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Learning in the wild: Predicting the formation of ties in 'Ask' subreddit communities using ERG models

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Abstract

The theoretical lenses, empirical measures and analytical tools associated with social network analysis comprise a wealth of knowledge that can be used to analyse networked learning. This has popularized the use of the social network analysis approach to understand and visualize structures and dynamics in online learning networks, particularly where data could be automatically gathered and analysed. Research in the field of social network learning analysis has (a) used social network visualizations as a feedback mechanism and an intervention to enhance online social learning activities (Bakharia & Dawson, 2011; Schreurs, Teplovs, Ferguson, de Laat, & Buckingham Shum, 2013), (b) investigated what variables predicted the formation of learning ties in networked learning processes (Cho, Gay, Davidson, & Ingraffea, 2007), (c) predicted learning outcomes in online environments (Russo & Koesten, 2005), and (d) studied the nature of the learning ties (de Laat, 2006). This paper expands the understanding of the variables predicting the formation of learning ties in online informal environments. Reddit, an online news sharing site that is commonly referred to as 'the front page of the Internet', has been chosen as the environment for our investigation because conversations on it emerge from the contributions of members, and it combines perspectives of experts and non-experts (Moore & Chuang, 2017) taking place in a plethora of subcultures (subreddits) occurring outside traditional settings. We study two subreddit communities, 'AskStatistics', and 'AskSocialScience', in which we believe that informal learning is likely to happen in Reddit, and which offer avenues for comparison both in terms of the communication dynamics and learning processes occurring between members. We gathered all the interactions amongst the users of these two subreddit communities for a 1-year period, from January 1st, 2015 until December 31st, 2015. Exponential Random Graph models (ERGm) were employed to determine the endogenous (network) and exogenous (node attributes) factors facilitating the networked ties amongst the users of these communities. We found evidence that Redditors' networked ties arise from network dynamics (reciprocity and transitivity) and from the Redditors' role as a moderator in the subreddit communities. These results shed light into the understanding of the variables predicting the formation of ties in informal networked learning environments, and more broadly contribute to the development of the field of social network learning analysis.

Keywords

Social Network Learning Analysis; Informal Learning; Reddit; Subreddit Communities; ERGm

Introduction

With the advent and consolidation of social media, learning is no longer an internal and individualistic activity. Rather, learners gather information and connect to others' knowledge using a wide range of social networking sites (such as Facebook, Twitter or Instagram, amongst others).

Learning in social media takes place in 'structured' platforms, such as Youtube or Wikipedia, or in open online discussions sites such as Digg, Snapzy and Reddit (Sankin, 2017). This second type of learning is what we are calling 'learning in the wild' (following Hutchins' Cognition in the Wild, 1995). This is learning that is not occurring in formal classes, guided by instructors and structured around a set syllabus. Instead, users of these platforms pose questions and other users provide answers, where crowds of participants comment, correct, agree and/or argue about the answers.

These new media forms of learning echo Siemens' perspectives of connectivism (Siemens, 2005), where social learning is integrated with information and communication technologies (ICTs) and learning becomes a networked process. These networked learning processes can be studied by using the social network analysis approach that 'provides a toolkit for exploring learning where connectivity is the major area of investigation' (Haythornthwaite, de Laat, & Schreurs, 2016, p. 253).

This paper is an exploratory study of the universe of 'Ask' subreddits in which we believe informal learning is likely to happen in Reddit. It examines what variables (network parameters and individual attributes) predict the formation of ties amongst the users of the 'AskStatistics' and 'AskSocialScience' subreddit communities. The paper addresses the following questions:

- How are learning processes taking place in informal social media environments?
- How do network configurations and individuals' attributes affect access to and the ability to act on informal networked learning environments?

The next section provides a brief review of studies that have used social network analysis to study learning, followed by a brief overview of Reddit.

Social Network Learning Analysis

Expanding the unit of analysis from individualistic learning to the influence of social relationships, social network analysis (SNA) provides unique theoretical lenses and sets of measures for exploring learning activities in the social media age. The core concepts of SNA, *nodes, relations, ties* and *networks*, can be used to understand network learning dynamics, and the meaning and roles of ties.

Research on learning has begun to use SNA to study learning processes in online communities and networks (e.g. Rainie & Wellman, 2012; Gruzd & Haythornthwaite, 2013; Kumar et al., 2018). As stated by Haythornthwaite, de Laat and Schreurs, SNA has been employed to (a) use evidence of social network patterns as an intervention to enhance social learning activities (b) find antecedents for online social learning activities (c) predict learning outcomes and (d) to understand the nature and meaning of learning ties (Haythornthwaite et al., 2016). This paper discusses the core concepts below:

Interventions. Within the area of social learning analytics, researchers designing intervention aimed to inform teachers and students about their online activities. They have been experimenting with tools to visualize social learning activities automatically (Bakharia & Dawson, 2011). An example of these tools is the Network Awareness Tool (NAT), designed by Maarten de Laat and Bieke Schreurs (Schreurs & de Laat, 2014) which visualizes networked interaction (both actors and ideas) by identifying relations between people who interact around similar topics.

Antecedents. To investigate antecedents of the formation of learning ties means finding the variables that predict the formation of learning ties in online environments. These variables can be individual, dyadic and network levels. The attributes of the individuals (nodes) can include personal characteristics (e.g. age or learning styles), and network characteristics, such as a person centrality in the network. Despite the relevance of this type of research, few studies have used these tools to analyse e-learning processes. A noteworthy example is Cho,

Gay, Davidson and Ingraffea who researched 31 learners working together in the design of aerospace system using online collaboration tools (Cho et al., 2007). The study showed that central individuals in the network stick to their networks over time, while individuals placed in the boundary of the network were more proactive in forming new learning ties over time. The results of this investigation have relevant implications for learning purposes since they show that instructors should focus on students' attributes (both the node level and the dyadic level) and the network properties when designing networked learning activities.

Prediction. Social network analysis has also been used to predict learning outcomes, i.e. to find associations between students' positions in the network and their success in the learning process. Research conducted by Russo and Koesten (2005) found that prestige and degree centrality measures had a positive effect on learning outcomes in the class. And the study of Cho et al., showed a significant association between students' closeness centrality and their final grades (Cho et al., 2007).

Learning tie. Current understandings of the nature of the learning tie has also been the focus of research. De Laat (2006) explored the gap between social network data, learning and learning processes using a multi-method approach which collected information on learning networks ('who learned from whom?') and on the relational content of the learning ties ('what were they talking about') and on how this combination facilitated learning ('why were they talking in such a way or in another'?). The use of these questions allowed him to triangulate data and explore the learning process considering all the aspects of the relationship between networks and learning.

Our investigation aims to expand the understanding of the variables which predict the formation of learning ties in online environments (Cho et al., 2007). To do so, we use some network properties and the Redditors' attributes of two subreddit communities ('AskStatistics', and 'AskSocialScience'). More information about these communities and the data and methods used in the research is provided in the following sections.

Reddit.com

Reddit is an online social news aggregation and internet forum that is commonly referred to as 'the front page of the Internet' for the way it presents headlines and how crowd-based online voting raises the profile of news or other items to a front-page equivalent. By its own account, "Reddit bridges communities and individuals with ideas, latest digital trends and breaking news" (Reddit, 2017). It has become increasingly popular since its launch in 2005, and as of September 7, 2017, ranks 8th in terms of global traffic and 4th in the U.S (Alexa, 2017).

The basic framework of the Reddit system revolves around (a) subreddit communities, (b) posts, (c) comments, (d) votes, and (e) karma. Reddit is composed of millions of user-generated and user-moderated online communities across a wide range of topics (e.g., politics, economics, academia, etc.) called subreddits. Subreddits have their own norms and rules determining, for instance, what can be and what cannot be posted. New users are auto-subscribed to 47 "default subreddits," but may choose to unsubscribe from these subreddits and/or subscribe to other subreddits to stay updated about the subjects of their interest. Any registered user (Redditor) can create a post or comment on posts. Comments are hierarchically threaded (root comment and subsequent comments) and can be in response to a general post (root comment) or in reply to another comment.

Redditors can upvote or downvote others' posts and comments. Posts and comments are displayed on the site according to the total vote ranking function, i.e. upvoted posts and comments rise to the top while downvoted posts and comments are pushed to the bottom. The votes to the Redditors' posts and comments contribute to their karma score; posts and comments that are upvoted contribute to Redditors' karma while posts and comments that are downvoted detract from total karma. This system rewards high quality contributions to the threads of the subreddits communities.

Reddit users can also become Gold members and moderators. Gold membership grants access to extra features such as reading more comments per page or creating a secret society, amongst others. Holding a moderator role gives to Redditors a range of controls for configuring the subreddits they moderate, for instance, editing the rules page of the subreddit or banning users from submitting, commenting, and reporting in the subreddit.

We felt that Reddit would be an ideal environment for our investigation of open online learning because conversations emerge from the contribution and promotion of the members, combine perspectives of experts and non-experts (Moore & Chuang, 2017), and take place in a plethora of subcultures (subreddits) occurring outside

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traditional classroom settings. This allows us to evaluate how the network dynamics and the attributes of the Redditors affect and effect the networked learning processes of these online communities.

Data and Methods

We collected data on all the 2015 Redditors' posts and comments of the 'AskStatistics' and 'AskSocialScience' subreddits. Further, we collected information about the (a) Karma (link) points, (b) Gold Membership status (being or not being a Gold member) and (c) Moderator role (being or not being a moderator) of the Redditors of these two communities. Both 'AskStatistics' and 'AskSocialScience' were created in 2012, and as of writing the former has 8,317, and the latter has 65,975 subscribers. We picked these two sample subreddits because we wanted to compare whether the group size made a difference.

To discover the network characteristics and the Redditors' attributes that were facilitating ties among the users of the these two subreddit communities, we employed Exponential Random Graph Models (p*models). ERGMs are 'tie-based models for understanding how and why social network ties arise' (Lusher, Koskinen, & Robins, 2012, p. 9). The idea behind ERGM is to generate a large set of random networks based on a chosen set of network properties and node attributes from the observed network. To determine the quality of the resulting model, 'randomly generated networks are compared to the observed network' (Gruzd & Tsyganova, 2015, p.131-132). This procedure allowed us to test whether the presence of ties in the subreddits was based more on the network properties and the nodes' attributes than by chance alone, and which of these properties influence their formation. We employed ERG models using the 'statnet' package in R (Goodreau, Handcock, Hunter, Butts, & Morris, 2008; Hunter, Handcock, Butts, Goodreau & Morris, 2008).

We started by building a null model without any predictors (*net~edges*), and then Model 1 that included three network parameters indicating: reciprocity (*mutual*), which is a static counting of mutual replies amongst Redditors (Goodreau, Kitts, & Morris, 2009), transitivity (*transitive*), that is, Redditors' tendency to reply the posts of the Redditors who reply to the posts of the Redditors replying to their posts, measured by capturing shared replies, and popularity, based on the number of Redditors who replied to a user (*gwindegree*). The underlying theoretical idea of adding these network parameters to the model is to evaluate their effects in increasing or decreasing Redditors' likelihood of establishing communication ties in both 'Ask' communities. We then added Redditors' attributes to Model 1. Model 2 included Redditors' 'Gold Membership' status (*nodefactor ['Gold_Member']*). Model 3 added Redditor's karma (link) as a measure of their popularity in the subreddit (*nodecov ['Karma']*). Finally, Model 4 added Redditors' moderator role (*nodefactor ['Moderator']*).

To determine the quality of the resulting model, randomly generated networks were compared to the observed networks by assessing the goodness of fit of the ERG models (Hunter et al., 2008; Li & Carriere, 2013). Results will show whether the network measures occur randomly, or how these are related to the network properties and/or Redditors' attributes.

Results

Descriptive network statistics and visualizations

Table 1 shows descriptive statistics of the 'AskStatistics' and 'AskSocialScience' networks.

Table 1: Descriptive network statistics of the 'AskStatistics' and 'AskSocialScience' subredddits

	AskStatistics	AskSocialScience
P (number of posts)	2,352	1,523
N (number of nodes)	1,951	3,689
R (number of replies)	4,301	7,723
Graph Density	0.001	0.001
Average Path Length	4.409	5.232
Average Degree	2.205	2.094

In the case of the 'AskStatistics' subreddit, 1,951 Redditors posted a total of 4,301 replies while for the 'AskSocialScience' subreddit a total of 3,689 Redditors posted 7,723 replies. In both networks, the graph density is very low (0.001), meaning that only 1% of the total relations amongst the Redditors occur. The

Average Path Length is 4.409 for the 'AskStatistics' subreddit and 5.232 for the 'AskSocialScience' subreddit, indicating that the average distance between the users is 4.4 steps in the former subreddit and 5.2 in the latter. The average Redditors connected in the 'AskStatistics' network is 2.2, and 2 for the 'AskSocialScience'. The above descriptive statistics show a low connectivity amongst the Redditors of both networks.

Results of the ERG models

Table 2 and Table 3 summarize the results of the ERG models. The selection criterion was driven by significance levels of the tested parameters and the iterative reduction in both Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) values (Goodreau et al., 2008).

Table 2: Factors underlying the formation of ties in the 'AskStatistics' subreddit

	Model 1		Model 2		Model 3		Model 4	
	EST	SE	EST	SE	EST	SE	EST	SE
Structural features								
Edges	**-7.631**	0.021	**-7.682**	0.026	**-7.318**	8.297	**-7.348**	8.111
Reciprocity	**6.523**	0.039	**8.096**	0.034	**6.826**	3.310	**6.789**	3.427
Popularity (~number of people who replied to a user)	**-0.751**	0.022	**-0.531**	0.024	**-1.064**	1.624	**-1.151**	1.362
Transitivity	**0.630**	0.000	**0.666**	0.000	**6.652**	1.168	**6.137**	3.383
Redditors' Attributes								
Gold Member			**-0.225**	0.049	**-2.340**	1.552	**3.939**	9.670
Karma					**3.341**	1.077	**-1.027**	3.658
Moderator							**9.343**	9.779
Akaike Information Criterion (AIC)	58,577		58,406		58,427		58,294	
Bayesian Information Criterion (BIC)	58,630		58,471		58,505		58,386	

Note: Coefficients in bold are significant at the 99 percent level

Table 3: Factors underlying the formation of learning ties in 'AskSocialScience' subreddit

	Model 1		Model 2		Model 3		Model 4	
	EST	SE	EST	SE	EST	SE	EST	SE
Structural features								
Edges	**-7.040**	0.023	**-7.102**	0.024	**-7.107**	5.283	**-7.174**	5.830
Reciprocity	**8.277**	0.105	**8.056**	0.131	**8.211**	4.111	**8.041**	1.031
Popularity (~number of people who replied to a user)	**-2.521**	0.050	**-2.398**	0.067	**-2.447**	8.392	**-2.375**	8.604
Transitivity	**0.377**	0.040	**1.003**	0.003	**3.799**	1.521	**3.940**	1.644
Redditors' Attributes								
Gold Member			**-0.075**	0.028	**4.914**	5.300	**-1.544**	5.207
Karma					**1.296**	4.013	**4.982**	3.966
Moderator							**9.903**	4.430
Akaike Information Criterion (AIC)	120,183		120,022		120,127		119,680	
Bayesian Information Criterion (BIC)	120,241		120,094		120,213		119,781	

Note: Coefficients in bold are significant at the 99 percent level

The last column of the two tables reports the estimates of Model 4, which includes all the variables of the analysis. The structural features contain the arc and the full specification of endogenous network effects: reciprocity, popularity and transitivity. In both tables the edge parameter is negative, a common characteristic of sparse networks (see Mai, Liu & González-Bailón, 2015). The estimates suggest that reciprocity and transitivity remain positive and significant ($p < 1e-04$) across model specifications whereas popularity remains significant ($p < 1e-04$) but negative. This means that reciprocity and transitivity increase the Redditors' likelihood of establishing networked ties, whereas popularity decreases their likelihood of forming these ties.

Results from Model 4 also show the effects of Redditors' attributes in facilitating networked ties. The estimates of the 'Gold Membership' status are positive and significant ($p < 1e-04$) for the 'AskStatistics' subreddit, yet they

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are negative and significant (p<1e-04) for the 'AskSocialScience' subreddit. This makes it very difficult to reach any conclusion of the effects of being a 'Gold Member' in increasing or decreasing the networked ties of a Redditor. The estimates of Redditors' karma (link) points are negative and significant (p<1e-04) for the 'AskStatistics' subreddit, but they are not significant for the 'AskSocialScience' subreddit. Again, these results do not allow us to draw conclusions of the effects of the karma (points) on the Redditors' likelihood of establishing networked ties and future research should help to clarify our findings. Lastly, the estimates of the 'Moderator' attribute are significant (p<1e-04) and positive for both the 'AskStatistics' network (with an odds ratio of 9.343) and the 'AskSocialScience' network (with an odds ratio of 9.903). This means that being a moderator highly increases the likelihood of establishing networked ties in both networks.

To assess how well the model captures the structure of the data, Figure 1 shows how the observed in-degree and minimum geodesic distance distributions reproduce the networks statistics seen in the original data.
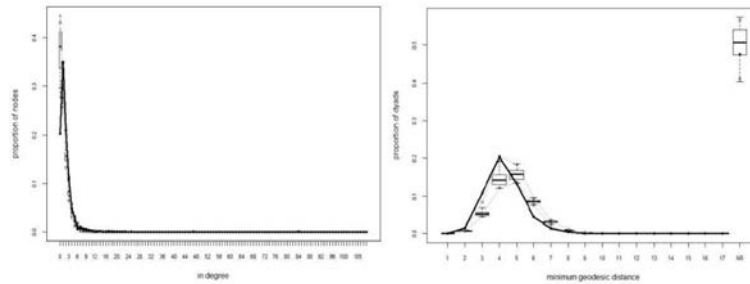

Figure 1: Goodness-of-Fit Diagnostics (Model 4- 'AskStatistics')

In the plots, the vertical axis is the relative frequency of nodes (in-degree) and dyads (minimum geodesic distance). The observed statistics in the actual network are indicated by the solid lines (thick black lines). The grey lines represent the range of 95 percent of the simulated statistics. The models perform relatively well for the in-degree distribution and the geodesic distribution. The observed distribution falls with the quantile curves for most of the range. The model over-estimates the average in-degree distribution and geodesic distance, but overall it captures well the shape of the distribution of the original network. Although we only present plots for the 'AskStatistics', the results for the 'AskSocialScience' network follow similar patterns. In the following section, we discuss and summarize how our empirical findings can help advance current SNA learning techniques in the field.

Discussion and Conclusions

This exploratory study sought to expand our knowledge of learning processes in informal social media environments by discovering and analysing the variables predicting the formation of ties in these environments. We gathered one year of data on all the relations (posts and comments) and some Redditor attributes ('Gold Membership'; 'Karma'; and 'Moderator') of the subreddit communities, 'AskStatistics' and AskSocialScience'. We studied these two subreddit communities because we believed that informal learning was more likely to happen in these 'Ask' communities than in other more focused communities (e.g. /r/gameofthrones)'.

At a network level, the results of the graph density (0.001 for both networks) and the average number of connected Redditors (2.2 for the 'AskStatistics' network and 2 for the 'AskSocialScience' network) indicate that the Redditors of these communities barely respond to the posts/comments of the other members, yet they also indicate that networked ties are formed in both communities.

At a meso level, the results of the ERG models (p*models) show that in both subreddits the likelihood of establishing networked learning ties is based on the Redditors' relations (mutual comments and clusters of users commenting other users' posts) rather than on the popularity of the user's posts. This finding could be explained by three related phenomena: first, because the Reddit environment collapses comments as threads get larger, users who are quickly scrolling through comments may not click on collapsed comments to view, read, and respond to them; second, reading popular posts with many comments may cause fatigue and thus others are more likely to respond to comments displayed at the top of the page rather than the bottom; finally, knowing that comments visible at the top of the page are more likely to be read and responded to, users may be more inclined to respond to top level comments as a way of increasing their karma score.

At a micro level, results concerning the Redditors' 'Gold Membership status' and their 'Karma (link)' points do not allow us to draw clear conclusions on the effects of these two attributes in establishing ties, and future research should improve our models to clarify the role of these two attributes in establishing networked learning ties, notably because our findings regarding karma scores differ from conclusions drawn by Kilgo, et al. (2016) which suggest that karma scores may be used to identify opinion leaders. However, we did find evidence to back the claim that being a moderator highly increases the likelihood of establishing networked ties in the 'AskStatistics' and the 'AskSocialScience' subreddits. Unlike Gold-membership, moderation is likely indicative of active and regular participation in subreddits as moderator include responsibilities establishing and maintaining rules and norms. In Reddit's topic-based "Ask" subreddits, moderators are also often subject experts, and thus also contribute to the community by responding to questions, thereby establishing learning ties.

New media has transformed how information is mediated and the way people interact. Technologies provide different kinds of features – asynchronicity, anonymity, text and pictures – that affect the content and the modes of communication. In open online forums, distinctions between teachers (producers) and learners (consumers) are blurring (Gilbert, 2016). New literacies are emerging that respond to the changed nature of mediated communications in online settings and online learning (Haythornthwaite, 2012; Esteve Del Valle, Gruzd, Haythornthwaite, Paulin, & Gilbert, 2017).

To conclude, in line with the results found by Cho et al., (2007), our findings suggest that learning processes in informal social media environments are determined by both network properties (reciprocity and transitivity) and individuals' attributes (being a moderator).

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