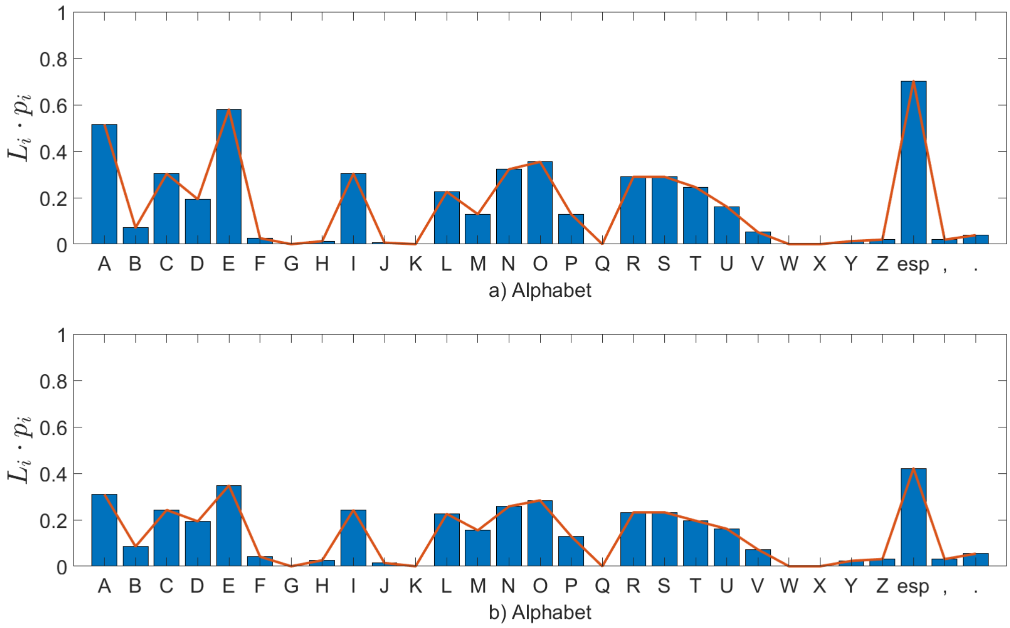

Figure 2: Histogram of the produced letters on a given message text. a) Original message text. b) Compressed message text.