A five-layer approach in Collaborative Learning Systems design with respect to emotion

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Abstract—This work presents a position paper that first reviews in depth the state of the art in Collaborative Learning Systems design with respect to emotion and then proposes a new conceptual framework that takes into account a five layer approach that considers physiological, emotional, sociological, technological and educational aspects in relation to learning. This study reveals the need for a more situated and affective Computer Supported Collaborative Learning system.

Keywords: Affective computing, CSCL, HCI, e-learning, e-education, emotion, emotion research, affection, ITS, VLE

I. INTRODUCTION

The advancements of education technology (Virtual Learning Environments-VLEs, Computer Support Collaborative Learning-CSCL, Intelligent Tutoring Systems-ITS) endue students with the opportunity to select their own teacher (school teacher, another peer, another system e.t.c.), their own curriculum, their own assessors [1]. However, we are still talking about the promise of this technology while searching for the leverage that will encourage its widespread adoption and classroom use. [2]. CSCL researchers evaluate group activities and systems using quantitative and qualitative data that describe impact on the cognitive aspects of engaging in activities. In contrast, there is a lack of experimental research to evaluate the affective aspects of these group activities [3].

A pure cognitive approach, one that omits consideration of emotions, motivations, and the like, paints an artificial, highly unrealistic view of real minds. Minds are not either cognitive or emotional; they are both and more [6]. Emotions are present in any form of education: learners worry, hope, become bored, embarrassed, envy, get anxious, feel proud, and become frustrated, and so on [7]. The innovative Human Computer Interactions-HCI models tend to focus exclusively on cognitive factors and are often unable to adapt to real-world situations in which affective factors play a significant role [4].

In their scientific meaning, emotion and affection are terms that are mostly used by psychologists. Unfortunately, CSCL systems, in their majority, are not designed by psychologists. The effective use of a new educational technology must be guided by a research-based theory of how students learn [8]. Advances in Cognitive Sciences (Cognitive Psychology, Artificial Intelligence, Neurobiology) provide the starting point of such theories.

There are two trends predominate when it comes to design learning systems and environments with respect to emotion/affection. First one is based on recognising, decrypting and exporting patterns of emotion/affection from user-to-computer interaction. What the user/student really wants and feels in a specific time and space, is appraised as valuable information that can lead into real personalised computers systems. The possibility of ITS that trace students’ emotions is an attractive concept [9].

The second approach is closer to the pure educational reality. It is questioning not only how to educate by using emotion/affection, but also how to educate emotion/affection. There have been substantial theories set forth, acknowledges the existence of emotion in relation to learning [4, 10, 11, 12].

II. BACKGROUND

When Cognitive Psychology was established by Ulric Neisser’s book “Cognitive Psychology” (1965), emphasis began shifting from the construction of meaning to the processing of information [13]. Human mind could be understood and studied as complex information processing system [14], leaving Behavioural theory (Watson, Thorndike, Skinner) behind.

Since then, Cognitive Psychology has dominated for more than three decades, endowed by the rapid evolution that was attained in Computer Science and Neuroscience. This trend has been acclaimed as the ‘cognitive revolution’ in psychology. Within the framework of mind dominance, emotions were one particular form of cognitive processing that was determined by cognition. This approach to emotions however has been proven inefficient to explain many emotional phenomena of everyday life [15].

Psychology turned to Cognitive Psychology, ignoring creative thinking and consciousness, and Cognitive Psychology has been dominated by Cognitivism, leaving human emotions out of question. By keeping terms like emotion and subliminal processing in the background, Cognitive Psychology reached its deadlocks [16]. As D.A. Norman has acknowledged [16], “the organism we are analysing is conceived as pure intellect, communicating with one another in logical dialogue, perceiving, remembering, thinking when appropriate, and reasoning its way through well formed problems that are encountered during the day. Alas that description does not fit actual behaviour”.

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Research convergence from different research domains (Neuroscience, Artificial Intelligence, Sociology e.t.c.) and “in vivo” study of the subject, can reveal a path out of the deadlocks. Emotion Research can improve the state-of-the-art in CSCL. Nevertheless, a more deep and complex process is required to describe a learning system that takes emotion into account. Next section provides a startup in this direction.

III. A FIVE-LAYER SYSTEM DESIGN APPROACH WITH RESPECT TO EMOTION: A CRITICAL REVIEW OF THE STATE OF THE ART

Influenced by B. Davou’s multidimensional approach (Neuro-Bio-Cognitio-Emotio-Socio-Cultural) of human behaviour [15], and in analogy to the layer model of network communications, we describe a five (5) layer approach in designing collaborative learning systems with respect to emotion.

A. Physiological (Biological) Structures- (Layer 1)

When an axon of cell A is near enough to excite cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A’s efficiency, as one of the cells firing B, is increased. 

Hebb’s Law (1949)

This is often paraphrased as "Neurons that fire together, wire together" and is often described as the basis of neural networks. Every new piece of information is imprinted through neurosynaptic changes in the form of:

- Morphological transformations in neurons’ structure and synapses via the creation of dendritic spikes.
- Biochemical cellular processes that also elaborate the composition of new proteins [18].

The above is ascribing the cognitive basis of learning. We learn, because of an electromagnetic to biochemical transformation of energy; because our cells are able to remember and join together, in order to survive. In cognitive terms, those synapses are semantically crystallised into cognitive tokens, -e.g. propositional units in propositional networks, or cognitive schemas- that are able to pursue reasoning in human language.

Whenever an external stimulus is perceived by a sensory modality, it travels inside the human neuro-network by triggering specific neurotransmitters, following the pathway of the human brain evolution, before being redistributed to the cortex for analysis. On this pathway, D. Goleman [9] discriminates the following important brain parts that play a less or more crucial role in the stimulus’ decryption process:

- The old/emotional brain that featured by:
  - The Brain Stem or Primitive Brain (MacLean’s Reptilian Brain [19]) that regulates Cardiac and respiratory function.
  - The limbic system (Hypothalamus, Amygdala, Hippocampus), the seat of emotion memory and attention.
- The thinking/cognitive brain (Neocortex or Cortex) that is involved in higher functions, such as sensory perception, generation of motor commands, spatial reasoning, conscious thought and language.

In other words, there are two brains: the emotional and the cognitive, which reside in different locations in the cerebrum. The above three distinct brains (Brain Stem, Limbic, Neocortex) emerged successively in the course of evolution and now co-inhabit the human skull [19].

Amygdala and Hippocampus have a privileged position in perception, a point where everything converges. Sensory signals go from the hypothalamus to the amygdala in 15 milliseconds and from the hypothalamus to the cortex in 25 milliseconds [21]. As a result, the amygdala is creating emotional responses before the cortex has even received the signal to be processed. However, the amygdala has limited pattern recognition capabilities compared to the cortex, and performs “a quick and dirty” pattern recognition and response. A stimulus is firstly, and above all, appraised if it is a threat. The amygdala has presumably been structured in answer to one critical question for survival: Do I eat it or does it eat me? Brain is able to sense fear before human can think of it (D. Goleman).

B. Emotion/Affection Consideration (Layer 2)

Emotions have wittingly neglected from scientific research, and there is one significant reason for that; “everyone knows what emotion is until they are asked to define it” [21]. Emotions have a stigma in science; they are believed to be inherently non-scientific [5]. Emotion research is susceptible to the risk to be focused on subjective emotional experience. However, recent neurological studies have proven the essential role of human’s emotional centers not only in perception and learning, but also in decision making [22].

Emotion, Affect, Feeling

The words affect, feeling and emotion are often treated as synonyms. Emotions can be considered to rise from the...
The basic circuitry that aims to satisfy the primary human needs (survival, feed, protection from natural threats, breeding, sociality, etc.) is called Regulatory System by D.A. Norman. This system's requirements are the roots of the Cognitive System that is going to be developed, later on. In other words, the Cognitive System tents to serve the Regulatory System, and not the opposite, as commonly believed by humans [17].

C. Sociological Aspects (Layer 3)

Man is by nature a social animal; and an unsocial person who is unsocial naturally and not accidentally is either unsatisfactory or superhuman (Aristotle).

In Social Psychology, concept representations are both intrapersonal and interpersonal. The person’s thoughts are communicated through the channel of a ‘social representation’ to another mind. One is ‘present’ to oneself as one communicates, and, if ‘reification’ can be avoided, one becomes present to another in consensual meaning [26, 27].

The human brain is able to decrypt new information according to experiences that are being stored in its "cognitive database". Whether the selected place for the new data is ecological [15] or not, whether new cellular synapses will strengthen or atrophy, it will be confirmed by individual’s everyday life, by his or her social reality in a specific time and place. The frequent recall of a concrete piece of information to satisfy different needs, to resolve various problems, confirms its validity and ensures a place for it in the long-lasting memory.

Alike the Neural and the Propositional Networks, the Semiotics Networks Theory has been developed with respect to “Situative” perspective [28]. These networks are semantic representations that are built by the participants (actors), modified and adapted in a way.

Bibb Latané put forward the Dynamic Social Impact Theory-DSIT [29], which views society as a self-organizing complex system where individuals interact and impact each others’ beliefs. Social structure is the result of individuals influencing each other in a dynamic and iterative way. The likelihood of being influenced by someone nearby, rather than far away, (the immediacy factor) produces localized cultures of beliefs within communication networks [30]. DSIT provided the basis for SITSIM, a simulation program designed to trace the expected evolution of populations of people following the assumptions of social impact theory [31].

D. Technological Applications (Layer 4)

If we want to build real personalisation systems, we must consider not only user preferences, but also user emotional/affective state. Affective computing is computing that relates to, arises from, or deliberately influences emotion or other affective phenomena [5].

Affective elements in the analysis of the interaction with the student, has become an increasingly prominent theme in recent years. This is due to a clear evidence of correlation between affect and learning [33]. An 'emotionally intelligent' tutoring system (or any learning
Affect measurement can be grouped into three areas: collaborative activities in which data can be recorded, collaboration is setting up controlled, yet meaningful sensors are not used, and emotional states, which is much better than when these sensors are not used. Summaries of this physiological activity can help tutors tutoring software for students in real educational settings. Inferred from physiological data that is streamed to the computer systems, EMA-Emotion and Adaptation, Miró, system (WinWhatWhere Investigator, Kismet, Wearable computer systems, EMA-Emotion and Adaptation, Miró, Affecter, Augsburg Biosignal Toolbox, AutoTutor e.t.c.) successfully detecting some affective states (e.g., pleasure when the computer fixes his/her spelling, then the computer should continue applying its spell-fixing behavior. If the user expresses annoyance, then the computer should consider asking the user if he/she would like that behavior turned off or adapted in some other way.

There have been various updated endeavours in modelling the management of emotions and affectivity in Intelligent Systems. Research has focused on automated detection of affective states in a variety of learning contexts and it has shown promising results by successfully detecting some affective states (e.g., frustration or boredom) within one intelligent tutoring system (WinWhatWhere Investigator, Kismet, Wearable computer systems, EMA-Emotion and Adaptation, Miró, Affecter, Augsburg Biosignal Toolbox, AutoTutor e.t.c.) [3,5].

Students’ self-reports of emotion can be automatically inferred from physiological data that is streamed to the tutoring software for students in real educational settings. Summaries of this physiological activity can help tutors predict more than 60% of the variance of students’ emotional states, which is much better than when these sensors are not used [9].

The first challenge posed by the study of affect in collaboration is setting up controlled, yet meaningful collaborative activities in which data can be recorded. Affect measurement can be grouped into three areas [41]:

1) Physiological signals (skin conductance, heart rate, blood pressure, respiration, pupillary dilation, electroencephalography-EEG, muscle action potentials e.t.c.)

Drawbacks: Necessitates specialized and frequently expensive equipment and technical expertise to run the equipment. This method is often obtrusive or even invasive.

2) Behavioral (facial expressions, voice modulation, gestures, posture, cognitive performance, cognitive strategy, motor behavior e.g. hand muscles, head movement, corrugator’s activity)

Ekman’s Facial Action Coding System (FACS), constitutes the most significant example of this category.

	| Computer | Cannot express affect | Can express affect |
|----------|-----------------------|-------------------|
| Cannot perceive affect | I | II |
| Can perceive affect | III | IV |

The IV category is providing truly “personal” and “user-friendly” computing without implying that the computer would be driven by its emotions. The guiding principle of pleasing the user is greater than the guiding principle of maximal efficiency. Thus, if a user expresses pleasure when the computer fixes his/her spelling, then the system should continue applying its spell-fixing behavior. If the user expresses annoyance, then the computer should consider asking the user if he/she would like that behavior turned off or adapted in some other way [34].

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Drawbacks: These methods are tested almost exclusively on “produced” affect expressions. Recognition accuracy would drop heavily in natural situations. Furthermore, video cameras are considered obtrusive.

3) Psychological (self-reports, rating scales, standardized checklists, questionnaires, semantic and graphical differentials projective methods).


Drawbacks: People can feel pressed to give wrong answers. They are considered retrospective and assess the conscious experience of emotion and mood, but much of the affective experience is non-conscious. Questions about affect are potentially influenced by when they are asked.

Klaus R. Scherer differentiates three major schools of emotion recognition: the basic emotion, the emotional dimension, and the eclectic approach. In the basic emotion theory, patterns are equivalent with basic emotions, emotions that can be easily recognised universally, in most of the people, in most of the countries. In the emotional dimension, researchers acknowledge the Heller & Nitschke dimensions: Arousal (calm/excited), Valence (negative/positive) and Control/Attention (contempt/surprise) [36]. The eclectic approach consists in choosing verbal labels that seem appropriate to the aims of a particular study, choosing terms from the rich affect vocabulary.

Manfred Clynes’ has mentioned seven principles for sentic (emotional) communication, which pertain to “sentic states”, (a description given by to emotional states) [35]. R. Calvo has tested pattern recognition strategies that were used to detect successful learning processes, in order to detect combination of affective sequences that produce satisfactory results [3].

E. Educational Perspectives (Layer 5)

If we are able to recognize emotion and affection, the next step is to find out what to do with this decrypted information. Technology must not be viewed as a way of automating education and reducing costs, without changing the traditional way of view of education [39]. One can never go from a scientific finding to an educational practice [12]. Any finding has a multitude of implications, none of them consistent with one another. When designing systems for educational purposes, educational goals must be clearly stated.

How effective can education systems be if we are indifferent to “what’s on the student’s and teacher’s minds”? It is important to help students know how and when their “emotional intelligence” works to help or hinder their success. A student with a positive disposition would see an F on a math test as evidence that he needs to

1 Clynes emphasizes that emotions modulate our physical communication; the motor system acts as a carrier for communicating our sentic state.
work harder, while another may see it as evidence that he is stupid [10]. When negative emotions create a pessimistic perceptual attitude they divert the learner’s attention to aspects irrelevant to the task which activate intrusive thoughts that give priority to a concern for a well-being rather than for learning [38]. When fear is present, learning is leaving [21].

A typical learning experience involves a range of emotions, cycling students around a four quadrant cognitive-emotive space as they learn [4]. It is important to recognize that a range of emotions occurs naturally in a real learning process, and it is not simply the case that the positive emotions are the good ones. The negative half is an inevitable part of the learning cycle. Our aim is to help students to keep orbiting the loop, teaching them to propel themselves, especially after a setback.

M. Csikszentmihalyi identifies a zone, where most of the people have concentrated their attention so intensely on solving a problem or doing things that they lose track of time [11]. Nothing else seems to matter; the experience is so enjoyable that they will do it even at great cost, for the sheer sake of doing it. Such “flow”, is “optimal experience” that leads to happiness and creativity. If a task is not challenging enough, boredom sets in, while too great a challenge results in anxiety, and both cases result in task, and thus learning, avoidance. A learning environment in which students are challenged at an appropriate level, which can produce flow, will be more productive.

With respect to individual-centered education, Howard Gardner’s Multiple Intelligence (MI) theory introduces a concept of a model that respects the various talents, inclinations, proficiencies, abilities, the multiple forms of intelligence [12]. According to MI theory we each have, not a single one, but eight or more intelligences\(^2\), and we can use them to carry out all kinds of tasks. Multiple Representations of Key Concepts can be applied in a way that suits to the student’s needs and goals.

Daniel Goleman [10] presents convincing evidence that the emotional intelligence quotient (EQ) is just as important in academic success as cognitive intelligence, as measured by IQ or SAT scores. He is referring to a variety of self-help programs (Transaction Analysis, Self Science) that have been developed to assist people in gaining control of their emotions. This is different from suppressing the emotions. Rather, the goal is to get in touch with feelings, to know what causes them and to take appropriate action in response to them.

IV. A NEED FOR A MORE SITUATED AND AFFECTIVE CSCL SYSTEM

CSCL applications for on-line collaborative learning are characterised by a high degree of user–user and user–system interaction and there has been a plethora of collaboration platforms and monitoring systems (Tatiana, Argonaut, Knowledge Space Visualiser, CANS e.t.c.). However, most of the existing learning systems still have limitations when used by students in real settings [39] or have difficulties in connecting with the teachers needs.

Current e-learning design often fails to situate the learner within the context resulting in a lack of engagement in electronic learning, while the content still remains poor [40]. Furthermore, most of the past research efforts, have been conducted in laboratory experiment settings, in small groups of university students, leaving almost unexplored the age of secondary education, at which emotions are easier expressed and “in vivo” studies can be easier guided.

Emotional scaffolding can improve the state-of-the-art of CSCL [32] and real life observation would be the ideal study to aid the development of the theory of emotions [5]. R. Picard [42] envisioned involving participants in richer ways than as paid subjects, enabling people to learn about their own data and benefit directly from findings in a study, while also contributing to online analysis (visit. http://www.experience-sampling.org/, for more details).

Research literature has produced successful recognition techniques that classify physiological and neurophysiological signals, behavioural data and text/speech into different sets of emotions. Emotion researchers should bear in mind that affect measurement must assess user affect in parallel with real-life task processing in an unobtrusive and non-invasive way. Wearable technologies can be deployed comfortably without encumbering daily activity. However, they cannot be easily adopted in a school experiment, because of their high cost.

An inexpensive, unobtrusive, non-invasive way of measuring affect directly on the computer without any additional devices, concurrent with the task performed is through motor-behavioral parameters from the standard input devices like mouse and keyboard [41].

Additionally, we have to consolidate all those applications that aim to the school age where is more feasible to unfold pure emotional and affective aspects of cognition. There is a need to develop and design methodologies that are pedagogically guided and which would handle the emotional/affective systems of learning [3]. We can turn teachers to researchers and train them to learn how to learn, as “meta cognition seems to work” (Naomi Miyake). Instead of developing only complex monitoring applications, we can also use those teachers that have already built the bridge of trust with their students, and can easily decrypt what’s on their minds.

The role of affect in learning is at best in its infancy and there is still much to be discovered. There is a lack of research projects that take into account emotion and affection in learning in secondary education. Designers must keep in mind to offer true-to-sCHOOL aspects. If we can design learning conditions conducive to flow, perhaps our students will wish to learn. If we can mobilize the spectrum of human abilities, students will feel better about themselves, more competent, more engaged and better able to join the rest of the world community in working for the broader good [12]. That’s a real collaboration.

\(^2\) Linguistic, Logical-mathematical, Musical, Bodily-kinesthetic, Spatial, Interpersonal, Intrapersonal, Spiritual & Natural
V. CONCLUSION

We have tried a critical review of the state of the art in collaborative learning system design approach with respect to emotion. In our analysis, we proposed five layers that must be considered: (a) Physiological/biological transformations that are taking place in the brain circuitry behind cognitive and emotional possessing. (b) The critical role that emotions play in relation to attention, memory and decision making. (c) The sociological need to “situate” learners in context, if we want to guide information processing in the right “ecological” way. (d) Affect recognition tools and methods that are used to mine patterns that lead to successful learning processes. (e) Educational perspectives of individual-centered models that promotes emotion in learning.

Finally we address the need for more situated and affective CSCL systems. Affective computing provides the technology needed on that direction. How real are, however, students’ reactions when they know that they are taking part in lab experiment that is trying to explore their deep emotional thoughts? Maybe it is the right time to exploit the real emotionally intelligent teachers that have spent hundreds of hours to built effective relationships with their students; the right time to turn teachers into researchers.

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