Ethical issues of a Smart System to enhance students' attention

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***Abstract*— In collaborative research, developing innovative technologies for education based on cloud computing and data analytics raises ethical issues of different nature. This work discusses ethics related within the implementation of a Smart System with such technologies in eLearning context under the Internet of Things (IoT) paradigm. The system, uses electrocardiogram (ECG) and electroencephalogram (EEG) wearables and computes students' attentional state to perform recommendations to maximize it and thus contribute to the decrease of students' dropout in Universities. Furthermore, it is presented a 6-step procedure solution to solve ethical issues raised by this type of scenario that includes articulation between different actors in a center for supporting students inside the university.**

Keywords—ethics; collaborative research.

I. INTRODUCTION

Education Technology topic, i.e. the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources [1], mentions technologies such as eLearning as well as hardware devices. However, when using such technologies ethical issues are inherent, such as student privacy and computer ethics, which have been matter of debate.

Innovation is a booster factor in the development of new technologies, for which it is necessary to find new answers concerning ethical boundaries and good practices. In this work, it is presented an application of an innovative scenario to improve eLearning experience by offering to the student appropriate music based on personal data collection from ECG and EEG. Such scenario raises ethical questions from different points of view: from the perspective of participants of the experiment, i.e. the users of the final system and among developers of the solution itself (e.g. research collaborators).

This document is organized as follows: next section is dedicated to the ethics topics sensitive to the presented scenario. In section III it is presented the smart system scenario, and it is discussed their sensitive ethical issues. Then in the next section it is proposed a procedure to solve ethical questions in the context of the ACACIA project that the scenario belongs to. Finally, are drawn some conclusions.

II. ETHICS

Nowadays it is common to do research in a collaborative way, rather than in isolation [2]. Ethics is an important issue in an international collaborative research. The goal of research ethics is to determine the moral acceptability of appropriateness of specific conduct and to establish the actions that moral agents ought to take in particular situations [3]. In one hand, International ethical codes and professional practice guide collaborative research in order to avoid unethical practices. On the other hand, the critical ethical issues of the concrete scenarios should be addressed. In this paper, regarding the proposed scenario which goal is to use music to enhance eLearning experience using biosignals (ECG and EEG) to detect student 's attention, addresses sensitive ethical issues related to the technological solution itself. Thus, the following sections introduce the ethical topics that in some how are related to it.

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A. *International Ethical Codes and Professional Practice*

International ethical codes and practices can be applied to many fields. Here are summarily presented in a broad view aspects of well-known international codes of ethics and professional practices that might be important to technological developments and research in the field of education technology, to which the case study under study belongs to.

1) Belmont Report

Belmont Report is summarily based on three basic principles [4]:

- Respect for persons – includes two different moral requirements: a) treat people as autonomous agents; b) protect individuals who have diminished autonomy. An application of this concept is the informed consent.
- Beneficence – two rules were formulated in this context: a) do not harm; b) maximize possible benefits and minimize possible harms. The Assessment of risks and benefits is a practical application of this principle.
- Justice – refers to the justly distribution of burdens and benefits. An application of this principle is the selection of subjects.

2) Declaration of Helsinki

Developed by the World Medical Association, the declaration of Helsinki is composed by a set of principles regarding human experimentation, including research on human material and data [5]. The first version was published in 1964, preceded by several other versions (1975, 1983, 1989, 1996, 2000, 2008, 2013). The later Declaration of Helsinki focused on the following summarized topics [5]:

- Risks, Burdens and Benefits – the medical research should be performed only if the objectives exceed the risks and burdens of the research subjects. Risks and burdens to the individuals and groups involved must be compared with the foreseen benefits for them and the target population that they represent. The physicians should be involved in a research if and only he/she believes that the risks have been appropriately assessed and can be adequately managed.
- Vulnerable Groups and Individuals – is considered a group of individuals that should be appropriately protected. Medical research should be conducted only if it is responsible for the group needs or priorities and if the research cannot be performed in a non-vulnerable group. The results of the research should benefit this group or individuals.
- Scientific Research and Research Protocols – research involving humans must agree with scientific principles. The animals' welfare must be considered. If the study involves human subjects, then a research protocol must contain its description and justification.
- Research Ethics Committees – this well classified committee is responsible to comment, guide and approve research protocols. It is important and must be maintained the independence of the committee from the researcher, the sponsor and any other influence. It must be considered also the legislation of the countries in which the research will be applied. In addition, international norms and standards must be taken in consideration. The committee also has the right to monitor the studies.
- Privacy and Confidentiality – can be voluntarily given by research subjects, although family or community leaders may be consulted in some contexts.
- Informed Consent – In medical research involving human subjects, they need to be informed about: aims, methods, sources of funding, any possible conflicts of interest, institutional affiliation of the researcher, the benefits and risks of the study. In addition, must be informed that is available to reject participate in the study without any redress. Individuals physically or mentally incapable of giving consent can be included in research if and only if the condition that causes the impossibility of give consent is the required to perform the study. If a patient refuses to participate in a study, it shouldn't ever affect the patient-physician relationship. For medical research using human material or data, the inform consent should refer to its collection or storage and/or reuse.
- Use of Placebo – should be avoided the abuse of this option.
- Post-trial Provisions – Provisions should be made for post-trial access for participants who still need an intervention considered beneficial in the trial.
- Research Registration and Dissemination of Results – The accessibility of research study in a public database before recruitment of participants is mandatory. Furthermore, researchers, sponsors, editors and publishers are charged with ethical responsibilities concerning the dissemination of research results. It also expected that researchers make research results public.
- Unproven Interventions in Clinical Practice – might be adopted after expert advice, informed consent from the patient, and if the physician believes that offers hope of saving life, re-establishing health or alleviating suffering.

3) Nuremberg Code

Nuremberg code refers to ethical principles for research with human individuals, expressing [6]:

- the necessity of the informed consent;
- benefit of the experiment to society;
- that study should have theoretical basis;

- the experimentation should be performed such that doesn't cause physical and mental damage and injury;
- that the risk should be balanced;
- that the experiment should be prepared in order to ensuring the protection of the experimental subject from injury, disability or dead;
- that the experiment should be performed by qualified persons;
- that the scientist responsible for the experiment conduction must be prepare to finish the experiment at any state if he/she believes that the experiment would cause injury, disability or death of the experimental subject.

4) Code of Professional Ethics of Association for Educational Communication Technology

Association for Educational Communication Technology (AECT) developed the Code of Professional Ethics [7] that includes several aspects that are related to the individual, the society and the profession. Concerning to "Commitment of to the individual" it mentions the protection of the privacy and the personal integrity of the individual. Furthermore, the individual should be protected from prejudicial situations to health, safety, including those caused by technology. It is fomented the use of current technologies in education.

5) IEEE Code of Ethics

The IEEE codes of ethics [8] encloses aspects such as the responsibility of taking decisions aligned with the safety, health and welfare of the public; to treat honestly all and do not evolve them in acts of discrimination; avoid injury others as well as their property, reputation, or employment by false or malicious action.

6) Software Engineering Code of Ethics and Professional Practice

The Software Engineering Code of Ethics and Professional Practice [9], was developed based on the following principles: public, client and employer, product, judgment, profession, colleagues and self. Concerning public, in a broad view, professionals should act accordingly with public interests. Furthermore, it is stated, for example, that "software should be approved only if is safe, meets the specifications, passes appropriated tests, does not diminish quality of life, diminish privacy or harm the environment" [9]. Regarding the product it defines, among others, that software engineers should consider ethical issues related to work projects and maintain the integrity of data.

B. Privacy in ICT

According to Berman et al. [10], "IoT will sharpen the tension between individual privacy and the use of personal information to promote effectiveness, safety, and security". Privacy has a huge impact when considering data storage and those computational systems that manipulate that data. According to Baggett [11] "privacy (in relation to technology) is one's right to be left alone from personal intrusions and the ability to determine how much of one's personal information should be communicated to third parties". Blarkom et al. [12], interpret the characteristics of information privacy, the right to be left alone; and the right to decide oneself what to reveal about oneself, as including rules of conduct that guide the interaction between the individual and the person's environment, concerning personal data processing in the Internet environment.

Two points of view concerning data privacy in systems can be considered: 1) the persistence of user data in the system, 2) the purpose of use of the data itself. Thus, information privacy can refer to data stored and communicated among devices as well as information circulated between parties (e.g. email, wireless communication devices) [13]. For instance, when the goal of the system is to discover personal patterns using data mining, a debate has been emerged. An application of data mining is web-data mining in which the whole of data mining and techniques are used to automatically discover and extract information from web documents and services [14]. In that context, despite data can be made anonymous before the computation of the user group profile and thus with no reference to the personal data itself, those group profiles can be used to unfair judgement of people [14]. At personal level, can be used privacy enhancing technologies (PET) which "stands for a coherent system of ICT measures that protects privacy by eliminating or reducing personal data or by preventing unnecessary and/or undesired processing of personal data, all without losing the functionality of the information system" [13]. Specifically, PET are grounded in seven main principles : "1) limitation in the collection of personal data; 2) identification/authentication/authorization; 3) standard techniques used for privacy protection; 4) Pseudo-identity; 5) Encryption; 6) Biometrics; 7) audit ability." [14]. Solutions at collective level are those implemented by government or other organizations. Information privacy, especially in democratic countries, is acknowledge and stablished in treaties, EU directives, national laws, and other regulations [14].

1) Bioethics

Bioethics is a term proposed by Rensselaer Potter [15] in 1970, that can be defined nowadays as: "the systematic study of the moral dimensions – including moral vision, decisions, conduct, and policies – of the life science and health care, employing a variety of ethical methodologies in an interdisciplinary setting" [16]. An important factor that has been affecting bioethics is the emergence of innovative technology [17], such as in biotechnology. Biotechnology is known as "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use" [18]. Key areas of research in biotechnology are: cellular biotechnologies and regenerative technologies, genetic engineering, pharmaceutical biotechnology, personalised medicine, synthetic biology and biological applications of nanotechnology, such as biosensors [19]. Nanotechnology, which can be seen as "concerned with the development and use of structures and devices with organizational features at the intermediate scale between individual molecules and about 100 nm where novel properties occur as compared to bulk materials." [20]. Ethical issues related to nanotechnology include several areas, such as: equity, privacy, security, environment [21]. Though wireless technology in medicine is not new and provides many useful

applications in medical monitoring systems to measure physiological data, nanotechnology can improve the technology by decreasing it in size, better properties, and more similar to natural tissues [22].

2) Neuroethics

Neuro-ethics refers to issues raised by neuroscience as it affects our understanding of the world and of ourselves in the world. At present, there are two main categories related to the neuro-ethical issue: 1) issues related to what we can do with neuroscience and these are the technological aspects of functional neuroimaging, brain-machine interfaces and 2) issues related to what we may know from neuroscience with regard our understanding of the neural bases of behavior, personality, consciousness, and states of spiritual transcendence.

In terms of neuro ethics several aspects should be taken into consideration. As far as concerns the research issues these are connected to reliability and validity. A general problem posed by neuroscience techniques is the apparent objectivity of visualizing the '*brain in action*'. The complex assumptions required for jumping over the gap between subjective experience and electromagnetic signals is a main issue. Complex phenomena such as social attitudes and behavior are difficult to be grasped by simplified scenarios of neuroscience, applying video games or faces on a screen instead of real social interactions [23]. The possible benefit of predictive imaging would have to be carefully weighed not only against possible harm but also against the burden of knowledge and the possible discriminations.

Another aspect is dealing with privacy. Brain processes are intimately bound to ourselves and personal identity. Our sense of privacy may be threatened by technologies that can reveal the neural correlations of our inner thoughts and unconscious attitudes [24]. In future, could be exploited for such purposes as screening job applicants, assessing insurance risks, detecting a vulnerability to mental illness, determining who qualifies for disability benefits, and so on [24].

III. Application Scenario

The application scenario refers to the implementation of a smart system that will be able to infer emotion and attention analysis based on biosignals using wearables, specifically ECG and EEG. That system will suggest recommendations such as a pause in study, adjust volume, presence/absence of music based on the attention of student.

This scenario system's architecture uses a cloud computing approach under the paradigm of IoT. IoT allows people and things to be connected Anytime, Anyplace, with Anything, and Anyone, ideally using Any path/network and Any service [25]. By definition, cloud computing: "is a model for enabling ubiquitous, convenient, on-demand network access to a share of pool configurable computing resources (e.g., networks, servers, storage, applications and servers) that can rapidly provisioned and released with minimal management effort or service provider interaction" [26]. One of the aspects clearly related to privacy is the data from users that are stored in the cloud and which may lose control from who has access and usage rights [27].

This architecture has the following function mode (Figure 1): the student logs in the system (1); gets the student's music profile from the cloud (2); the student has the option to turn on/off the music (3) while are being collected data from his/her ECG (4) and EEG (5). These signals are measured and recorded into the cloud (6); then an attention analysis based on those values and students' profile using data analytics is performed (7); based on such analytics the profile of the users is acquired and improved, which is also recorded in the cloud to use in further iterations (8).

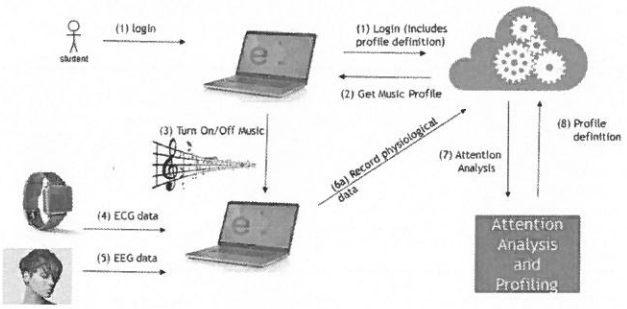

Fig. 1. Scenario Architecture

This architecture is partially implemented. Several parts of it, such as the ECG data acquisition using Arduino and the ECG features calculation to perform further data mining operations has already been tested. What is missing to accomplish all the architecture development is to integrate all of its components. Furthermore, a first study about it was also published, which paper is entitled "Student's attention improvement supported by physiological measurements analysis" [28]. Its main objective relates to the measurements of physiological signals as a basis to improve students' attention in eLearning context. It analyzed the effect of music in students' attention and arousal in eLearning environment. As a result from such study it was concluded that better attention was achieved in courses with music. This result was supported by the analysis made over the ECG data, which obtained the Heart Rate Variability LF and HF parameters decreasing simultaneously, as can be seen in the graphs of the figures 2 [28]. This means as proved by [29] that attention increased on that moments. This was also concluded in the experiment made.

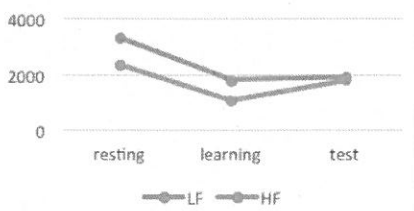

Fig. 2. Average LF (ms^2) and HF (ms^2) for a scourse with no music [30].

Thus, the study of the parameters (LF and HF) proved that Heart Rate Variability features might be a good source of information to detect personal user's attention patterns using machine learning. Additionally to this study the authors also identified among various other research works as in [30] that the

following features, this means a specific data analysis over the ECG signal, should be also used in a work like this one.

- Standard deviation.
- Standard deviation of NN intervals (Normal-to-Normal intervals).
- Square root of the mean of the sum of the squares of differences between subsequent NN intervals (RMSSD).
- The number of successive differences of intervals which differ by more than 50 ms, expressed as a percentage of the total number of heartbeats analyzed (pNN50).
- The integral of the probability density distribution divided by the maximum of the probability density distribution (HRV triangular index).
- The triangular interpolation of NN interval histogram (TINN).
- Power VLF.
- Power LF.
- Power HF
- LF power nu.
- HF power nu.
- LF/HF power ratio.
- Approximate entropy.
- Detrended Fluctuation analysis features.
- The standard deviation related to the points that are perpendicular to the line-of-identity $RR_{n+M} = RR_n$. It describes the HRV short-term variability. Based on Lagged Poincaré Plots (SD1).
- The standard deviation that describes the long-term dynamics and measures the dispersion of the points along the identity line. Based on Lagged Poincaré Plots (SD2).
- The ratio between SD1 and SD2. Based on Lagged Poincaré Plots (SD12).

There are other potential features, to be used as well in conjunction with the previous ones, which are more general but not less important as grades of courses, ethnicity and gender as proposed by [31, 32].

The EEG application inside this same application scenario (see step 5 in Figure 1), integrated the Neurosky headset supported by a brain-computer interface (BCI) technology, which works by monitoring electrical impulses with a forehead sensor. The headsets sense the electrical activity inside a person's brain using a technique known as electroencephalography, or EEG. Such BCI come in two varieties. Noninvasive techniques use electrodes placed on the scalp to measure electrical activity. Invasive procedures implant electrodes directly into the brain. In both cases, the devices interact with a computer to produce a wide variety of applications. The general architecture of this particular step of the overall application scenario is presented in Fig. 3.

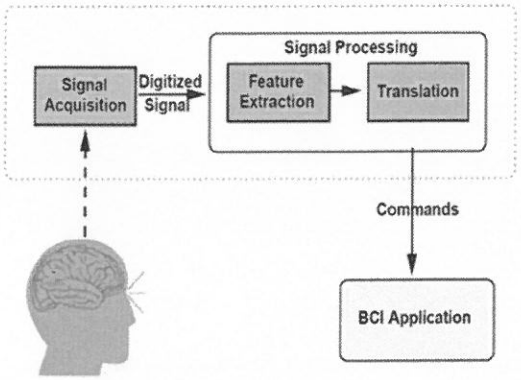

Fig. 3. EEG Architecture.

Neurologists can identify patterns in a patient's brain wave activity, allowing them to spot abnormalities that could give rise to seizures or other neurological disorders. Brainwaves are tiny electrical impulses released when a neuron fires in the brain. The neural signals are input into our ThinkGear chip, and interpreted with patented Attention and Meditation algorithms, which integrates specific features for the EEG signals. The measured electrical signals and calculated interpretations are then output as digital messages to the computer or mobile device, allowing one to see its brainwaves on the screen, or use its brainwaves to affect the device's behavior.

1) Ethical issues handled in the scenario

Ethical issues that arise from such type of research are set forth in an ethical contract concluded between the developer/researcher and the user. The ethical contract grounds moral decisions on a mutual agreement between parties. Information that is usually stipulated in such ethical contracts: 1. How much information will be provided to the user of the system that uses emotional detecting biosensors; 2. Types of emotions that the system will be gathering; 3. Who will have access to the recognition results and 4. How these results will be stored and used.

Special attention is also required towards cases like this that implies working with sensitive user groups, dealing with technological complexity, and handling multidisciplinary teams. Managing the expectations of a novel technology is important on different levels, ranging from individual users to legal representatives to the general public.

B. Ethics resolution of technological application scenarios in ACACIA Project

The aforementioned scenario has been developed in the context of ACACIA, which is a collaborative research project. ACACIA aims to face specific problems such as forms of exclusion and discrimination and marginalization due to disparity and/or inequality affecting Higher Education in Latin and Central America. To face those challenges are constructed pilot centers, namely CADEP, in the universities Universidad de las Regiones Autónomas de la Costa Caribe in Nicaragua,

Universidad Distrital Francisco José de Caldas, in Colombia, Universidad Nacional Mayor de San Marcos in Perú.

1) CADEP

The ACACIA CADEP define a system of centers that support the professional and educational development that support, cultivate, adapt, communicate, and receive the experiments, resources, teams, problems solutions that require the professional development of their members to decreases the student desertion, to modernize its organizational structures in order to respect others and their differences. That structure can be seen as a new institutional tool to detect, study and solve problems that a university or professional program can't face in an isolated manner. CADEP ACACIA includes an integrated system of modules ("Empodera", "Innova", "Cultiva", "Apoya" and "Convoca") that follow the students at risk, offers training and support for university members, explores with a laboratory implementation new strategies for teaching and for innovative ICT in didactic practices. To solve the problem addressed Convoca module will contribute to this solution.

2) Convoca

Convoca is the module responsible to articulate different elements of CADEP, both at internal and external levels, and offer the guidelines to evaluate the action of the modules and CADEP. The development of the articulation function implies the definition of relations and protocols between modules, universities, external entities (governmental and non-governmental institutions) and other CADEP, that allows to support actions and activities implemented by CADEP. The development of the evaluation function implies processes definition, procedures and indicators of the modules and CADEP that allow determining the performance.

The development of functions and activities of the CADEP implies design the technological application and handling information about persons to whom the CADEP offers alternative solutions. In the design of technological applications should have special consideration about the implications and impact that it can generate on persons that use them. Handling personal information of those that benefit from alternatives offered by CADEP also should be a matter of consideration, since it's confidential.

In this context, Convoca module in its articulation function, should allow to establish relations and cooperation protocols with the universities and external entities (governmental and non-governmental institutions) that allow to define guidelines to the design of technological applications to control the consequences and impact that it may have on people. In the evaluation function should be defined the processes and procedures of handling information, that should be according to the regulation of the country where functions the CADEP. In Figure 4 it is possible to appreciate how the Convoca functions are applied both internally and externally.

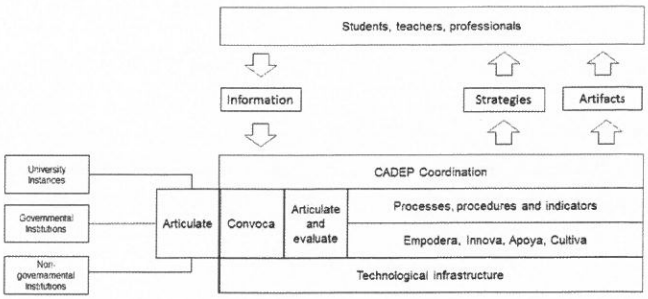

Fig. 4. Functions of Convoca.

The presented application scenario was defined before the establishment of the CADEP but, if it was today, the way Convoca would handle it is illustrated in the following:

In a university that has a CADEP a teacher requested support to help students to pay more attention and improve their emotional state. The CADEP coordination receives that request and committed to provide an alternative that allows supporting the students' work. Posteriorly the CADEP coordination summons the meeting to the module coordinators to evaluate the case. In the meeting, it arises the design of a technological artifact (a software and devices), namely a smart system to enhance students' attention in online courses that suggests appropriated music based on the biosignals using ECG and EEG. From this decision, modules work producing guidelines to the design of the technological solution and later its delivery, integrating student's training in the management of the artifact.

To this type of solutions, Convoca module intervenes with the following actions:

1. Establish contact with departments of the university that allow to evaluate the consequences and impact that generates the use of the technological solution by teachers and students, such as offer guidelines for its development. Among the dependencies that offer guidelines are the ethical committee and institutional wellness of the university that evaluate and present recommendations to the use and development of the technological artifact.
2. The module coordinators get in contact with the previously mentioned dependencies to receive the evaluations and recommendations.
3. The technological artifact is developed according to the recommendations.
4. In the process of artifact development are interviewed students from which is acquired personal information.
5. The members of the modules store the students' personal information following the established procedures to manage the information. These procedures establish the protocol to manage of the students' personal information that benefit from the technological artifact that are designed in the CADEP. The Convoca module defines those procedures.

6. Convoca module performs periodical audits of compliance with the requirements.

In a case of non-compliance, i.e., any violation concerning regulation governing human research or any deviation from ethics committee approved protocol; Convoca must report the issue to the ethical committee chair. Additionally, principal researchers may also report incidents of non-compliance as well as any member of the study team, ethics committee members, and research participants. The ethics committee is responsible to determine whether non-compliance occurs. Ethics committee at first review reports of non-compliance, then inspect written materials, conducts interviews and collect relevant documentation. Based on the acquired information, the chair will produce a resolution report. Such report may determine to suspend or terminate the study, modify the research objective or procedure, include frequent committee reviews, require that the principal researcher and study team receive training about ethics, limit the research of the researcher, monitor the inform consent process, or just conclude that no further action is necessary.

The presented scenario, as mentioned before is still under development, however it already took the following initiatives expecting to be in line with this 6-step procedure.

During the initial conducted prospective experiment was demonstrated respect for the participants, as autonomous agents according to the ethical principles and guidelines for the protection of human subjects of research of Belmont Report. As recommended by the Nuremberg Code and Declaration of Helsinki, the inform consent form used in the conducted experiment, informed participants about the aims, methods, sources of funding the benefits and the risks of the study. Additionally, they were also informed that they could refuse participate in the study without any reprisal. The experiment is considered to be aligned with the guidelines given by the Nuremberg Code since the experiment intends to benefit the society, the study has theoretical basis, the experiment was prepared to ensure the protection of the participants from injury, and because of that qualified persons performed it.

Additionally, the procedure was defined in considerations to contribute to the welfare of the target population, which is in line to the IEEE Code of Ethics and the actions were performed accordingly to their interests, which is aligned with the Software Engineering Code of Ethics and Professional Practice as well.

Thus, in the technological implementation the privacy and the personal integrity of the individual has been protected, and the integrity of data intends to be maintained. This will follow the PET paradigm mainly because the scenario presuppose the storage of personal data, provided from ECG, EEG and other personal information to then accomplish data mining able to detect user patterns to finally perform recommendations appropriately. Furthermore, the proposed technological solution has to include the bioethics topic since physiological signals from the participants are acquired.

IV. Conclusions

International collaborative research benefits from many advantages including knowledge, resources, and costs sharing, as well as joint efforts to publish original work. In such collaborative environment, ethical issues play an important role, since it is crucial to operate in a serious and reliable manner.

The aforementioned scenario has been developed in the context of ACACIA, an international collaborative research project, which aims to fulfil solutions concerning specific problems (e.g. forms of exclusion, discrimination and marginalization). A set of centers, called CADEP are projected in the scope of ACACIA, which are composed by a system of modules. Among them is Convoca whose responsibility is to articulate elements of CADEP both at internal and external level. Concerning ethics, Convoca proposes a 6-step procedure, which main step is to contact the university instances to evaluate the impact of using such technological solutions, to then provide an evaluation and recommendations to developers.

It is expected that such procedure facilitates the deployment of technological innovations in education. On the one hand, a technological scenario as the one proposed can offer a tool to contribute to the decrease of student dropout in Latin America Universities. On the other hand, such technologies raise always issues related to the privacy of data [10]. This delays the introduction of technological innovations to the educational system. Despite having always a discussion like this, it is necessary to clear and save all the privacy of all the stakeholders of such system deployment.

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