Quantum entanglement and the emergence of collaboration in social media

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Quantum Entanglement and the Emergence of Collaboration in Social Media

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Abstract

In this paper we devise a slightly modified version of the Vote with the Wallet Game used by Becchetti et al.(2015, 2017) to the use of Social Media, where the player decides whether to responsibly share social knowledge or not. We follow the point of view of Bennet and Bennet (2010) according to which another social settings may emerge trough the so-called "process of collaborative entanglement". In this environment members of a community interact continuously with strong emotional feelings to combine the sources of knowledge and the beneficiaries of that knowledge and move toward a common direction. By applying our model to the quantum game theory we substantially confirm that the cooperative strategy becomes the optimal one depending on frequency of interactions and people cultural, geographical and social reachability and traceablity.

1 Introduction

Thanks to the Internet and the digital technologies, nowadays we can share information and knowledge, spread culture and education faster and more easily than before. The collective body of knowledge produced by the community or social circle is what is known as *Social Knowledge*. In a social or cultural context, Social Knowledge can be the collective knowledge based on small groups, like a family, or it can be a massive and constantly evolving body of knowledge, like Wikipedia. According to the theory of Social Knowledge it is not simply the total sum of a group's knowledge, but it is the product of relationships and connections within a particular group. These groups are known as social knowledge networks, and their size and influence can often depend on the group topics, features and relationships. On a much larger scale, the Internet has produced massive social knowledge networks through websites or other sites where people regularly gather to share information on a particular topic. Websites like these are are known as *wiki*, namely a digital application that allows for collaboration and often requires user-generated content to remain relevant. Because of the social knowledge networks and wikis don't rely on the on central control to care information but they are an evolving collective knowledge resource produced by community participation, the most critical challenge is how to use them effectively in a collaborative way and avoiding the fake news. There is a broad range of literature which analyzes the problem of how detecting fake news and trolling/haters (see for instance Tschiatschek S., 2018, and the literature there cited) and the rising phenomenon of online incivility, that has made the environment of social networking sites hostile to many users. In a recent work Antoci et al.(2016) studied how the effect of social media on trust varies depending on the civility or incivility of online interactions. By conducting a experiment in a Facebook the authors found that participants exposed to civil Facebook interaction are significantly more trusting(for a survey on this topic see literature there cited). In this paper we explore another way of stimulate cooperation in the use of social media, based on the model on collaborative entanglement (Bennet and Bennet, 2010). This is a highly participatory model where knowledge creators, who may be individual, team, or community, and the audience interact continuously with strong emotional feeling to combine the sources of knowledge and the beneficiaries of that knowledge and move toward a common direction to satisfy community needs. From these interactions it emerges both a new knowledge informed by learned expertise and a large amount of tacit knowledge (embodied, effective and intuitive)- due to the continuing iterative loop of collective learning, that visibly affects the community . Therefore, "the process of collaborative entanglement among individuals not only helps to provide a specific solution to a current issue, but seeds the ground for continuous community self improvement, collaboration and sustainability" (Bennet and Bennet, 2010). We analyze this framework by using a quantum game model, substantially based on the pioneristic work of Eisert et al.(2000). Quantum game models have been largely applied in game theory mainly to show how new cooperative equilibria arise when players act as entangled particles. In their recent work Guo et al.(2008) depict a complete survey of these models and their vaste application. In this work, our aim is to point out the importance of textit Media education, namely the education for the fair and correct use of social media since age school, also with the collaboration of families. Our starting point is that, given the level of dissemination the use of Social Media has reached, they have become of essential use nowadays. However, the existence of many haters and fake news can make the use of Social Media dangerous to the sensible dissemination of knowledge and, even worst, can harm people. Benvenuto et al.(2017) provide a systematic large scale measurement and analysis study of hate speech in online social media. In their work, they use large data sets from two social media providers: Whisper and Twitter. The first data set counts up more than 27 million whispers and the second gathers more than 512 million tweets. Furthermore, the authors set up and validate a methodology to identify hate speech and delineate a definition of hate speech. According to them, hate speech is " *an offensive post, motivated, in whole or in a part, by the writer's bias against an aspect of a group of people The offended aspects can encompass offline hate crimes , based on race, religion, disability, sexual orientation, ethnicity, or gender. However, they might also include behavioral and physical aspects.*"

In light of the above, besides the positive spillovers of knowledge dissemination, the use of Social Media brings out the need of protection from haters as well as from fake news. To protect ourself, we can use appropriate methods and laws, but they can be very expensive and not always feasible. Although they are fundamental, the entanglement approach represents another additional (not alternative) solution which consists in educating people, since the age school, to an appropriate use of social Media. According to this approach the right information benefits everyone not only because it increases social knowledge, but also because people feel better as they do their civic duty, belong to a group, increase the own and the others' awareness and that there will be around now another person informed and corrected, etc. We see this through a simple model of game theory, by using a version of the modified game of Becchetti et al.(2015, 2017), which is more suitable for our purpose being a cooperative game model in which the change comes from citizens, from bottomed up pressure. In Section 2 we devise this modified version by highlighting the importance of laws and methods to correct fake and haters. While in Section 3 we see additional effects of the entanglement model by applying our model to the quantum game theory we substantially confirm that the cooperative strategy becomes the optimal one depending on frequency of interactions and people cultural, geographical and social reachibility/traceablity. In the Discussion section we summarize our results and discuss the media education importance to enforce the entanglement in practice.

2 The Basic Model

In this Section we aim to set up the basic features and parameters that we think are at work in a classical game when the agents must decide whether to cooperate or not in building and sharing Social Knowledge. To this purpose we extensively draw from the Model of Becchetti et al.(2015, 2017) by using a slightly modified version of that game where now we denote by:

- c the real costs (bills, expenses to stay connected, etc.) and the cost opportunity of the free time spent on Social instead of other leisure activities or face-to-face interactions.
- b the positive benefit related to the enrichment in Knowledge due to the exchange of information.
- a the individual advantage deriving from interacting with other people at a distance or just from releasing emotions and contents.

The individual payoff associated to the strategy of cooperation is:

$$P_{CC} = b\left(1 - \frac{f}{2}\right) + a\left(l - e\frac{h}{2}\right) - c \tag{1}$$

where f is the cost to detect fake news, which we may assume is proportional to the amount of the exchanged Information (i.e. more news and websites people see more probably they can incur in fake news). The parameter e measures the number of haters that we assume are exogenous. That is, we adopt the point of view of hating as psychological disordered behaviour which is substantially independent on the others' responses and which worsen individual well-being proportionally to individual feelings of empathy and sensitivity measured by the variable e. Finally the parameter l measures how much a increases thanks to the others' reply, for instance with the number of "like" and emoticons or comments of approval received.

Similarly the payoff the agent gets when the strategy chosen is to cooperate while the other one defects is:

$$P_{CD} = \frac{b}{2}(1 - f) + \frac{a}{2}(l - eh) - c \tag{2}$$

where now the agent must support the entire cost of detecting fake news f. The defector instead gets $P_{DC} = \frac{b}{2} + \frac{a}{2}$. If both players choose the strategy of defecting they both get 0. All the parameters are clearly nonnegative: $a, h, c, f, h, l, e \in [0, \infty]$

Therefore the final set of payoffs may be written as it follows:

$$U_i(S) = \begin{cases} b\left(1 - \frac{f}{2}\right) + a\left(l - e\frac{h}{2}\right) - c & ifS = (C, C) \\ \frac{b}{2}(1 - f) + \frac{a}{2}(l - eh) - c & ifS = (C, D) \\ \frac{b}{2} + \frac{a}{2} & ifS = (D, C) \\ 0 & ifS = (D, D) \end{cases} \tag{3}$$

The Nash Equilibrium of this Social Knowledge Responsible game (since now on SKR) is the cooperative solution (C, C) if $\frac{b}{2}(1 - \frac{f}{2}) + \frac{a}{2}(l - eh) > c$, while defection prevails otherwise. Therefore having a cooperative equilibrium in this classical game strongly depends on:

i) The costs of detecting fake news f. The seriousness of the problem of the raising fake news and their misconception damages makes critical the need to develop new techniques to tackle this challenge. To this end, Facebook has recently announced a series of efforts towards addressing this challenge (Facebook 2016). Fake news and misinformation have historically been used as tools for making political or business gains (Ewen 1998). The institutions have been proposing several solutions, as well as scientific literature is full of examples and propositions. One of the most interesting can be the detection of fake news via expert's verification or fact-checking (see Solferino et al., 2015). This methodology has given rise to some third-party fact-checking organizations such as Snopes3 and Factcheck.org4 and code of principles (Poynter, 2016) that should be followed by these organizations are build up. However, the volume of news content that is generated in online social networks has become so vast and the speed of spread in these networks so fast that developing new computational techniques and complement the expert verification is strongly required (see for instance Conroy and Chen,2015, for a survey). An alternate approach is to build hybrid human-algorithm methods via engaging users of online social networks by enabling them to report the fake news(Thsiactchekck et al.,2018).

ii) The number of haters h. Hate speech is expressly considered in the laws of many countries that define it as "a speech intended to degrade, intimidate or incite violence or prejudicial action against someone based on his/her race, ethnicity, national origin, religion, sexual orientation, or disability". When coming to statutory debarment of the hate speech, controversies arise. Firstly because of the conflict with the shielded right to freedom of expression of every citizen. However, one can counter-argument that the violence of some hate speeches, the way they depict marginalized individuals or groups sometimes reach a demeaning and derogatory pick so that freedom of expression is quickly put out of weight. As it was not enough, we have to add that marginalized people do need societal protection against any form of abuse. In our society, interlacing mechanisms of oppressions make hate speech even powerful and dangerous to the very "zoa" (i.e. "natural life") of individuals, not only to their "bios politikos" (i.e. "the good life characteristic of participation in the polis".). It is indeed the case that hate speech not only can humiliate, chastise and exclude the person or the group they hurl abuse at but will hardly damage people by discriminating them according to gender, race, sexuality, disability status, religion etc. This risk of harming people and going back to old - but not soothe - discrimination culture is perhaps the primary reason why more and more countries are adopting laws against hate speech. For instance, very exemplary is the case of Germany which has recently enforced a law that demands social media sites move quickly to remove hate speech, fake news and illegal materials. Websites that do not delete "obviously illegal" posts could face fines of up to 50mln euros. The law gives the networks 24 hours after notice to act against the law-breaking material.

3 The Model of Quantum Entanglement in Social Media

The Quantum entanglement is a physical phenomenon that occurs when pairs or groups of particles interact in a way such that, even when they are separated by a large distance, the quantum state of each particle cannot be described independently on the others. That is, they are not individual particles but are an inseparable whole. To better understand the property of entanglement we can assume the two particles are located in two distant countries A and B. If we want to measure a particular characteristic of one of these particles, after we get a result then measure the other particle using the same criterion and we find that the result of the measurement of the second particle will match (in a complementary sense) the result of the measurement of the first particle.

The quantum mechanic and the concept of entanglement has been largely applied in recent years in Game theory, shading light in new important results with respect to the traditional ones. For instance in his pioneristic work on quantum games Eisert et al(2000) investigated the quantization of nonzero sum games. For the particular case of the Prisoners' Dilemma they show that it is ever possible to construct a particular quantum strategy which always gives a reward if played against any classical strategy.

In this paper we strongly refer to this quantum version of the Prisoner Dilemma as developed in Eisert et al.(2000) and we apply it to a context of our Social Knowledge responsible game devised in the previous section. We aim to show that, depending on players'social cultural and social proximity and interactions, the cooperative quantum strategy may give a higher reward with respect to the classical one even when the number of haters and the costs of fake news make it not profitable.

We rewrite classical game in term of matrix as:

$$\left(\begin{array}{ccc} & C & D \\ C & (r,r) & (p,t) \\ D & (t,p) & (s,s) \end{array}\right) = \tag{4}$$

	C	D
C	$b\left(1-\frac{f}{2}\right)+a\left(1-e\frac{h}{2}\right)-c, b\left(1-\frac{f}{2}\right)+a\left(l-e\frac{h}{2}\right)-c$	$\frac{b}{2}(1-f)+\frac{a}{2}(1-eh)-c, \frac{a}{2}+\frac{b}{2}$
D	$\frac{a}{2}+\frac{b}{2}, \frac{b}{2}(1-f)+\frac{a}{2}(l-eh)-c$	$(0,0)$

(5)

where we have normalized l to 1.

For a quantum formulation of the classical game of SRK developed in Section2, we proceed like Eisert et al.(2000) by assigning the possible outcomes of the classical strategies D and C two basis vectors $|D\rangle$ and $|C\rangle$ in the Hilbert space of a two-state system, i.e. a qubit. At each instance, the state of the game is described by a vector in the tensor product space which is spanned by the classical game basis $|CC\rangle, |CD\rangle, |DC\rangle$ and $|DD\rangle$, where the first and second entry refer to the first and the second player, called A and B respectively. The board of our quantum-game is depicted in Fig. 1. The final total expected payoff may

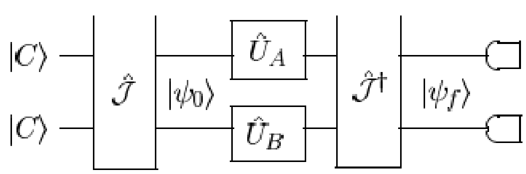

Figure 1: The setup of a two-player quantum game.

be derived as weighted sum of each possible payoff and may be in general written as (for more details about how to derive a quantum game see Eisert et al,2000):

$$\Pi = rP_{CC} + pP_{CD} + tP_{DC} + sP_{DD}$$

Therefore the payoff operators for each of the two players are

$$P_A(S_A, S_B) = \left[b\left(1 - \frac{f}{2}\right) + a\left(1 - e\frac{h}{2}\right) - c\right] P_{CC} + 0 \cdot P_{DD} + \left(\frac{a}{2} + \frac{b}{2}\right) P_{DC} + \tag{6}$$

$$\left[\frac{b}{2}(1-f) + \frac{a}{2}(1-eh) - c\right] P_{CD},$$

$$P_B(S_A, S_B) = \left[b\left(1 - \frac{f}{2}\right) + a\left(1 - e\frac{h}{2}\right) - c\right] P_{CC} + 0 \cdot P_{DD} + \left(\frac{a}{2} + \frac{b}{2}\right) P_{CD} + \tag{7}$$

$$\left[\frac{b}{2}(1-f) + \frac{a}{2}(1-eh) - c\right] P_{DC}.$$

The final state of the quantum game is

$$|\Psi_f\rangle = \hat{J}^\dagger(\hat{U}_A \otimes \hat{U}_B)\hat{J}|CC\rangle$$

where J is the entanglement operator acting on the two bits, J its adjoint, is the disentanglement operator, and U_A, U_B are the single-bit operators selected by the two players, that in other words measure the density matrix applied to the expected payoff to evaluate the final result.

The general single-qubit operator or density matrix which must be applied to the expected payoff is

$$\begin{pmatrix} e^{i\phi}\cos\frac{\theta}{2} & \sin\frac{\theta}{2} \\ -\sin\frac{\theta}{2} & e^{-i\phi}\cos\frac{\theta}{2} \end{pmatrix}$$

where $o \leq \theta \leq \pi$ and $0 \leq \phi \leq \frac{\pi}{2}$.

where the angle θ and the spin ϕ represent the analogue of players' social cultural-social proximity and frequency of interactions as well as the possibility of opening up, recognizability, reachability, e.g. when the particles have spin $\phi = \pi$ it means that players are maximally distant or can never meet (as when particles are on parallel lines). Therefore for A and B we have respectively:

$$\hat{U}_A = U(\theta_A, \phi_A) = \begin{pmatrix} e^{i\phi_A}\cos\frac{\theta_A}{2} & \sin\frac{\theta_A}{2} \\ -\sin\frac{\theta_A}{2} & e^{-i\phi_A}\cos\frac{\theta_A}{2} \end{pmatrix}$$

$$\hat{U}_B = U(\theta_B, \phi_B) = \begin{pmatrix} e^{i\phi_B}\cos\frac{\theta_B}{2} & \sin\frac{\theta_B}{2} \\ -\sin\frac{\theta_B}{2} & e^{-i\phi_B}\cos\frac{\theta_B}{2} \end{pmatrix}.$$

After some manipulations it is possible to show that in this SRK quantum game the final payoff for the agent A becomes (additional details are available upon request): Equation (6) becomes:

$$P_A(S_A, S_B) = \left[b\left(1-\frac{f}{2}\right) + a\left(1-e\frac{h}{2}\right) - c\right]\left(\cos^2(\phi_A+\phi_B)\cos^2\frac{\theta_A}{2}\cos^2\frac{\theta_B}{2}\right) +$$
$$\left[\frac{b}{2}(1-f) + \frac{a}{2}(1-eh) - c\right]\left[\sin\phi_A\cos\frac{\theta_A}{2}\sin\frac{\theta_B}{2} - \cos\phi_B\sin\frac{\theta_A}{2}\cos\frac{\theta_B}{2}\right]^2 +$$
$$\left(\frac{a}{2}+\frac{b}{2}\right)\left[\sin\phi_B\sin\frac{\theta_A}{2}\cos\frac{\theta_B}{2} - \cos\phi_A\cos\frac{\theta_A}{2}\sin\frac{\theta_B}{2}\right]^2.$$

Equation (7) becomes:

$$P_B(S_A, S_B) = \left[b\left(1-\frac{f}{2}\right) + a\left(1-e\frac{h}{2}\right) - c\right]\left(\cos^2(\Phi_A+\Phi_B)\cos^2\frac{\theta_A}{2}\cos^2\frac{\theta_B}{2}\right) +$$
$$\left(\frac{a}{2}+\frac{b}{2}\right)\left[\sin\phi_B\sin\frac{\theta_A}{2}\cos\frac{\theta_B}{2} - \cos\phi_A\cos\frac{\theta_A}{2}\sin\frac{\theta_B}{2}\right]^2 +$$
$$\left[\frac{b}{2}(1-f) + \frac{a}{2}(1-eh) - c\right]\left[\sin\phi_A\cos\frac{\theta_A}{2}\sin\frac{\theta_B}{2} - \cos\phi_B\sin\frac{\theta_A}{2}\cos\frac{\theta_B}{2}\right]^2.$$

The equilibrium solution shows that a lower threshold now is requested to make more convenient, for both players, to benefit from deviating from D. The cooperative strategy is associated to the couple $(\phi, \theta) = (\frac{\pi}{2}, 0)$, while the defection strategy corresponds to $(\phi, \theta) = (\pi, 0)$. In particular, another Nash equilibrium emerges when each player chooses the cooperative strategy $(\phi, \theta) = (\frac{\pi}{2}, 0)$, as the associated individual payoff now is equal to P_{CC} which is higher that P_{DD}. This Nash equilibrium, that we call $(\hat{Q}, \hat{Q})$, is unique and serves as the only acceptable solution of the game. No player could gain without lessening the other player's expected payoff. In this sense one can say that the dilemma of the original game has fully disappeared.

If a quantum game is not maximally entangled, that is the probabilities of the possible outcomes of the game are not uniformly distributed, the entanglement operator may be rewritten as follows (see also Sun,2009):

$$\hat{J} = e^{i\frac{\gamma}{2}\hat{D}\otimes\hat{D}} \tag{8}$$

where the parameter $\gamma \in [0, \frac{\pi}{2})$ can be considered as a measure for the game's entanglement that allows to determine the entropy

$$E = \sin^2\frac{\gamma}{2}\ln\sin^2\frac{\gamma}{2} - \cos^2\frac{\gamma}{2}\ln\cos^2\frac{\gamma}{2}$$

of the initial state $|\Psi_0\rangle$.

For a maximally entangled quantum game $\gamma = \frac{\pi}{2}$ and the unique feasible NE equilibrium of the quantum game is $(\hat{Q}, \hat{Q})$. Otherwise when the game is not maximally entangled we adopt $\hat{Q}$ only as cooperator's strategy and the modified matrix in the non-maximally entangled quantum game becomes:

$$\begin{pmatrix} b\left(1-\frac{f}{2}\right) + a\left(1-e\frac{h}{2}\right) - c & (\frac{a}{2}+\frac{b}{2})\sin^2\gamma \\ (\frac{a}{2}+\frac{b}{2})\cos^2\gamma & \frac{b}{2}(1-f) + \frac{a}{2}(1-eh) - c \end{pmatrix} \tag{9}$$

The Prisoner Dilemma is resolved if

$$\sin\gamma > \frac{b}{2}(1-f) + \frac{a}{2}(1-eh) - c \tag{10}$$

which it is ever satisfied for $\gamma \in [0, \frac{\pi}{2})$.

For simplicity we restrict our attention to the production and benefits of social knowledge, so that we assume $a = 0, c = 0$. Notice that while in the classical version of the game for $\frac{b}{2}(1-\frac{f}{2}) >$, that is $f > 2$, the cooperative strategy never represents a feasible NE equilibrium, instead in the quantum game it is a possible solution depending only on (10). Therefore the condition above for a cooperative unique NE substantially means that the benefit that comes from interacting entangled with each other even when defecting gives the player a greater benefit than when he chooses to cooperate while others defecting but without entanglement. This result substantially depends on the values of the parameters θ, ϕ and γ. Notice that in our analysis essentially θ and ϕ represent the distance and frequency of interactions among agents'. Therefore the entanglement is greater for less distant people (not only geographically but also in terms of cultural and social differences) and when

they are easily reachable/traceable. In this case, even if the costs of detecting fake news (and fighting heaters) are huge, the entanglement give to the agents an additional benefits when cooperating that derive from contributing to the change in the society, in spreading the right information,as well as rising awareness, self-esteem, altruism, fairness, developing critical thinking, etc. This make the cooperative strategy more attractive also when the other agents might defect if the entropy of the system is not too high,i.e. $\gamma \in [0, \frac{\pi}{2}]$.
This result has been confirmed by the recent paper of Sabatini and Sarracino (2017) who show that the use of Social Networks has a positive impact on well-being also because it increases the probability of face-to-face interactions.

4 Discussion

Nowadays Social Media are part of our daily culture and communicative practices in the family, at school and with the group of friends. In this paper we have devised a simple Quantum game theoretical model on how to foster a more beneficial and fair use of Social Media. This model is based on the physical concept of the entanglement. In this section we discuss how it mat be built in the society trough the work of schools and families. Indeed it is necessary then that schools, on the one hand, are geared to understand how to bring out consumer practices and values so to create more awareness in students. On the other hand they must promote training meetings to involve families so that they can pay more attention to their children media consumption, both in terms of content and emotions arouse, and consider the Media as an area to deepen explore and to be challenged. The problem of media education was also expressively taken into account by the European Parliament, trough the resolution of 16 December 2008, the Parliament recognized the importance of media education as an essential element to increase cultural literacy, awareness and to promote the active civic participation of people. Consequently the Parliament alleged that media education should be part of formal education to which all children have access and be an integral part of the educational programme in all the kind of schools and degree.

An exemplary case in this regard is represented in Italy by the schools involved in the italian project of Corecom (*http : //www.corecomragazziemiliaromagna.it*). The projects carried out for five years during which,several activities have been realized whose mainstream consisted in the realization of free tools, Research, sharing of practices, training, involvement of families have been the mainstays of activity. The projects involve in substance the design and the realization of films, videos, articles, comments to the same and their analysis, learning the information necessary to interpret the contents manifest and latent, the recognition of the own and the others' emotional responses, self-awareness, etc. This methodology has been substantially inspired by the five principles of pedagogy of media education identified by De Smedt et al.(2013).

The first, used very frequently by teachers, consists in the practical production of Media, that is it requires students to create a transmission radio, an announcement, a short film, a publication, or a text. Putting students in the position of producers is considered by educators a relevant way for students to evolve their relationship with the media. The second is the decomposition of message and consists in choosing a medium and analyzing it in depth to discover which mechanisms of significance are at work, what elements are contained and how they produce meaning. The third pedagogy consists in teaching directly some concepts, trough frontal lessons, to learn some contents taken for example by the Humanities (economics, anthropology, sociology, political science),which are very useful to analyze the media.The fourth is based on introspective processes: it invites the pupil to take awareness of his own perceptions, of the different modifications that the media provoke on his sensibility, his needs, feelings, concerns, expectations in an environment of sharing and socializing of experiences and opinions, using specific and appropriate terms. Finally the fifth pedagogy De Smedt et al.(2013) suggested refers to the game and problem solving: simulation games, roles and activities that do not propose the only media production, but that present to the young students a problem that needs to be solved. Pupils have to find strategies to get by themselves; the solution they will find will be a new competence that they will have acquired.

The aim of Social Education is to increase media literacy and acquire the key competence in the information and communication society. So that all potential users get the ability to autonomously use the various media, to understand and evaluate the different aspects of content of media, to communicate in heterogeneous contexts and to produce and disseminate media content, to filter and classify the information sought in the tide of data and images offered by new media. Media education is a key element of consumer information policy, a conscious and competent approach to copyright issues, the active democratic participation of citizens and the promotion of intercultural dialogue. This is necessary to finally return to the media their primary function of information diffuser in real time and to break down the inability to communicate at a distance instead of being transformed as it happens nowadays in a tool of opportunistic falsification of news or a basket where to vomit the own negative emotions.

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