

Outdoor play and interaction skills in early childhood education: approaching for measuring using social network analysis

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Abstract:

Over the last decade, researches show evidences that the free play and the outdoor activities have positive impact on children, namely on social skills' development as cooperation. However, the study of children interaction, especially when we want to identify and study a particular type of interaction, like cooperative interaction, requires a reflexion about the most efficient tolls and methods that can be used. With this article we intend to present a first reflective review of mathematical techniques and methods that can be potentially useful in the study of cooperative interactions with children in outdoor free play. Considering the characteristics of outdoor learning environments, which are based on freedom and free play exploitation of nature, the methods used in studies of this nature in indoor environment, tend to be more controlled by adults and more spatially limited, may not be the most effective. We intend to demonstrate that it is necessary to create a combination of mathematical techniques and methods based on the social network analysis, given the specificity of the educational outdoor environment or the space level and the dynamics of activities that there are usually generated.

Key words: graph theory, adjacency matrix, network, outdoor play environment, cooperative skills, early childhood

Introduction

A cooperative learning environment can provide to children the opportunities for sharing ideas and learning how others think and react to problems. "Cooperation is working together to accomplish shared goals. Within cooperative situations, individuals seek outcomes that are beneficial to themselves and beneficial to all other group members" (Sash, Candlin & Rose, 2003, p. 181). As creative process, cooperative learning append when children combine materials, ideas and experiences to achieve new effects, "they learn through immediate experience with items and they use their own words to talk about their experience" (Vodopivec, 2011, p.89). Play is, in fact, the most important activity in childhood. Children need to play. Is through play that children experiment, touch, feel, imagine and create, and they can understand dimensions like verbalization, social interaction and conceptual conflict (Spodek & Saracho, 1998). During play, when children interact with others, they build cooperative skills and increase their ability to sustain relationships (Wajskop, 1995).

The outdoor educational programs, inspired on the idea that children can develop optimally outside through free play, have increasing followers around the world, especially in the last decade (Hygum, 2014). The reasons for that relate to the fact that the surveys indicate a wide range of benefits for children who attend it. Some reports show that outdoor play provides important skills development and health benefits for children (e.g. Bird, 2007; Dillon et al., 2005; Fjørtoft, 2000, 2001; Mårtensson et al., 2009; Taylor, Kuo & Sullivan, 1998). Multiple studies show that children who participate in outdoor environment develop more varied and elaborated patterns of play (e.g. Mårtensson et al., 2009; Taylor et al., 1998).

Although Scandinavian studies report positive impact from playing in nature on the children's social play, more studies are needed to determine "whether there are specific skills or abilities that are learned better in a natural environment than in other environments" (Fjørtoft & Sageie, 2000, Fjørtoft, 2004, p.40). It is necessary understand how can outdoor play improve the development of cooperation skills on children. This will involve understanding what approaches, models and methods can be useful to better understand the potential relation between de outdoor play and cooperative skills development in early childhood education. With this article we intend to present a first reflective review of tools and methods that can be potentially useful in the study of cooperative interactions with children during outdoor free play. Taking into account the nature of the context and the data we intend to collect, we try to find possible tools and methods that make possible explore this domain.

Collect data during outdoor free play

Outdoor play can be recognized as a collective structure, like a team sport with members that work together to achieve a common goal. Like a team sport, during the play can emerge sub-groups, but can also emerge, for instance, leaders that compete for the leadership on the group. The play must be analysed because there exists different types of play and some of them don't involve cooperation, as parallel play through which interaction does not occur. Those different possibilities must be analysed to better understand the cooperation process during the free outdoor play, the way it emerges and how it arises. It is necessary to collect a substantial number of recording sessions and categorized the different interactions that can be emerged during them. But, how can it be done? There are several ways to study the peers' interactions. The questionnaires and systematic observation are the two most common types. Nevertheless, it's important to understand what methods can be useful and effective in the specific context to be analyzed for the main goal – understand the potentiality of outdoor free play to the development of children's cooperation skills.

To examine the degree to which pro-social peers' affiliation predicted the subsequent emotional quality of young children's peer interactions, Fabes et al. (2012) conducted a study using the extended number of 33138 observations, collected across 3 years. Like Hanish et al. (2005) has done to analyse 19832 observations on a study which was intended to examine the predictors and effects of exposure to externalizing of homophily and peer contagion processes on preschoolers and kindergarteners, they "compute the proportion of time spent in social play by dividing the number of times a child was observed to engage in a social interaction with a peer (e.g., social conversation, cooperative play) by the number of times he/she was observed" (Hanish et al., 2005, p.7). In the both cases the data analyses involved the categorization of children behaviours during play and the analyses of questionnaires completed by children's teachers (Fabes et al., 2012; Hanish et al., 2005). According to Hanish et al. (2005, p.14), "this method is particularly suited for use with observational data because they provide a relatively precise count of the number of times children interact with all possible play partners". On the other hand, with this method we can't measure the nature of the interactions. Moreover, although systematic observation in a predetermined context captures the ecological environment of the child and the variability of social interactions, it is a process of slow collection, susceptible to various influences, because the camera can influence the child's behaviour and the observer's expectations can influence the observations and sequent encodings (Veiga, Capucho, Neto and Rieff, 2015).

One of the common instruments used to evaluate children social skill's is the Preschool and Kindergarten Behaviour Scales. This tool, specifically developed to 3-6 years old children, with some similarities with Likert instrument, includes the Scale and Social Skill, seeking to assess the social and emotional behaviours of children and where social cooperation is included, and Behaviour Problems Scale that assesses the behavioural problem to social and emotional level (Merrell, 2002). However, this type of instruments puts the focus on adult perception and their evaluation of children's competencies. One of the limitations that may point to this instrument is that, like most of the questionnaires, allows to gather information on various dimensions; questionnaires focus behaviour in a global manner, sometimes influenced by memory, which may underestimate the least frequent interactions (Veiga et al., 2015). Nevertheless, this instrument in association with other methods and data can provide important information to reach our main goal.

Also sociometrics tools for measuring social relationships across children are well established in educational research. We can define sociometry as a "way of measuring the degree of relatedness among people" (Rostampoor-Vajari, 2012, p. 570). According to Moreno (1941, p.26), responsible for the development of sociometric technique, when sociometric tests are applied, for instance, to a formal group in a public school, the findings permit "an analysis of inner structures, percentages of attractions and repulsions, the number of isolates, pairs". This tool can provide us information about the children's preferences, telling us, for instance, with whom a child likes to play or cooperate. This information can be represented as networks, as a systematic method for graphically representing individuals and the relationships between them (Rostampoor-Vajari, 2012). Basically, sociometry is a "mathematical study of psychological properties of populations, the experimental technique of and the results obtained by application of quantitative methods" (Moreno, 1953, p. 15-16, in Rostampoor-Vajari, 2012, p. 570). However, Child and Nind (2012) suggest that social cognitive mapping may provide an alternative to sociometrics, because it has more information about the nature of social networks and the relations amongst peers. In fact, these authors present a critic point of view about sociometric methods, from a social justice perspective, drawing attention to the potential for harm through the normative pressures and labelling processes entailed. However, different than Preschool and Kindergarten Behaviour Scales, sociometric methods and tools can give us access to children's perspective, as an important information in studies involving their interpersonal relationships.

Cognitive mapping approaches have been used to identify people's perceptions of complex social systems. According to Vanwindekens, Stilmant and Baret (2013), the cognitive mapping approaches are typically used to identify the individuals' perceptions of complex social systems. Cognitive maps are made of several variables interconnected by an interval relationship, considering individuals points of view, gathered during open interviews. The mathematical formulation of cognitive maps allows us to draw a cognitive individual maps that could be aggregate to a cognitive social map (Vanwindekens, Stilmant & Baret, 2013). According to Bacete and Perrin (2013), the social cognitive map is an effective method used to identify groups

of people in natural environments and can be applied in various fields such as in the educational field. The social cognitive map provides information about each individual from a group and the people with whom each is most closely linked, the number of peer groups and the centrality of each group within the social network and the centrality of each individual in the large group. The social cognitive maps develop a procedure to define the centrality of individuals and groups in a social network that does not depend on the preferences or relationships that a subject has with another (eg, friendship, enmity, or any other type of affinity) (Bacete and Perrin, 2013). Bacete and Perrin (2013, p. 61) present a study where this method was introduced, “with its foundations, the interview procedure, the use of social cognitive map software 4.0, and the analysis of the information it yields”. They concluded that the procedures related to the social cognitive maps offer a more complete and accurate method for identification of social networks, as they allow to analyze simultaneously the social experiences with peers from different perspectives or analysis units: a single, a dyadic and group. Accordingly, we consider that social cognitive maps can be an important feature, in combination with other methods and instruments, for the study of children cooperatives interactions in outdoor environment.

Golemiec, et al. (2016) developed a study that aimed to examine the structure of behavioural interactions among kindergarten classroom to understand all possible underlying patterns in the formation of layered networks of “reciprocal” interactions, using MatLab to code analyses. They show evidences that “social interactions are not isolated behaviours and that the commonly paired types (Leadership/Followship, Aggression/Submission) interact with each other in a complex manner unpredictable given simple rules of reciprocation and transitivity” (Golemiec et al., 2016, p. 7). The authors also report that the mechanisms used is also applicable on a more general scale, stating that is possible to extend the method to more than two interaction types (Golemiec et al., 2016). In fact, social network analysis has emerged as a key technique in modern sociology. According to Wasserman and Faust (1994, p. 3), “from the view of social network analysis, the social environment can be expressed as patterns or regularities in relationships among interacting units”. The relational structure of a group consists on the patterns of relationships between each element (actor) of that group and ties among them (Wasserman & Faust, 1994). According to the fundamental concepts in network analysis presented by Wasserman and Faust (1994), formal relations (for example authority), behavioural interaction (for example talking together) and association or affiliation (for example belongs to a same social club) are examples of ties employed in network analysis. According to Clemente, Martins and Mendes (2015a), social networking is potentially useful in studies on children's interactions in outdoor environment because allows quantifying the interactions resulting from the child's action. The reason for the increase of studies on human relationships through network analysis is related to the multiple possibilities it offers. In fact, several areas such as sport, use this method because of the versatility in the analysis of interpersonal relationships (Wasserman & Faust, 1994). Social network analyses have been commonly applied, for instance, to team sport analysis especially in football and basketball (Clemente, Martins & Mendes, 2015b, Grund, 2012; Fewell et al. 2012). This method is usually used to recording the interactions between teammates in sports with the support of semi-automated system. In these case is possible to compute a set of network metrics that characterise the relationship between the elements of the team (Clemente et al., 2015b). Unfortunately, throughout this data we can analyse and quantify the interaction, but not what kind of interaction. So, this method per se could not be enough. As we already outlined, interaction and cooperation are different concepts that require tools' and methods' adaptations and/or complementation of different tools and methods that enable their identification.

Recently, Veiga et al. (2015) published a study presenting a set of methods that can be used to collect continued massive collections data through digital devices. According to them, using proximity sensors based on Radio-Frequency technology (RFID), an innovative measurement method through which it's possible the continuous and simultaneous collection and analysis of face-to-face interaction dynamics. Proximity sensors are based on identification of radio frequency devices and have the ability to detect the presence of other sensors within a specified proximity range. They communicate that information to an earpiece station through a system that registers each contact in a temporal resolution of 4 records per second, permitting a very detailed analysis. According to Veiga et al. (2015), from these data it is possible to calculate the number of contacts that each sensor has established with other sensors, how long each sensor was in close proximity to other sensors and how many and which sensors were in proximity. Therefore it is possible to calculate the time that each sensor has been without establishing contacts. It is also possible to monitor the evolution of these variables during the observation period. However, this instrument needs to be combined with other data collection tools, because through these data it is impossible to verify the existence/non-existence of interaction or cooperation among peers (Veiga et al., 2015). Another possible limitation of this instrument in a large space (outdoor educational environments) is its scope. Since these sensors have an operating range of 1.5 meters, if two children differ by more than such distance sensors record the lack of proximity. However, the facts of those children are distant of each other does not necessarily indicate that they are not interacting or cooperating. One more time, a possible solution is the introduction of another instrument that can collect the audio data that allow us to obtain this information, as microphones. However, according to Veiga et al. (2015), this instrument has the advantage that apparently did not influence the behaviour of children. The authors report that despite the curiosity of children by the sensors when they entered the playground their behaviour did not seem to have been influenced by them.

The fact that this method of collection does not require the presence of observers is a great advantage as it minimizes the child's reactivity.

How to quantify interactions based on graph theory: an approach based on social network analysis

The differences between interaction and cooperation compel us to rethink how we can adjust the different methods of collecting, processing and analysing data. Interactions correspond to the behaviour of individuals that participating with each other, for example during a conversation or a conflict. However, cooperation is much more than that. Cooperation is something more complex that involve a common goal, playing complementary roles (Warneken & Tomasello, 2007).

We already understood the potential of social network analysis on interactions studies (Clemente et al., 2015b). The aim of this chapter is to present the network measurements that allows to perform a meso-analysis and identify the specific interactions, as cooperation, between children. Clemente et al. (2015b, p. 69), presented a topological overlap measure that represents the pair of players that cooperates with the same players, applied on spots teams. According to them, “topological overlap measure may also represent the overlap between two players even if they do not participate in the same attacking plays with one another. Thus, this measure allows to identify the patterns of interaction between triads without consider the specific pairs relations”. To understand how that meso-analysis could be useful to study the interactions between children during free play, we present the, Clemente et al. (2015b) proposition. According to the authors (Clemente et al., 2015b, p. 66), “the average neighbour degree measures the correlation levels between pairs of players”. This measure can allows identifying the patterns of interactions and the strength of interaction between two children during play and can be used to identify patterns of cooperation inside the group of children and to associate these interactions with macro levels of analysis (Clemente et al., 2015b). The following, we present the *average neighbours degree* definition included in Clemente et al. (2015b):

Definition 1 (Clemente et al., 2015b)

Given one weighted digraph G with n vertices. The average neighbours degree index $\overline{ND}_D^w(n_i)$ of a vertex n_i , of G is calculated as

$$\overline{ND}_D^w(n_i) = \frac{\sum_{j=1}^n (a_{ij} + a_{ji})(k_j^{w-out} + k_j^{w-in})}{2 \times (k_i^{w-out} + k_i^{w-in})}$$

where a_{ij} are elements of the weighted adjacency matrix of a G , k_i^{w-out} and k_i^{w-in} degree index of vertex n_i .

To calculate the assortativity coefficient, Clemente et al. (2015b), resort to a set of formulas that allow analyse the tendency of connections between peer and the degree of that connectivity. The following, we present the assortativity definition included in Clemente et al. (2015b).

Definition 2 (Clemente et al., 2015b)

Given one weighted digraph G with n vertices. The weighted directed assortativity coefficient index, r_D^w , of G is calculated as

$$r_D^w = \frac{\frac{\sum_{(n_i, n_j) \in E} a_{ij} k_i^{w-out} k_j^{w-in}}{\sum_{i=1}^n \sum_{j=1}^n a_{ij}} - \left[\frac{\sum_{(n_i, n_j) \in E} \frac{1}{2} a_{ij} (k_i^{w-out} + k_j^{w-in})}{\sum_{i=1}^n \sum_{j=1}^n a_{ij}} \right]^2}{\frac{\sum_{(n_i, n_j) \in E} \frac{1}{2} a_{ij} ((k_i^{w-out})^2 + (k_j^{w-in})^2)}{\sum_{i=1}^n \sum_{j=1}^n a_{ij}} - \left[\frac{\sum_{(n_i, n_j) \in E} \frac{1}{2} a_{ij} (k_i^{w-out} + k_j^{w-in})}{\sum_{i=1}^n \sum_{j=1}^n a_{ij}} \right]^2}$$

where a_{ij} are elements of the adjacency matrix of a G , k_i^{w-out} and k_i^{w-in} degree index of vertex n_i .

According to Clemente et al. (2015b, p. 68), “we also can calculate the (weighted) assortativity coefficient for the indegree and outdegree of (weighted) digraphs”. The same authors refer the topological overlap measure as a representation of the pair of players that cooperates with the same players.

According to them, “topological overlap measure may also represent the overlap between two players even if they do not participate in the same attacking plays with one another” (Clemente et al., 2015b, p. 69). To that, the authors use “a measure that allows identify the patterns of interaction between triads without consider the specific pairs relations” (Clemente et al., 2015b, p.69). The following, we present the *topological overlap measure* definitions included in Clemente et al. (2015b):

Definition 3 (Clemente et al., 2015b)

Given one unweighted graph G with n vertices. The topological overlap measure index, TOM_{ij} , between vertices n_i and n_j is calculated as

$$TOM_{ij} = \begin{cases} \frac{\sum_{l \neq i,j} a_{il} a_{jl} + a_{ij}}{\min\{\sum_{l \neq i} a_{il} - a_{ij}, \sum_{l \neq j} a_{jl} - a_{ij}\} + 1} & i \neq j \\ 1 & i = j \end{cases}$$

where a_{ij} are elements of the adjacency matrix of a G ; considering $0 \leq a_{ij} \leq 1$, then $0 \leq TOM_{ij} \leq 1$.

Definition 4 (Clemente et al., 2015b)

Given one unweighted digraph G with n vertices. The overlap similarity index between vertices n_i and n_j at incoming or outgoing is calculated as, respectively

$$OS_D^{out}(n_i, n_j) = \frac{|N^{out}(n_i) \cap N^{out}(n_j)|}{\min\{|N^{out}(n_i)|, |N^{out}(n_j)|\}}$$

$$OS_D^{in}(n_i, n_j) = \frac{|N^{in}(n_i) \cap N^{in}(n_j)|}{\min\{|N^{in}(n_i)|, |N^{in}(n_j)|\}}$$

where $|N^{out}(n_i)|$ is the number of all outgoing neighbours of n_i and $|N^{in}(n_i)|$ is the number of all incoming neighbours of n_i .

Definition 5 (Clemente et al., 2015b)

Given one weighted graph G with n vertices. The weighted overlap similarity index, OS^w , between vertices n_i and n_j is calculated as, respectively

$$OS^w(n_i, n_j) = \frac{\sum_{n_k \in N(n_i) \cap N(n_j)} \min(w_{ik}, w_{jk})}{\min\{\sum_{n_k \in N(n_i)} w_{ik}, \sum_{n_k \in N(n_j)} w_{jk}\}}$$

where w_{ik} is the weight of $(n_i, n_k) \in E$ and $N(n_i)$ is a set of all neighbours of n_i .

Definition 6 (Clemente et al., 2015b)

Given one weighted digraph G with n vertices. The weighted overlap similarity index between vertices n_i and n_j at incoming or outgoing is calculated as, respectively

$$OS_D^{w-out}(n_i, n_j) = \frac{\sum_{n_k \in N^{out}(n_i) \cap N^{out}(n_j)} \min(w_{ik}, w_{jk})}{\min\{\sum_{n_k \in N^{out}(n_i)} w_{ik}, \sum_{n_k \in N^{out}(n_j)} w_{jk}\}}$$

$$OS_D^{w-in}(n_i, n_j) = \frac{\sum_{n_k \in N^{in}(n_i) \cap N^{in}(n_j)} \min(w_{ki}, w_{kj})}{\min\{\sum_{n_k \in N^{in}(n_i)} w_{ki}, \sum_{n_k \in N^{in}(n_j)} w_{kj}\}}$$

where w_{ki} is the weight of $(n_k, n_i) \in E$.

Conclusion

Could the outdoor education be a privileged place for cooperation?

The literature about outdoor educational environments allows us to understand that little is known in relation to the potential increase of cooperation skills development when children enjoy outdoor play. According to Fjørtoft and Sageie (2000, p. 84), “one reason may be an apparent lack of suitable methods for describing and analyzing natural (...) different play environments”. It is necessary to identify tools and methods that allow us to understand the potential of those environments to the development of children's cooperation skills.

On this paper we recognize some tools and methods usually used to study interactions that can be a starting point. To identify a cooperation situation we depend of the triangulation of different data and that work can be exhausted. The different data about each element of the group, the outdoor conditions of play, the interactions and proximity between the elements and the dialogs must be analysed. However, the categorisation of data and the aftermost triangulation can be extremely extended. Another situation that can be a problem to the data collection is the environment. In outdoor educational environment children must be able to play freely in all space. When we talk about free outdoor play, we can talk about a large spatial area with different small areas under the vegetation that requires multiple cameras strategically placed and we need to guarantee that we have a good sound system that preserves the quality of dialogs recording.

Using meso-levels of analysis, it is possible to analyse the cooperative relations between peers during free play. However, a big question remains: what combinations of tools and methods can be used to optimize the collecting and processing of data, that can permit understand the potential of free play in outdoor to the cooperation skills development, using social network analysis and meso-levels of analysis?

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