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Collective Emotional Intelligence and Group Dynamics Interplay: Can It Be Tangible and Measurable?

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ABSTRACT Significant efforts have been allocated over the last thirty years towards the conceptualization and assessment of the Emotional Intelligence (EI) construct. However, there is limited work on examining the EI construct in a group level. Collective Emotional Intelligence (CEI) is introduced as the ability of a group to promote awareness and regulation of members' and group's emotions, improving their capacity to collaborate effectively and avoid or easily resolve conflicts. High CEI levels in a group positively affect the group's performance. In this article, we provide a definition of collective EI constructs, based on the extension of the open-access EmoSocio EI model. EmoSocio is selected as a basis since it regards an EI model, enriched with sociometric indexes at an individual and group level. A set of new constructs are included in the model for representing abilities for emotions' management in a group level along with indicators for revealing the group dynamics. EmoSociograms is also presented as an open-source psychometric tool to dynamically manage and assess the social and emotional competences of individuals and groups. Evaluation results regarding the validity and the reliability of the extended EmoSocio model are made available, based on the assessment of CEI constructs in in-person and online groups, formed under an educational and working context, as well as an online discussion forum.

INDEX TERMS Collective emotional intelligence, EmoSocio EI model, EmoSociograms, emotional intelligence, group dynamics, social network analysis.

I. INTRODUCTION

During the last decades, existing work for the modeling and assessment of Emotional Intelligence (EI) constructs has been centered towards the assessment of EI competencies at individual level. Various intrapersonal and interpersonal competencies have been considered, while a set of EI models and relevant measures have been released [1].

By taking advantage of these foundations, recent studies consider the importance of developing EI competencies at

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group level, reinforcing EI as a contributing factor to successful organizational behavior. Groups are seen as social systems where group emotionality is considered as an emergent group-level property [2]. Group emotionality can be applied in groups where interaction among members can be in-person, digital or hybrid. In all cases, emotional awareness, emotional expression and capacity for emotional regulation are considered vital competencies within a group for managing conflicts and promoting collaboration and fruitful interaction among the members.

Individual EI without integration into the group context is not considered adequate to guarantee the establishment of

collaborative and affective relationships within a group, since individuals with high level of emotional intelligence may be overwhelmed by competition over cooperation or jealousy over solidarity [3]. To represent group-level emotional competencies, the term Collective Emotional Intelligence (CEI) has been introduced [2], [4]–[6]. CEI is defined as the ability of a group to develop a set of norms that encourage awareness and regulation of member and group emotions, considering the affective dynamics within the group and improving the ability of group members to interact and work together effectively [2], [5]. CEI is a group-level competency that emerges from the integration of individual competencies of the group members, based on their interpersonal interaction [2]. The development of CEI is tightly coupled with the type of group dynamics that exist in a group and vice-versa. Higher quality of interpersonal interactions improves the affective similarity within the group, while high collaborative spirit among the group members and effective management of emotions generate interpersonal attraction and improve interpersonal relationships.

A. MOTIVATION

The main motivation for our work in this article stems from the need to provide an open-access EI model that can be applied at both individual and group level, enabling the examination of the relationship among the development of individual and collective emotional competencies with the group dynamics. A gap has been identified in the existing literature for the provision of such a model that can be openly accessible by the scientific community and self-explainable in terms of concepts.

Moving one step further, we have also identified the need for the development of an open-source psychometric tool for assessing and tracking the evolution of individual EI, CEI and sociometric indexes within groups. Up to our knowledge, there is no open-source solution available that can jointly consider the assessment of emotional and social competencies of individuals and groups and examine the interplay of CEI constructs and group dynamics.

B. CONTRIBUTION

Following our motivation for the work presented in this article, our main contribution is threefold. The first part regards the theoretical foundation of an open-access EI model that can be applied for modeling and assessing individual and collective socioemotional competencies within groups. The second part regards the development of an open-source software to support tracking and assessment processes for such competencies. The third part regards the realization of a set of validation and evaluation activities in in-person and online groups, considering both the application of the produced EI model and the usage of the developed software.

To manage to represent and assess the development of CEI competencies and the quality of the interpersonal relationships, we have revised the EmoSocio EI model, having as a basis its specification in our previous work [1]. EmoSocio

is an open-access EI model that represents emotional and social traits. EmoSocio reduces the overlapping terminology and bridges ontological differences of existing EI models through the composition of EI constructs that are highly represented in well-known and reliable EI models [1]. It is represented in a semantically-enriched format in the form of an ontology. In addition to EI constructs, EmoSocio integrates sociometric indexes, aiming to capture the social environment dynamics where socioemotional assessment processes take place. EmoSocio has been considered as the most suitable starting point, given the consideration of both emotional and social competencies, as well as its development based on a semantic alignment of well-founded EI models [1].

The EmoSocio EI model and the associated ontology have been extended to represent abilities for emotions' management in a group level (emotional awareness, emotional regulation), along with indicators for revealing the emotional climate in the group. The construct of cohesion has been also revisited, considering its multi-dimensionality and the need to represent both social and affective cohesion aspects [7]. To achieve so, we have reviewed existing CEI models and measures, as detailed in Section II, and proceeded to semantic alignment of the denoted concepts. A set of scales and items are specified, as detailed in Section III. Based on the updates in the model, relevant updates have taken place in the description of the EmoSocio Ontology.

Building upon the theoretical foundation of the revised EmoSocio model, EmoSociograms is developed as an online open-source psychometric tool, as detailed in Section IV, that aims to tackle assessment of both emotional and social competencies of individuals and groups. The concept of emosociogram has been introduced (see Section III-D) and supported by the software, by adopting the term sociogram from the sociometry area and extending it to include information related to the emotional competencies of individuals and the overall group. EmoSociograms jointly considers the advances in the areas of emotional intelligence and sociometry. It has been developed following a continuous integration approach.

Based on the adoption of the revised EmoSocio model and the usage of EmoSociograms, evaluation activities have taken place (with 507 participants in total) in a set of working and educational groups in Spain, as well as an online discussion forum in Greece. In these activities, as they are presented in Section V, we have evaluated the validity and reliability of the revised EmoSocio model, while revealing insights regarding the effect of the development of strong interpersonal relationships and the increase of a group's social cohesion to the development of CEI and vice-versa.

II. RELATED WORK

A. COLLECTIVE EMOTIONAL INTELLIGENCE CONCEPTUALIZATION

The construct of Collective Emotional Intelligence (CEI) - called also as Team Emotional Intelligence (TEI) or Group Emotional Intelligence (GEI)- has been discussed in the field

TABLE 1. CEI models, measures and constructs.

CEI Model - Measure	CEI Constructs / Dimensions	Base Theory
Workgroup Emotional Intelligence Profile (WEIP-3) [9], [10]	- Own emotions (Awareness of own emotions; Discuss own emotions; Use of own emotions to facilitate thinking) - Others' emotions (Recognise others' emotions; Detect false displays of emotion in others; Empathetic concern; Manage others' emotions)	Salovey and Mayer's EI Model [11]
Team Emotional Intelligence (TEI) [5]	- Individual-level (Interpersonal Understanding; Addressing Counterproductive Behaviour; Caring Behaviour) - Team-level (Team Self-Evaluation; Creating Emotion Resources; Creating an Affirmative Environment; Proactive Problem-Solving; Organisational Understanding) - Cross boundary level (Building External Relationships)	Goleman's EI Model [12]
Team-Trait Meta Mood Scale (T-TMMS) [4]	- Attention: individual beliefs about the importance of paying attention to team emotions and feelings - Clarity: capacity for understanding team's emotions - Repair: ability to repair negative emotional states and maintain positive ones within the team	Salovey and Mayer's EI Model [11]
Team Referent EI Scale [6]	- Team Emotional Self-Awareness - Use of Team Emotion - Regulation of Team Emotion - Team Emotional Interpersonal Understanding	Salovey and Mayer's EI Model [11]

of work and organizational psychology, mainly for examining positive effects on the performance of the groups [8]. Conceptualization and measurement of CEI is done in two ways; by summing the individual EI indicators of the group's members or through the assessment of EI constructs that consider the interactions among the group members [2], [4]. In the latter case, it is considered that emotional experiences that are present at individual level can lead to the development of a group level affective construct.

Emotion in groups primarily comes from whether the social and emotional needs of the group members are satisfied [5]. These include the need to belong and the need for shared understanding and solidarity among the group members. Emotion is considered contagious within a group, influencing the quality of interactions among the members and triggering further positive or negative effects. Aspects related to awareness of the emotional status of the group members, use of positive thinking to repair negative moods, understanding of the motives that lead to actions and the daily group emotional climate (e.g., quality of interactions) contribute towards the building of the CEI construct.

High CEI is associated with various positive effects in the group, such as the improvement of the cohesion (the force that keeps the group together) within the group, the capacity to manage conflicts and devise creative solutions to disagreements, the recognition and management of the emotional spirals of conflicts and the improvement of the overall group effectiveness [2], [5].

Various measures have been made available for measuring the CEI construct. The Work Group Emotional Intelligence Profile (WEIP) is a self-report measure that evaluates the aggregated construct of the group EI using an individual-referent model (instead of a collective construct) [9], [10]. It captures two dimensions of emotional intelligence; the ability to deal (recognize, discuss, manage) with own emotions and the ability to deal (recognize, manage) with others' emotions. The Team Emotional Intelligence (TEI) Survey [5] evaluates a set of norms that guide the team's interaction with its members (individual-level), the team as a whole (team-level), and others outside the team (cross-boundary level). At each level, there are norms that create emotion awareness and regulate the behaviour in the team. Based on the Trait Meta-Mood Scale (TMMS) instrument that is developed according to the EI model proposed by Mayer and Salovey [11], a collective measure known as the T-TMMS has been also derived for evaluating CEI [4]. T-TMMS measures the same constructs with TMMS, however from a team-based perspective. The considered dimensions include the importance of paying attention in the emotions within the team (attention), the capacity for understanding team's emotions (clarity) and the ability to repair negative emotional states and maintain positive ones within the team (repair). A team-referent measure for EI is also provided at [6]. The considered constructs are team emotional self-awareness, use of team emotion, regulation of team emotion, and team emotional interpersonal understanding. A list of the existing CEI models and their detailed constructs is provided in Table 1.

The definition of these constructs is provided as input towards the specification of the CEI constructs in the revised EmoSocio model, as they are presented in Section III-B.

B. GROUP DYNAMICS EVOLUTION AND EMOTIONAL CLIMATE

To properly interpret the estimated CEI within a group, it is important to track in parallel the group dynamics. Through people's ordinary behavior and everyday interactions, an emotional climate within the group is created, indicating the quality of the emotional relationships among members and the quality of the environment within a particular context (e.g., working, educational, clinical) [13], [14]. For instance, in existing research outcomes, a positive association is noticed between the number of friendship ties with the emergence of CEI [2], while a negative association is noticed between the level of team conflicts and CEI [15]. Groups that are composed of friends are more cohesive and in turn display more similar emotions. By acquiring a complete understanding of the social structure of a group, interventions aiming to reduce conflicts, increase group cohesion and collaboration spirit can be planned [16]–[18].

Tracking of group dynamics can be realised by exploiting sociometric techniques [19]. Sociometry theory has been introduced by Moreno to facilitate constructive change in individuals and groups through the scientific measurement of

social relationships in groups [16], [17]. It is considered as a methodology for tracking the energy vectors of inter-personal relationships in a group. The individual is examined based on its relationship with others, considering both short and long term relationships and their evolution across time. The outcome of a sociometric assessment process is represented through a sociogram.

In the work presented in this article, we consider the joint examination of group dynamics and emotional competencies at group level through the conceptualization of the relevant constructs in the revised version of the EmoSocio model and the extension of the concept of a sociogram towards an emosociogram.

C. COLLECTIVE EMOTIONAL INTELLIGENCE IN DIGITAL COMMUNITIES

As our physical world inevitably becomes more digitalized and more connected, it is evident that digital interaction and experiences of people in digital communities are also connected on an emotional level. Such communities may regard -among others- teleworking groups, students interacting through online learning systems, digital forums, social media groups. Online communities are bigger and broader, supporting the faster and broader transmission of messages [20].

There are different ways that online behaviors reflect our emotional state. Emotional sharing, awareness and empathy can be expressed digitally in the form of speech, video, text or declaration of preferences (e.g., likes/shares/usage of Emojis in social media). The existence of a virtual environment make most people more confident to express their feelings than doing so in person. Emotions contagion is stated to be bigger in case of digital expression of emotions, potentially due to the speed of dialogue and the virality of digital communications [21].

Similarly to in-person groups, development of CEI is considered to be equally important for online or hybrid groups [22]. Positive effects in terms of performance due to increased cohesion levels, better understanding of the group members and common tackling of difficulties should jointly apply in case of in-person or online groups.

In the current work, given that the proposed EmoSocio model and the developed open-source psychometric tool can be applied in both in-person and online groups, we have realised evaluation activities for both cases and come up with a set of insights, as they are presented in Section V.

III. EMOSOCIO EMOTIONAL INTELLIGENCE MODEL

In this section, we present the main constructs of the revised version of the EmoSocio EI model [1]. The revision regards updates in the definition of group-level constructs and has a two-fold objective. We aim to conceptualize the CEI construct and represent emotional competencies at a group level, as well as to revise the definition of the social constructs at group-level to be able to examine the interplay among the CEI

and the group dynamics. To achieve so, it is crucial to come up with a proper representation of the groups' cohesion.

Cohesion has an instrumental basis in a group and refers to how people cohere for some purpose, whether this is done for a task or for social reasons. Cohesion is considered as a multidimensional construct, while it is dynamic in nature [7]. According to Carron *et al.* [23], cohesion may be defined as "a dynamic process that is reflected in the tendency for a group to stick together and remain united in the pursuit of its instrumental objectives and/or for the satisfaction of member affective needs". Cohesion may change over time, considering the dynamic nature of the formation and evolution of groups in terms of members, establishment of relationships and quality of these relationships. However, changes in the cohesion level are considered to happen gradually. In addition to a set of dimensions that are related to the group dynamics, cohesion has also an emotional dimension that refers to how cohesion is pleasing to its group members [7], leading to a pleasant and collaborative group emotional climate.

In EmoSocio, we represent both the social and emotional dimension of cohesion and define proper scales for their assessment. We consider that by providing an easily explainable representation of the main dimensions and measurement scales of cohesion, EmoSocio can be helpful to promote interdisciplinary research in the areas of psychology, sociology and social networks analysis.

A. EMOSOCIO MODEL CONSTRUCTS AT INDIVIDUAL LEVEL

Prior to delving into details for the composition of the group-level constructs, we shortly refer to the main existing constructs in EmoSocio that represent individual emotional and social personality traits.

The individual EI constructs in EmoSocio are classified in two categories as intrapersonal or interpersonal. The intrapersonal skills refer to something taking place within one individual, helping oneself to recognize his own strengths and weaknesses (e.g., understand oneself, appreciate one's feelings, fears and motivations). The interpersonal skills refer to something taking place between people, helping someone to understand, collaborate and work with others (e.g., understand the intentions, motivations and desires of other people) [1]. The intrapersonal EI constructs are self-awareness, emotional regulation, self-motivation, optimism and self-esteem. The interpersonal EI constructs are empathy, teamwork, flexibility, emotional expression, assertiveness, influence and relationships.

Regarding the individual level social constructs, their definition and assessment is meaningful within a specific group context (e.g., an individual may be popular in one group and unpopular in another group). They focus on the positioning of a member within a group, considering its relationship with the group members. The defined constructs are popularity, antipathy, affective connection, sociometric status, social expansion and realistic perception.

B. EMOSOCIO MODEL CONSTRUCTS AT GROUP LEVEL

1) COLLECTIVE EMOTIONAL INTELLIGENCE CONSTRUCTS

In the case of CEI, focus is given on the collective emotional competencies of the group as a whole. To define the constructs that compose CEI at EmoSocio, we have examined the set of CEI models that are presented in section II-A. A semantic alignment process has taken place leading to the selection of the most dominant constructs. The outcome of this process is made available in Fig. 1. Three main constructs are derived for the representation of CEI, namely group emotional awareness, group emotional regulation and group emotional climate. The specification of each derived construct is based on the synthesis of the associated definitions of the relevant constructs in the examined models.

Group emotional awareness refers to the identification of the emotions that are experienced within a group by ourselves and the members of the group [4], [6], [9], [10]. High levels of emotional awareness within a group mean that the emotional states of the members are well communicated among them, improving their interpersonal understanding and the explanation of the monitored reactions, especially in case of facing difficulties. It also leads to the development of a culture of accurate and shared understanding among the group members and the increase of the sense of belonging to the group.

Group emotional regulation refers to the ability for management of our own emotions and the emotions of the group members [4]–[6], [9], [10]. It is crucial in the process of conflict resolution and the proactive solving of potential problems in the group. It helps to repair negative emotional states and maintain positive ones within the team.

Group emotional climate refers to the emotional dimension of the group cohesion, sometimes referred as affective cohesion [4]–[6]. It refers to the creation of an affirmative environment with strong sense of belonging by the group members, strong sense of collaboration and solidarity among the group members, as well as capacity to repair negative emotional states and maintain positive ones within the team.

2) SOCIAL CONSTRUCTS AT GROUP LEVEL

Regarding the social constructs at group level, we have proceeded to a revision of the social group constructs that were detailed at the initial version of EmoSocio [1]. The main reason for this revision was the consideration of cohesion as a multi-dimensional construct. As already mentioned, social cohesion in a group reflects the tendency of the group members to stick together and remain united. This tendency can be applied to achieve task-based objectives (e.g., high performance or goals achievement at work) or improve the social interaction and well-being among the group members (e.g., develop fulfilling relationships within the group) [7]. Concepts specified in the sociometry and social network analysis theory [24] can be applied for the measurement of different dimensions of social cohesion.

Under this perspective, we have conceptualized social cohesion as the main social construct in group-level, while

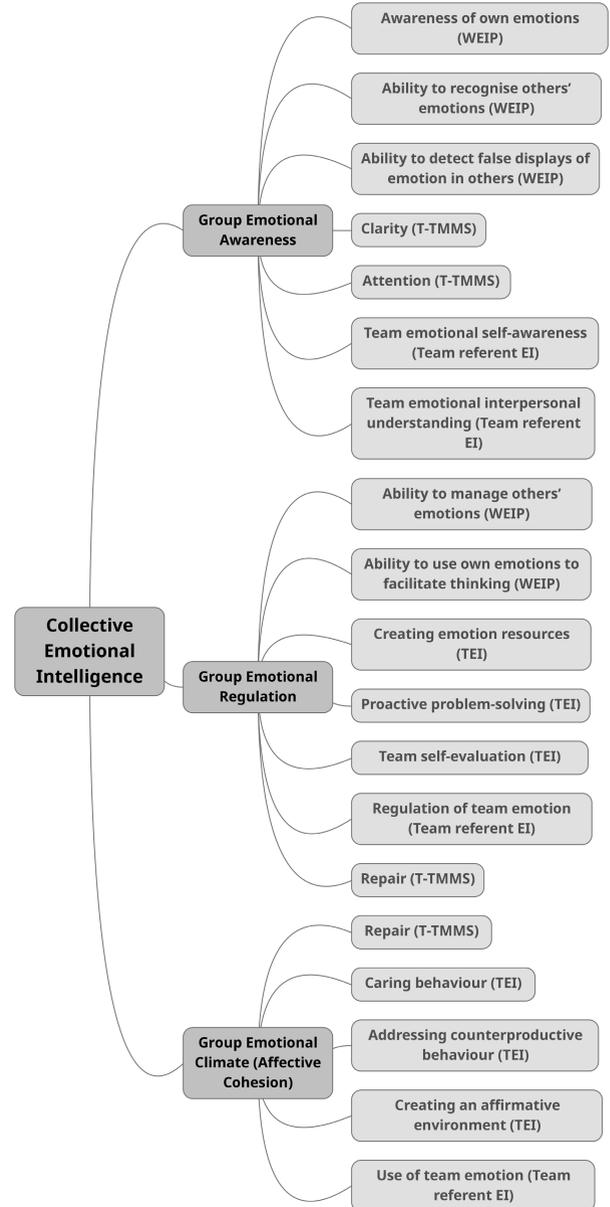


FIGURE 1. EmoSocio CEI constructs.

we have specified a set of scales for assessing this construct, as depicted in Fig. 2. The selection of the most suitable set of scales depends on the type of the examined group.

High density of a group in terms of preference relationships (or low density in terms of rejection relationships) is an indication for high cohesion. To assess the density of the group, the density index can be used, while it is also helpful to examine the average shortest path and diameter indexes (low values denote fewer intermediate relationships among the members), as well as the social intensity index (high values denote high social expansion). High reciprocity is also a significant indication of cohesion, since it shows mutual agreements in terms of preferences or rejections. It can be

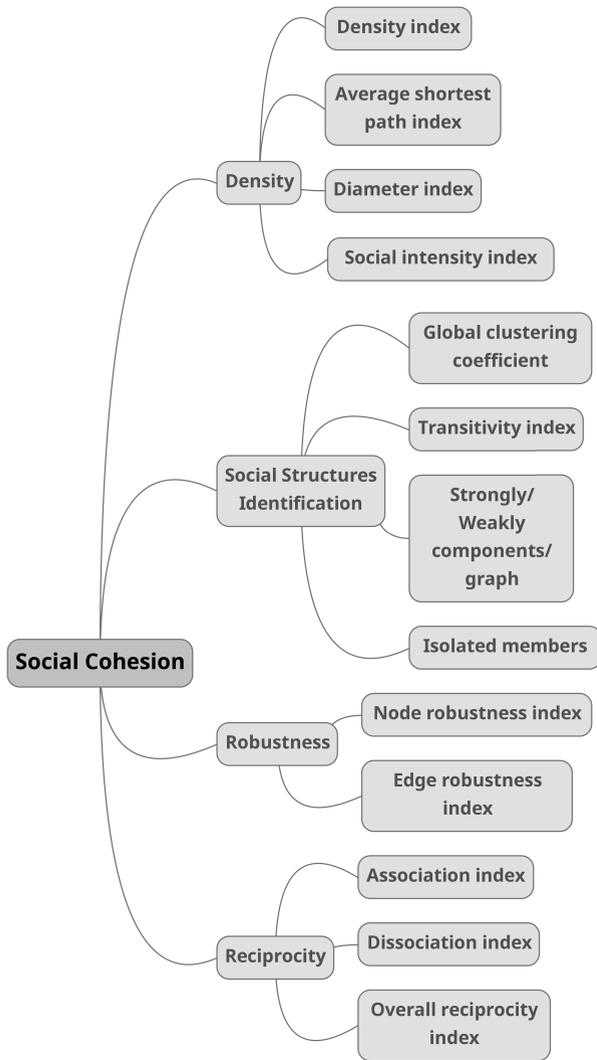


FIGURE 2. Scales for assessing social cohesion in a group.

measured by the association (reciprocal elections), dissociation (reciprocal rejections) and the overall reciprocity (reciprocal elections divided by reciprocal rejections) indexes. High values of the association and overall reciprocity indexes lead to high cohesion. A group is considered to have better cohesion when it contains tight social preference structures (or loose social rejection structures). The existence of such structures can be evaluated by the global clustering coefficient and the transitivity index. The identification of strongly or weakly connected sub-groups also reflects the cohesion of a group. Ideally, the whole group should be strongly connected, meaning that there is a communication path between all members, however in real social graphs this may be difficult. Identification of cliques may apparently raise the overall reciprocity of the group, but often create antagonism within a group and, thus, it should be tackled with attention in terms of interpretation of the group cohesion levels. The percentage of isolated members should be also small. Robustness can

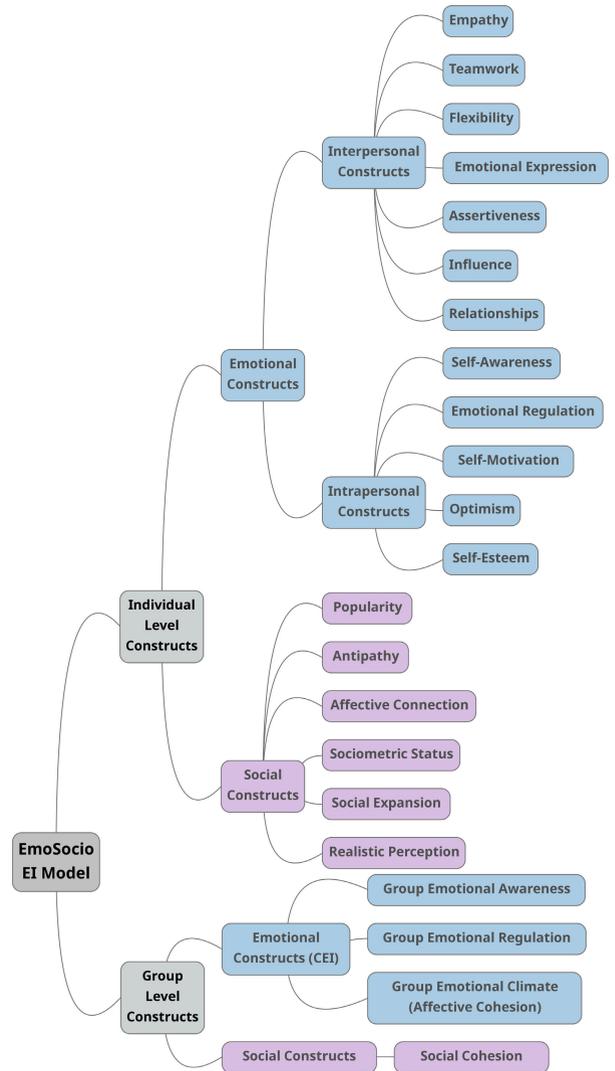


FIGURE 3. EmoSocio EI model constructs.

be also used to assess whether a group maintains its general structural properties in case of changes (e.g., maintain connectivity despite of members removal). It can be evaluated based on the node and edge robustness indexes.

C. OVERALL EMOSOCIO EMOTIONAL INTELLIGENCE MODEL

By considering the provided updates, the overall constructs composing the revised EmoSocio model are depicted in Fig. 3. All the constructs that are denoted in the blue color regard emotional traits, while those denoted in the purple color regard social traits.

By representing emotional and social constructs in a joint model, we are able to examine the interplay among the group dynamics and the development of CEI. Furthermore, by having access to the emotional profiles of individuals, we are able to assess CEI following both an individual-referent and team-referent approach and to compare both approaches.

TABLE 2. EmoSocio emotional constructs definition.

Construct	Definition
Self-awareness	Understand our own emotions and the effects they have on us.
Emotional Regulation	Modulate an emotion or set of emotions and maintain our effectiveness under stressful conditions.
Self-Motivation	The impetus that gives purpose or direction to behavior and operates in humans at a conscious or unconscious level.
Optimism	The anticipation of positive outcomes and things to happen in life and the confidence for achievement of the desired goals.
Self-esteem	The degree to which the qualities and characteristics contained in one's self-concept are perceived to be positive.
Empathy	Sense others' feelings, needs and perspectives, taking an active interest in their concerns and picking up cues to what is being felt and thought.
Teamwork	Work with others towards a shared goal, participating actively, sharing responsibility and rewards.
Flexibility	The ability to adapt to new environments and conditions.
Emotional Expression	Communicate our emotions to others and express accurately and unambiguously our feelings.
Assertiveness	An adaptive style of communication in which individuals express their feelings and needs directly, while maintaining respect for others.
Influence	Effectively manage others' emotions to achieve a desired outcome and/or change their behavior or attitude.
Relationships	Start and maintain emotional bonds with others, establish mutually satisfying relationships and relate well with others.
Group Emotional Awareness	Understand the emotions that are experienced within a group by ourselves and the members of the group and the effects they have on the group.
Group Emotional Regulation	Manage own emotions and the emotions of the group members, facilitating conflict resolution and proactive problem solving.
Group Emotional Climate	Develop strong sense of belonging, collaboration and solidarity by the group members, enabling them to repair negative emotional states and maintain positive ones.

TABLE 3. EmoSocio social constructs definition.

Construct	Definition
Popularity	How preferable is a member within the group.
Antipathy	How rejected is a member within the group.
Affective connection	The proportion of congruence between reciprocity and a member's elections.
Sociometric Status	The degree to which someone is liked or disliked by their peers as a group.
Positive Expansion	The tendency of a member to select positively many peers of the group.
Negative Expansion	The tendency of a member to reject many peers of the group.
Realistic Perception	The degree to which someone correctly identifies the way his/her peers feel about him/her.
Social Cohesion	The tendency of a group to stick together and remain united in the pursuit of its instrumental objectives [23].

Following, in Table 2 and Table 3, we provide the definitions of the EmoSocio constructs, taking into account the definitions in the initial version of the model [1]. For each CEI construct, we have considered relevant definitions in the examined CEI models.

Subsequently, we defined the scales and items for the measurement of the EmoSocio constructs, focusing on the introduced CEI constructs. This process includes the revision of the initial version of the EmoSocio items aiming at the provision of a shorter version of the inventory (questionnaire), as well the addition of the items to assess the CEI constructs. For the later, we have reviewed and selected items based on the inventories used in the measures listed in Table 1. The full list of items is provided in Appendix. This list was produced upon filtering and processing of the initial items to reduce their dimensionality, while in parallel maintaining items that can holistically express the semantics of each EmoSocio construct. It should be noted that the set of items for the assessment of the individual EI constructs was selected from the International Personality Item Pool (IPIP) [25] that is intended as an international effort to develop and continually refine a set of traits, whose items are in the public domain, and whose scales can be openly used for both scientific and commercial purposes. The items are made available in three languages, namely English, Spanish and Greek to support the collection of data in the applied groups in Spain and Greece on our assessment study.

D. EMOSOCIO ONTOLOGY AND GRAPH-BASED REPRESENTATION

By having conceptualized the constructs that compose the EmoSocio EI model, we proceeded to the revision of the EmoSocio Ontology, as it was initially defined at [1]. The main objective of the EmoSocio Ontology is to formally and unambiguously represent the defined constructs along with their scales and inter-relationships. In this way, the transparency and explainability of the denoted concepts will be increased, facilitating the adoption, re-use and extension of the EmoSocio model by the scientific community [1]. Furthermore, the provision of a clear, consistent and computable representation of the EmoSocio model will enable its comparison, testing and integration with other emerging models or theories, as well as its inclusion by software tools that can support psychological assessment processes [1]. Such a case regards the open-source tool EmoSociograms that is detailed in Section IV. The main updates in the EmoSocio Ontology regard the definition of the classes for the CEI scales that are used for the assessment of the relevant constructs. The full version of the EmoSocio Ontology along with its description is available at [26].

Following the formalism and the clarity of terms provided by the definition of the EmoSocio Ontology, we have also come up with a graph-based specification for the representation of the social and emotional attributes of the individuals and the group that they belong to. The term emosociogram is introduced, by adopting the term sociogram and enriching the information on it with the inclusion of data related with the emotional competencies of the individuals or the group. An emosociogram is a directed weighted graph with asymmetric relationships, where the nodes represent the members of a social group, while the edges the relationships among

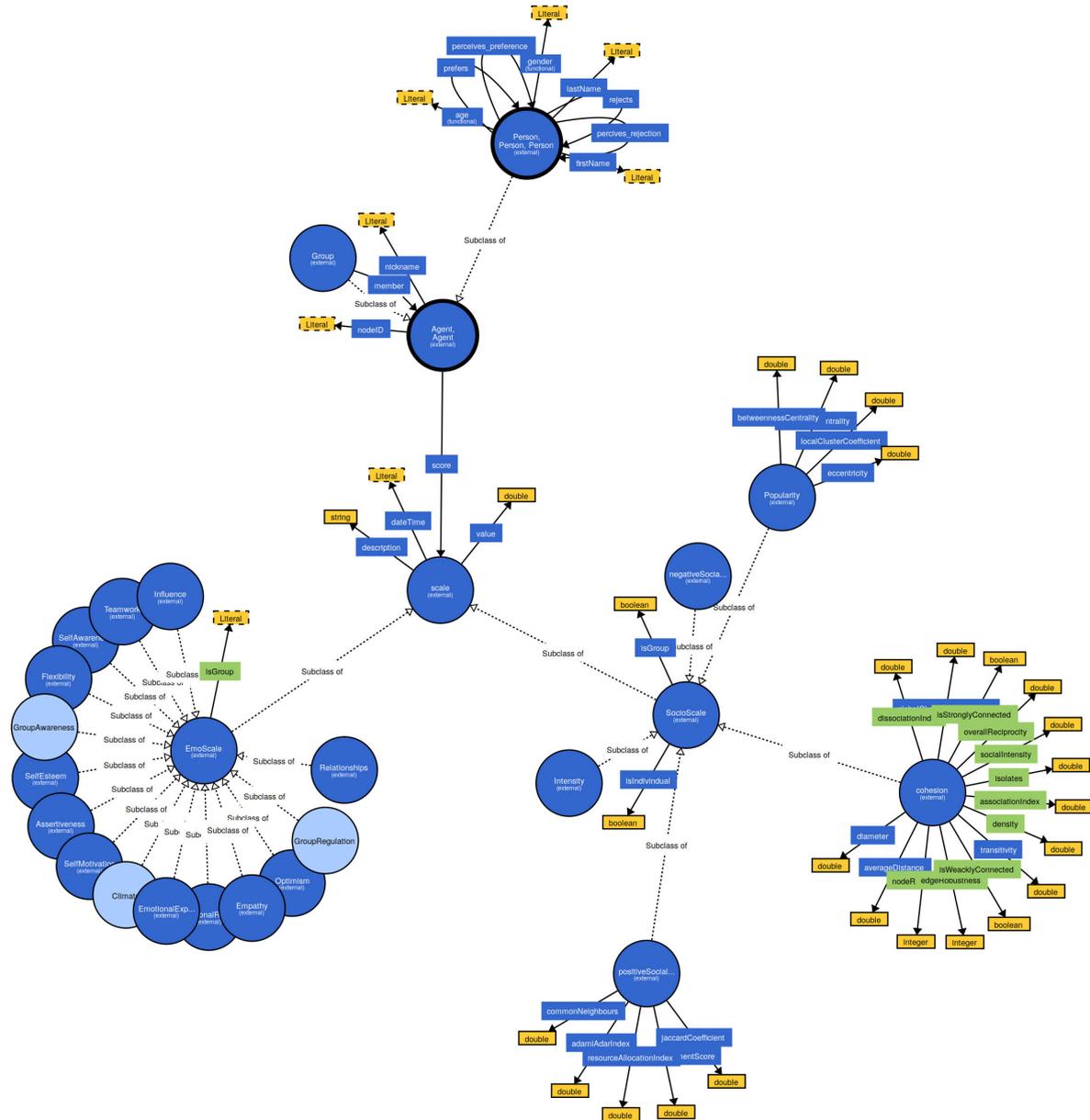


FIGURE 4. Revised EmoSocio ontology [26].

them (Fig. 5). Four type of relationships are considered, denoting preference, rejection, perception of preference and perception of rejection among the members of the group. Different weights represent the intensity of each relationship. An emosociogram is a multi-graph, meaning that a pair of nodes may have different types of relationships simultaneously (parallel edges). For instance, node A may have a “preference” relationship towards node B and at the same time a “perception of preference” relationship with node B.

Each node of an emosociogram is associated with a set of EI properties that may change across time. These properties refer to the twelve scales of the individual part of the emotional constructs of EmoSocio. Each node is also associated

with a set of sociometric properties that evolve across time. These properties refer to the seven scales of the individual part of the social constructs of EmoSocio. The emosociogram also includes information for a set of properties at a graph level. These properties regard the three CEI scales of EmoSocio and the set of cohesion scales presented in Fig. 2.

IV. EMOSOCIOGRAMS PSYCHOMETRIC TOOL

Building upon the theoretical foundation of the EmoSocio model, we have developed an open-source psychometric tool to support the assessment of the emotional and social competencies of individuals and groups. This tool, called as EmoSociograms [27], is targeted to organizations that want

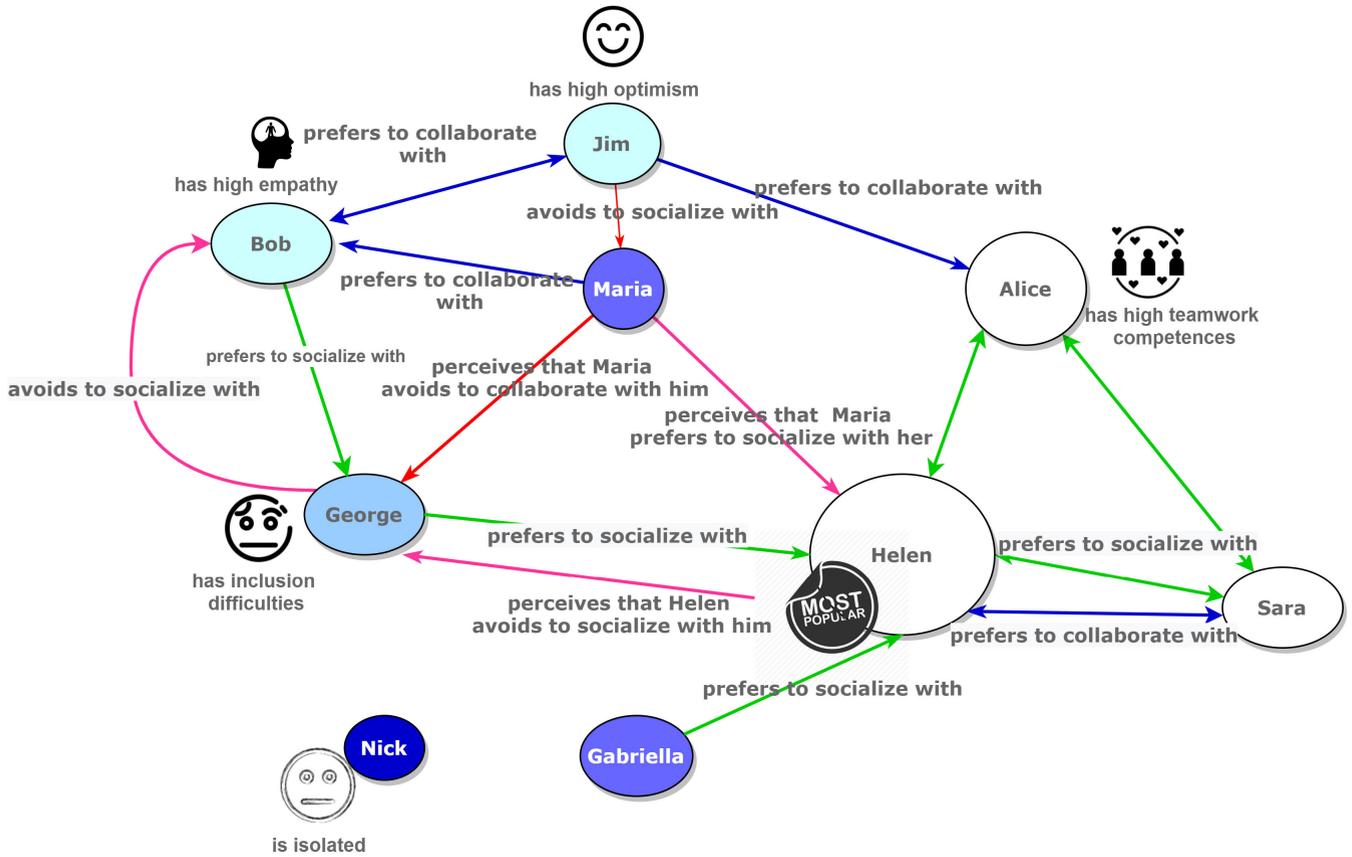


FIGURE 5. High level representation of an emosociogram.

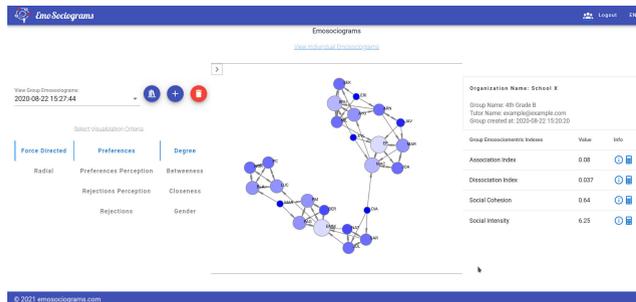


FIGURE 6. Group level emosociograms tool screenshot.

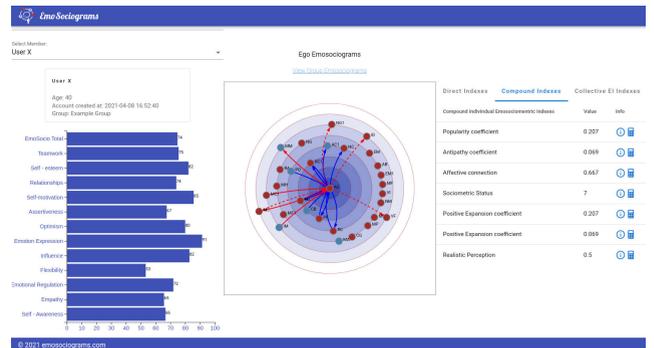


FIGURE 7. Individual level emosociograms tool screenshot.

to improve the performance of their groups. Among others, it can be applied in working environments for the improvement of the emotional climate of groups and their overall productivity, in educational groups for the improvement of the collaboration among students, the reduction of social exclusion phenomena and the improvement in the achieved learning outcomes, in sport teams for the improvement of the collaboration and the bonding among athletes in the same team, and in clinical teams for the physical and mental health improvement of the patients. The groups may interact in a in-person, digital or hybrid way.

EmoSociograms regards a modular open source software under GNU General Public License v3.0. The core

functionalities include the management of the groups (creation of groups, management of group members), the management of the produced emosociograms and the assessment of social and emotional competencies at individual and group level. At the work presented in this paper, the adopted inventory regards the EmoSocio items that are listed in Appendix, however it is possible to include modified versions of these questions. This applies mainly to the type of criteria used for the sociometric assessment process (e.g., criterion related to collaboration among colleagues, criterion related to preferences for interaction during social activities).

Different views (user interfaces) are made available for the people that manage the assessment process and are responsible for the interpretation of the provided results and the participants in each assessment process. The latter have access to a set of questions and their individual results, while the former have full access to all the reports produced at group and individual level. The group-level reports (see Fig. 6) include the visualization of emosociograms, the calculation of the values for the social constructs of EmoSocio and the calculation of the values of the CEI constructs. The individual-level reports (see Fig. 7) include the production of egocentric sociograms, as well as the emotional and sociometric values per group member.

For each applied sociometric criterion, the produced sociograms concern the preferences among the group members, the perception of preferences, the rejections and the perception of rejections. The considered criteria regard work preferences and social interaction preferences. Different graphs are produced based on the application of different centrality measures (e.g., degree, betweenness, closeness centrality).

A. EMOSOCIOGRAMS ARCHITECTURAL APPROACH

The EmoSociograms architectural approach is depicted in Figure 8. EmoSociograms consists of a backend and a frontend part.

The backend part includes the EmoSocioX library and a set of Representational State Transfer (REST) Application Programming Interfaces (APIs). The EmoSocioX library supports various graph analysis functions (e.g., calculation of graph density, diameter, global clustering coefficient, identification of isolated members or cliques, comparison among graphs) and is based on the NetworkX Python library. The REST APIs are written in Python and provided through a Flask web server. The REST APIs support a wide set of functionalities, including the registration of end users, the creation and management of groups and group members, the creation and management of surveys and the provision of the produced results per group. Information storage and retrieval is supported by a MySQL database.

The frontend part is implemented based on Vue.js and the D3.js JavaScript library. The user interfaces are implemented on Vue.js 3 by taking advantage of the Quasar user interfaces development framework. A responsive design approach has been followed, making available views for different types of devices. The visualisation of emosociograms (graphs visualization) is implemented with the D3.js library and integrated in the provided user interfaces.

V. EVALUATION RESULTS

A. ASSESSMENT PROCESS, PARTICIPANTS AND OPEN DATA

The assessment of the revised version of the EmoSocio model is based on a set of evaluation activities that took place in twelve groups in Spain and Greece. These groups regard

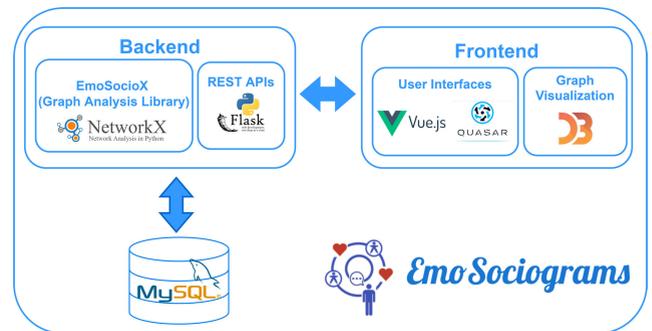


FIGURE 8. EmoSociograms architectural view.

classrooms composed by undergraduate students, associations of teachers in primary and secondary education level and a digital forum community.

Specifically, the groups of students come from classrooms in the Pedagogical Department of the University of Barcelona. Eight groups of students are formulated with number of participants ranging from 24 to 33 per group (total number equal to 215). These students participate in undergraduate programmes of the university. During the time period of the assessment, their interaction in the classroom was both in-person and virtual, since, due to Covid-19 pandemic, a combination of in-person and online lessons took place. The groups of associations of teachers come from primary and secondary schools in Barcelona. Three groups are formulated with number of participants ranging from 18 to 58 per group (total number equal to 106). Similarly with the groups of students, interaction among teachers was both in-person and virtual, however with much greater time period of familiarity among the group members. The online discussion forum is a Greek forum where the main posts and discussions regard issues tackled in the daily life of women. Interaction is taking place online through sharing of posts, declaration of preferences in the posts, posting of comments and participation to discussions. Upon a call for interest that was announced in the forum, a group with 350 participants was formulated. From the aforementioned participants, the total number of persons that were actively engaged in the assessment is 507. The participants provided their consent and voluntarily collaborated with the study and provided responses to the questionnaires without receiving any financial compensation. The collected data have been anonymized in such a manner that the identity of the participants cannot readily be ascertained, directly or through identifiers linked to each one of them. The anonymized data is used for analysis purposes. No further approval was required.

By using EmoSociograms, the participants rated themselves on each of the 127 items of the EmoSocio model, using a five-point response scale. Two sociometric criteria were used, related to preferences in terms of socializing with the group members and in terms of cooperation with the group members. Each member had to select a set of members, denoting preferences, rejections, perception of

preferences and perception of rejections. By collecting all the data, an emosociogram was produced per group, including the assessment outcomes for both the individual and group level constructs of EmoSocio.

Following, we proceeded to three main type of analysis. The first type regards reliability and validity analysis for the EmoSocio constructs. The second type regards social network analysis of the social and emotional status of the groups. The third type regards the examination of the interplay among CEI and group dynamics indicators, including indicators provided based on the digital footprint of the members of the digital community.

It should be noted that the provided work and material in this manuscript is made openly available to be accessible, discoverable and usable by the scientific community. The data collected by the participants are anonymized and made available as open data [28], while the analysis results can be easily reproduced. The EmoSocio Ontology [26] is also made publicly available, facilitating its adoption, usage and extension by interested parties. The EmoSociograms psychometric tool [27] is released as an open-source software, while being in a development phase towards a stable release.

B. EI MODEL RELIABILITY AND VALIDITY ANALYSIS

Reliability and validity results regard the revised version of the EmoSocio model that is presented in this paper, while a detailed reliability and validity analysis is provided at [1]. The presented results regard the final set of items used for the composition of the constructs, upon an elimination process that was followed, leading to a final set of 90 items for the individual EI part, 29 items for the CEI part and 8 sociometric items.

Internal consistency is a measure of reliability used to check consistency on the responses of the participants across the items of the questionnaire. It is applied per construct as well as for the overall EI indicator. To evaluate internal consistency, we have used the Cronbach’s α statistic and the McDonald’s ω statistic, while we also examine the average inter-item correlation per construct. The results are made available in Table 4.

Good to high internal consistency scores are measured (values from 0.60 to 0.84) for the various constructs, while most of them have values close or higher from 0.70. This result is considered satisfactory in terms of assessment of the reliability of the set of constructs. Furthermore, the average inter-item correlation varies from 0.15 to 0.46 (ideally, the average inter-item correlation for a set of items should be between 0.20 and 0.40 [29]), showing that there is homogeneity across the items, while a sufficiently unique variance between them is maintained so as to not be isomorphic with each other.

In the case of divergent (or discriminant) validity, we check whether concepts or measurements that are not supposed to be related are poorly correlated. We check the divergent validity based on the correlation coefficients between different EmoSocio constructs to ensure that theoretically-based non-

TABLE 4. EmoSocio constructs reliability.

Construct	Cronbach α	McDonald ω	Average inter-item correlation
Self-Awareness	0.79	0.79	0.38
Emotional Regulation	0.78	0.79	0.26
Self-Motivation	0.76	0.76	0.31
Optimism	0.84	0.81	0.46
Self-Esteem	0.79	0.81	0.30
Empathy	0.60	0.62	0.20
Teamwork	0.69	0.68	0.20
Flexibility	0.66	0.67	0.25
Emotional Expression	0.82	0.83	0.39
Assertiveness	0.67	0.67	0.22
Influence	0.66	0.67	0.22
Relationships	0.81	0.83	0.30
EmoSocio Total (Individual)	0.94	0.94	0.15
Group Emotional Awareness	0.69	0.69	0.36
Group Emotional Regulation	0.77	0.77	0.25
Group Emotional Climate	0.83	0.82	0.28
Collective Emotional Intelligence	0.91	0.90	0.27

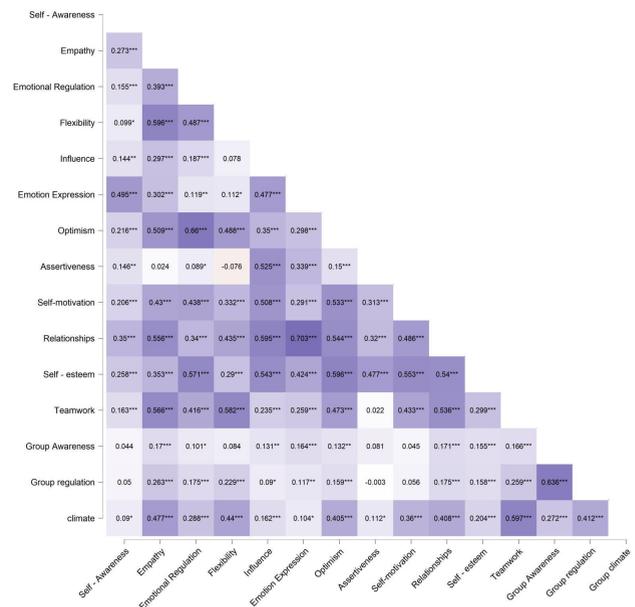


FIGURE 9. EmoSocio divergent validity correlogram (individual level).

overlapping constructs do not significantly overlap. To do so, a correlogram is produced for the statistically significant correlations (p -value < 0.01), as depicted in Fig. 9.

Given that the produced correlation values are in most of the cases lower than 0.6 (low to moderate correlation values), no major overlapping is identified among the EmoSocio constructs. The only cases that the correlation coefficient is bigger than 0.6 are between the scales of Relationships and Emotional Expression (0.7), the scales of Optimism and Emotional Regulation (0.66), and the scales of Group emotional awareness and Group emotional regulation

TABLE 5. Group sociometric and CEI indexes.

Group index	Working Groups	Educational Groups	Digital Community
Members	35	35	349
Association index	0.138	0.116	0.001
Dissociation index	0.007	0.005	0
Overall reciprocity	0.558	0.638	0.135
Social intensity	0.499	0.340	0.020
Density	0.259	0.215	0.017
Transitivity	0.422	0.516	0.224
Global clustering coefficient	0.392	0.505	0.229
Node robustness	1	0	0
Edge robustness	0.333	0	0
Is strongly connected	0.333	0	0
Is weakly connected	1	0.875	0
Isolated members (percentage)	1.9	5.3	22.9
Average shortest path	1.963	2.109	2.539
Diameter	4	5	7
Group emotional climate	72.887	71.026	43.07
Group emotional awareness	70.91	72.464	74.21
Group emotional regulation	66.753	74.514	71.36
Total CEI	70.183	72.666	62.88

(0.64). Regarding the divergent validity of the CEI part of EmoSocio, group emotional awareness, regulation and climate appear to be divergent enough with a moderate contiguity between group emotional awareness and group emotional regulation (0.6).

C. GROUP DYNAMICS ANALYSIS

The revised EmoSocio model has been introduced to the EmoSociograms psychometric tool and used for assessing the social and emotional competencies in the groups that are detailed in Section V-A. Following, we provide details regarding the identified social and emotional characteristics of these groups. The numeric results are summarized in Table 5.

Firstly, we present the outcomes for the educational and the working groups, considering that the produced emosociograms in these cases have some similarities. Both group categories are similar in terms of members size, association / dissociation indexes and density. In Fig. 10 and Fig. 11, we provide the produced emosociograms for the preference and rejection sociometric criteria for one of the working groups. Similarly, in Fig. 12 and Fig. 13, we provide the similar emosociograms for one of the educational groups.

In the working group, the preference emosociogram consists of a strongly connected graph where the majority of the nodes tend to be white and bigger in size (e.g., see Fig. 10), characteristic that is associated with an increased popularity of a member. It can be claimed that -for this group- popularity is not restricted to a limited set of members, but it is dispersed across the working group. In the case of the rejections, no negative “star” is identified, while the graph is not dense. On the other hand, in the educational environments, the preferences emosociogram consists of a weakly connected graph with risk

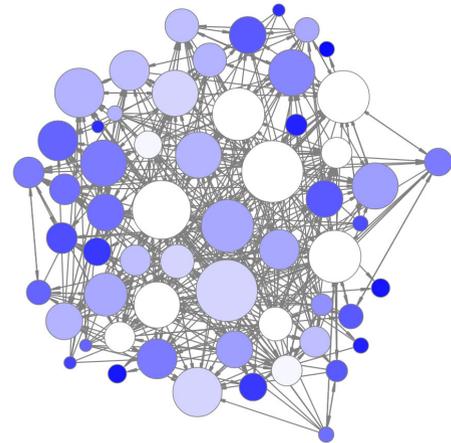


FIGURE 10. Preferences emosociogram for a working group.

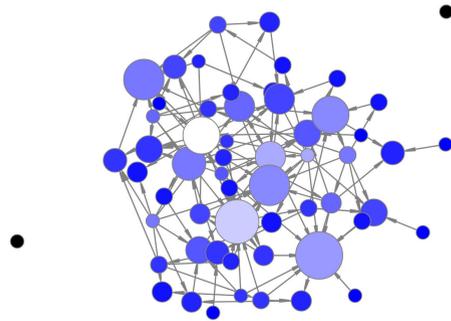


FIGURE 11. Rejections emosociogram for a working group.

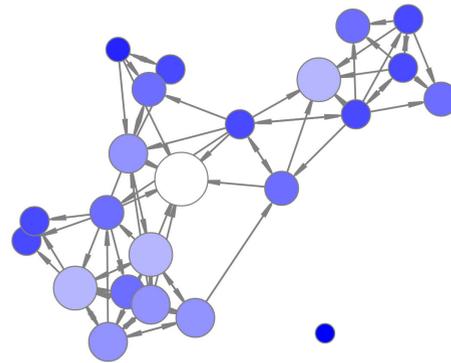


FIGURE 12. Preferences emosociogram for an education group.

to get disconnected in two sub-groups. In this case, the social intensity of the graph is lower (0.34 instead of 0.50), while the average shortest path and the diameter have higher values.

In terms of social structures identification, educational groups have higher value in the global clustering coefficient index, as well as in the number of isolated members (5.3% instead of 1.9%). In terms of reciprocity, working groups have lower overall reciprocity than educational groups. It can be claimed that educational groups share more reciprocal relationships, however manifested inside social cliques. This result can be also supported by the fact that 2 out of 3 of the

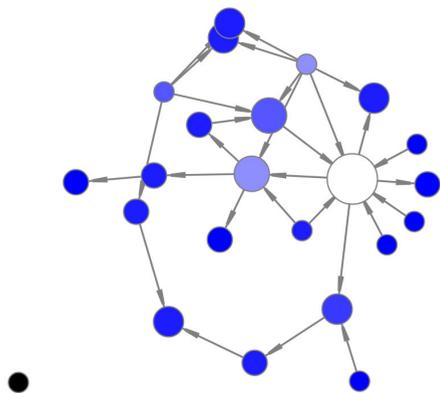


FIGURE 13. Rejections emosociogram for an education group.

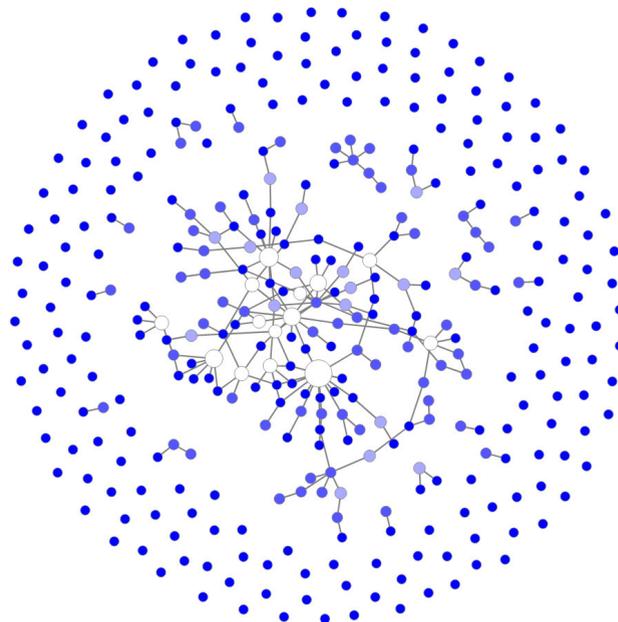


FIGURE 15. Rejections emosociogram for a digital community.

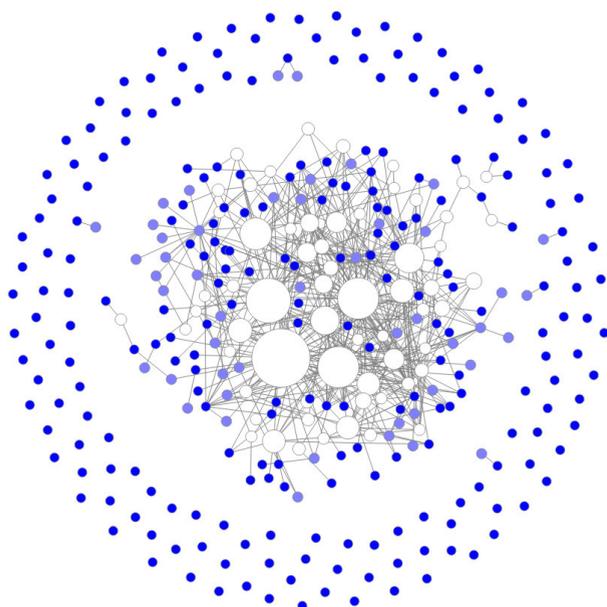


FIGURE 14. Preferences emosociogram for a digital community.

working groups graphs were strongly connected, compared to 0 for the educational groups. This setup can be also attributed to the effects of Covid-19 pandemic, where the students participated in both in-person and online lectures and maybe did not have the chance to expand their social interactions and bonding. In terms of robustness, the working groups have higher values in the node and edge robustness indexes.

Regarding the CEI constructs, the estimated values are very close (around 70 %) for both the educational and the working groups. The latter present somehow lower values in the group emotional regulation construct, possibly due to the deterioration in the relationships that can be an outcome of a long-term collaboration with various distributed responsibilities among the group members.

The digital community is much larger in terms of size (349 members), while it presents lower cohesion levels compared to the working and educational groups. Such a result is

expected, given that most of the digital community members do not know each other in person, while they freely and asynchronously interact without any collaboration framework in place. In Fig. 14 and Fig. 15, we provide the produced emosociograms for the preference and rejection sociometric criteria for the digital community.

A few popular members are identified, concentrating a lot of selections in terms of preferences, while a large part of the community members (22.9%) have the role of an observer. These members declared their interest to participate in the assessment survey, however were not actively engaged in due time and are categorized as isolated in the produced graph. The total CEI is lower than the other groups (63%), due to the low value in the group emotional climate (43%). The anonymous exchange of messages among the users and the raw expression of opinions, seems to affect negatively the emotional climate of the community.

D. GROUP DYNAMICS AND CEI INTERPLAY

As detailed in Section II-A, conceptualization and measurement of CEI is done in two ways; by summing the individual EI indicators of the group's members or through the assessment of CEI constructs. In Fig. 16 we provide the results of the calculation of the CEI in both ways for the constructs of (group) emotional awareness and (group) emotional regulation, given that there is a direct mapping between the constructs in the individual part and the collective part of the model. Average values are provided per group category. It is shown that in the case of the group-referent calculation, larger values are calculated for both constructs. The difference in the values can be due to the increased perception that people may have regarding their understanding of the emotions of

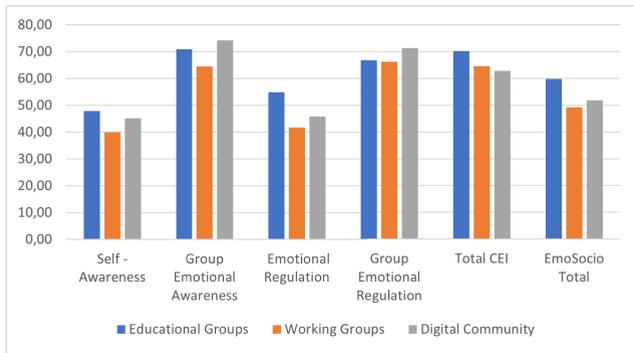


FIGURE 16. Individual and group-referent CEI calculation.

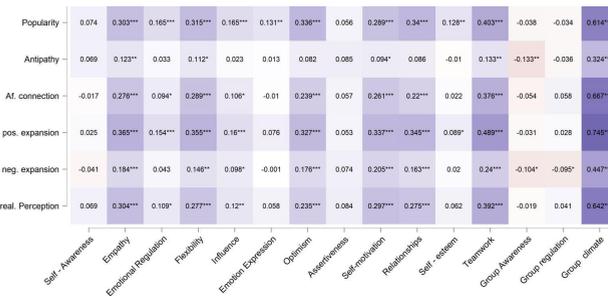


FIGURE 17. Correlations between EI traits and sociometric indexes per member.

others as well as their capacity to manage them, compared to the perception for the management of their own emotions. Cross-group differences seem to be maintained in both ways of measurements, especially in the case of the emotional awareness construct.

By comparing the collective with the individual EI constructs properties, based on their perception at individual level, some interesting insights are produced. As presented in Fig. 9, the group emotional climate (affective cohesion) construct presents moderate correlation with the teamwork individual EI construct (0.6), denoting that individuals with high cooperation skills enjoy the emotional climate in their groups. Similarly, at Fig. 17, the group emotional climate shows high correlations (from 0.61 to 0.74) with a set of sociometric indexes, including the popularity, the affective connection (reciprocity), the positive social expansion and the realistic perception indexes. These highlights make clear that members with high popularity and realistic perception of the dynamics of the group they belong to, feel empowered to shape the emotional climate of the group and enjoy it.

Similar comparisons have taken place at group level (see Fig. 18), based on the estimation of the collective EI constructs and the average values of the individual EI constructs per group. It is shown that values in the overall reciprocity (affective connection) and the density index are positively correlated with the group emotional climate (correlation values of 0.663 and 0.709), considering the establishment of strong preference relationships. A strong negative correlation is also depicted between the percentage of isolated members and the group emotional climate. It is reasonable that in

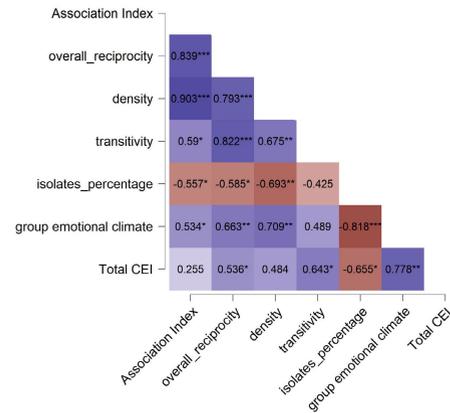


FIGURE 18. Interplay of sociometric and CEI traits at group level.

groups with low level of members inclusion, collaboration and solidarity levels among the group members will be low. Furthermore, in the analysis outcomes, it is shown that the group emotional climate is highly correlated with the flexibility (0.73) and the teamwork (0.72) construct at group level. The existence of a good collaboration spirit among the group members and the capacity to adapt in case of difficulties and changes in the operational environment contribute towards the building of a positive emotional climate.

Moving one step further, in the case of the digital community, we proceeded with a comparison of the calculated sociometric indexes with the digital footprint of the community members. To build their digital footprint, we collected data for the followers, the following members, the number of posts and the collected points of each member of the community. The points are gained based on the activity of the members in terms of posts, comments, likes or dislikes, their popularity in terms of followers and their expansion in terms of people that they follow. The popularity index of each member is highly correlated with the followers (0.84), the following members (0.68) and the points (0.67) of the member. This result shows that the declared preferences of the members in the sociometric part of the assessment study are in accordance with their real preferences in the digital forum. A moderate correlation also appears between the positive expansion index and the points of each member (0.52). Members with high positive social expansion seem to have a wide range of interactions with the rest members in the forum, including the participation to discussions, the expression of interest for their posts and the expansion of their social network within the forum.

VI. CONCLUSION

The work presented in this manuscript combines a theoretical foundation for the construct of Collective Emotional Intelligence (CEI) based on the revision of the EmoSocio EI model with the development of an open-source tool (EmoSociograms) to assess both social and emotional competencies of individuals and groups. A wide range of assessment activities have taken place in working groups,

educational groups and a digital forum with 507 active participants in total.

Based on the outcomes of the assessment activities, it can be claimed that the revised version of the EmoSocio model can effectively represent the constructs of Emotional Intelligence at individual and group level, as well as a set of social constructs regarding the abilities of individuals to establish and maintain qualitative relationships, belong and interact within a group. In this representation, the construct of cohesion, including both its social and affective aspects, is one of the most crucial construct for assessing the group-level competencies. In EmoSocio, we have managed to represent the multi-dimensional aspect of cohesion, while in parallel trying to keep its definition and way of assessment clear and explainable.

The interplay between the CEI construct and the group dynamics has been examined in both in-person and digital groups, considering the representation of the collected data in the form of emosociograms. In this way, a set of social and emotional data in individual and group level is made available for analysis. Some initial insights are produced regarding the effect of the evolution of the group dynamics to CEI indicators and vice-versa. These insights are in accordance with the real behaviour of the participants in the digital community, based on the comparison of similar indexes produced in the assessment study and their activity in the digital forum.

The produced results are considered promising to serve as a starting point for the realisation of further assessment studies in the future. The existence of an open-access EI model, an ontology and an open-source psychometric tool can act as catalysts towards the realisation of further studies by interdisciplinary scientists. In this way, more light can be shed on the interplay between the CEI and the group dynamics in different types of groups.

APPENDIX

EMOSOCIO INVENTORY ITEMS

Self - Awareness (6 items) (+) I am usually aware of the way that I'm feeling; I think about the causes of my emotions; I often stop to analyze how I'm feeling. (–) I rarely analyze my emotions; I rarely think about how I feel; I often ignore my feelings.

Empathy (7 items) (+) I take time out for others; I understand people who think differently; I anticipate the needs of others; I am good at sensing what others are feeling. (–) I find it hard to forgive others; I get annoyed with others' behaviors; I am quick to judge others.

Emotional Regulation (10 items) (+) I reflect on things before acting; I rarely feel depressed; I let others finish what they are saying; I remain calm under pressure; I don't let little things anger me. (–) I do things I later regret; I lose my temper frequently; I get upset by unpleasant thoughts that come into my mind; I change my mood a lot; I often worry about things that turn out to be unimportant.

Flexibility (6 items) (+) I adapt easily to new situations; I am good at taking advice. (–) I want to have the last word; I

react strongly to criticism; I am annoyed by others' mistakes; I get upset if others change the way that I have arranged things.

Influence (7 items) (+) I persuade others to change their views; I am good at helping people work well together; I try to lead others. (–) I am afraid to draw attention to myself; I am not good at planning group activities; I find it difficult to approach others; I wait for others to lead the way.

Emotional Expression (7 items) (+) I express my affection physically; I express my happiness in a childlike manner; I am able to describe my feelings easily. (–) I am not good at describing the emotions I feel throughout the day; I reveal little about myself; I keep my feelings to myself, regardless of how unhappy I am; I have difficulty expressing my feelings.

Optimism (6 items) (+) I look at the bright side of life; I think about what is good in my life when I feel down; I can find the positive in what seems negative to others; I remain hopeful despite challenges. (–) I am often in a bad mood; I see difficulties everywhere.

Assertiveness (8 items) (+) I challenge others' points of view; I say what I think; I am not afraid of providing criticism. (–) I hate to seem pushy; I can't stand confrontations; I hold back my opinions; I feel guilty when I say NO; I let others make the decisions.

Self-motivation (7 items) (+) I plunge into tasks with all my heart; I accept challenging tasks; I turn plans into actions; I never give up. (–) I need a push to get started; I am easily discouraged; I put little time and effort into my work.

Relationships (10 items) (+) I trust others; I try to forgive and forget; I have the ability to make others feel interesting; I know that there are people in my life who care as much for me as for themselves; I get along well with people I have just met. (–) I reveal little about myself; I often feel uncomfortable around others; I have difficulty expressing my feelings; I keep others at a distance; I don't know how to handle myself in a new social situation.

Self - esteem (8 items) (+) I know my strengths; I know that my decisions are correct; I feel comfortable with myself am not embarrassed easily. (–) I am afraid to draw attention to myself; I worry about what people think of me; I often see other people as my competitors; I am less capable than most people; I have a low opinion of myself.

Teamwork (9 items) (+) I don't talk badly to outsiders about my own group; I feel I must respect the decisions made by my group; I enjoy being part of a group; I support my teammates or fellow group members; I don't miss group meetings or team practices. (–) I feel that people have a hard time understanding me; I work best when I am alone; I suspect hidden motives in others; I impose my will on others.

Group Emotional Awareness (4 items) (+) Team members always know others' emotions from their behaviour; We make an effort to understand each others perspectives; We provide constructive feedback to members whose behaviour is unacceptable; In this team we usually care about what our workmates are feeling.

Group Emotional regulation (10 items) (+) Team members are able to control their temper so that they can handle difficulties rationally; We take time to talk about frustrations and other feelings in the group; We use humor to help us ease tension in the group; We have developed methods to help us tackle emotionally charged issues; We make each other feel better when we are down. (–) Jealousy or rivalry are present among the members of our group; Personality conflicts are evident in our group; Criticism was sometimes thrown without consideration for people feelings; Often there is tension among the members of our group; It was difficult to calm down quickly when we got mad at each other.

Group Emotional Climate (15 items) (+) I have a strong sense of belonging to this group; The group members feel comfortable in expressing disagreements in the group; Group members are receptive to feedback and criticism; The group members feel comfortable in expressing disagreements in the group; We all take responsibility if one of our group results goes poorly; Most group members contribute to decision making in this group; Members of this team act in a way that show they care about each other; Despite group tensions, members tend to stick together; We let members know that we value their contributions. (–) I do not enjoy the social interaction occurring in this group; I am not going to miss the members of this group when the group activity ends; Some members are quiet, and minimal attempts are made to include them; I feel vulnerable in this group; It appears that the individual and group goals are inconsistent; Many members engage in “back-biting” in this group.

Sociometry (8 items) (+) Who would you like to socialize with in your spare time? Who do you think they would like to socialize with you in their spare time? Who would you like to cooperate with? Who do you think they would like to cooperate with you? (–) Who would you rather not socialize with in your spare time? Who do you think they would rather not socialize with you in their spare time? Who would you rather not cooperate with? Who do you think they would rather not like to cooperate with you?

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