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# Social network analysis of a gamified e-learning course: Small-world phenomenon and network metrics as predictors of academic performance

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ABSTRACT

Social networks and gamification are having an important and growing role in education. Social networks provide unknown communication and connection possibilities while games have the potential to engage students. This paper analyzes the structure of the social network resulting from a gamified social undergraduate course as well as the influence that student's position has on learning achievement. In a semester long experiment, a social networking site was delivered to students providing gamified activities and enabling social interaction and collaboration. Social network analysis was used to build the network graph and to compute four measures of the overall network and nine measures for each participant. Individual measures were then assessed as predictors of students' achievement using three different methods: correlation, principal component analysis and multiple linear regressions. The resulting social network has 167 actors and 2505 links, and it can be characterized as a small-world. All analyses agreed on the potential of structural metrics as predictors of learning achievement but they differ in the measures considered as significant. A moderate correlation was found between most centrality measures and learning achievement.



## 1. Introduction

A social network is a structure made up of a set of actors and connections between them. Social networks are pervasive in many aspects of life and nature but most connections in social networks of the real world remain hidden. With the information age, social networking sites like Facebook, Twitter, Flickr and others have made these connections explicit, visible and exploitable. Information about the network can now be gathered and analyzed. The network can be represented as a graph in which nodes are the actors of the network and the arrows represent relationships between actors. Social network analysis (SNA) aims to find patterns of connections among actors analyzing the structure of the network in order to discover the effects of such patterns on people and organizations (Martínez, Dimitriadis, Rubia, Gómez, & de la Fuente, 2003). Teachers and educational researchers have increasingly turned their attention to educational networking, which is the use of social networks for educational purposes, as a method to create better and more efficient learning experiences. Educational networking provides the means for collaborating and sharing information towards solving problems and building knowledge, and SNA then provides the tools to analyze the structure of the network offering additional insights.

Videogames offer interactive feedback-driven experiences in immersive worlds with rich narratives that create compelling stories. Furthermore, good videogames are learning tools that challenge gamers with a seamless set of short term goals enabling them to master skills in a motivating and engaging environment (Gee, 2007); so educators are also trying to harness the potential of videogames in education. Game-based learning has taken several forms: educational games, serious games and gamification. Educational games are explicitly designed for learning. Serious

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gaming is a broader area which is focused on building games for a primary purpose other than pure entertainment, which can be educational or not. Gamification is a wider term that encompasses the use of game-design techniques in non-game contexts to engage people and motivate action (Kapp, 2012). While there is significant evidence of the positive impact of computer games and serious games on a wide range of educational outcomes (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012), gamification is a relatively new field with potential that teachers and researchers are just beginning to explore. Gamification provides a set of tools that can motivate action and make learning experiences more engaging. With challenges, levels, points, badges and leaderboards, among others, students can have timely feedback, meaningful rewards and social recognition.

Bringing together social networking and gamification is then a promising approach to create engaging and collaborative learning experiences. But the question that remains open, beyond the effectiveness of these approaches, is whether they create meaningful learning scenarios. Significant network effects have been reported in business, education and e-learning settings (Baldwin, Bedell, & Johnson, 1997; Cho, Gay, Davidson, & Ingraffea, 2007; Sparrowe, Liden, Wayne, & Kraimer, 2001). This study sets out to test whether similar effects can also be found in social e-learning settings driven by gamification, because competition and external rewarding make them considerably different from traditional classrooms and collaborative e-learning. In particular we want to examine whether the underlying social network of a gamified undergraduate course is a small-world. Small-worlds are a natural emergent structure in human activities and organizations that was reported in larger social networks like Flickr, YouTube, LiveJournal, and Orkut (Mislove, Marcon, Gummadi, Druschel, & Bhattacharjee, 2007). We also analyze the influence of the network on individual students as measured by the impact that positioning may have on learning achievement. The rest of the paper is structured as follows: Section 2 presents previous research. Section 3 presents the experimental design, the instrument and the measures. Section 4 presents results. Discussion follows in Section 5. Finally, Section 6 summarizes conclusions and outlines future research.

## 2. Prior research

Our study focuses on the social gamification of e-learning to analyze the effects of gamification in the resulting structure of the network and it also examines how the position of each particular learner impacts in her learning performance. It builds on previous work about gamification and social networks in education. This study uses gamification as an instrumental overly layer to promote participation in a social networking tool so existing literature on gamification in education is firstly examined. Education is the most common context of use of gamification (Hamari, Koivisto, & Sarsa, 2014) although contrasting evidence can be found about its effectiveness. Previous research suggests that learners anticipate higher value from gamified initiatives (Landers & Armstrong, 2016) and also that they like it (Attali & Arieli-Attali, 2015). Gamification also improves productivity and participation (Denny, 2013; Halan, Rossen, Cendan, & Lok, 2010; Li, Grossman, & Fitzmaurice, 2012) although no effects, positive or negative, have been found in duration (Halan et al., 2010), quantity (Denny, 2013) or quality (Li et al., 2012) of contributions by students. Positive influence on the quality of learning artifacts produced by students has also been reported (Hew, Huang, Chu, & Chiu, 2016). Impact in motivation is contradicting in educational (Hakulinen, Auvinen, & Korhonen, 2013; Hanus & Fox, 2015; Landers & Landers, 2014) as well as in non-educational contexts (Mekler, Brühlmann, Tuch, & Opwis, 2016). Providing that gamification aims to drive motivation resulting in better learning outcomes, such results can ultimately question its effectiveness for educational purposes. In terms of learning performance, contrasting evidence has also been reported (Boticki, Baksa, Seow, & Looi, 2015; Denny, 2013). Several studies examine different reasons that may account for such contradicting results like the kind of evaluation item (Domínguez et al., 2013), the kind of learning outcome assessed (Denny, 2013) or the kind of knowledge that learning actions convey (de-Marcos, Domínguez, Saenz-de-Navarrete, & Pagés, 2014; de-Marcos, Garcia-Lopez, & Garcia-Cabot, 2016), suggesting that the effectiveness of gamification is highly contextual.

Previous research on gamification mostly points to the positive attitude of students stressing its potential in education but also suggesting that more research is required to determine the specific circumstances under which gamification yields measurable learning benefits. Contrastingly, literature on the utility and effectiveness of social networks in education mostly reports positive learning outcomes suggesting that a significant potential lies in the integration of both approaches (gamification and social networking). We now review the literature on the effectiveness of social networking in education. A social network is a structure that represents a set of actors and the connections among them. Computers and information systems are not necessary to support or use social networks and indeed the positive effects of non-computer-supported networks are reported in education (Kadry & Fadl, 2012; Oskouei, 2010). Internet-based information systems make explicit the connections of social networks and facilitate social media that allows participants to create, share and exchange content. The effectiveness of social media in education has also been widely studied. The educational use of paradigmatic social media tools like Facebook results in positive effects on students' attitude, communication, collaboration, interaction and learning performance (Despotovic-Zrakic, Labus, & Milic, 2011). Networking tools, like the Elgg blogging and peer-rating social system, also return a positive relation between usage and learning achievement (Thoms, 2011). Self-reported evidence also suggests that students that prefer sharing information in a social network outperform students that prioritize knowledge creation, acquisition and application (de-Jorge-Moreno, 2012). Specific educational networking tools, like Ning, improve collaboration (Brady, Holcomb, & Smith, 2010) and significantly influence students' motivation, retention, engagement, individual creativity and personal interaction (Hoffman, 2009). Previous studies also address other educational issues such as the quality of knowledge construction and the role of participants (Aviv, Erlich, Ravid, & Geva, 2003), the sense of community of students (Shen, Nuankhieo, Huang, Amelung, & Laffey, 2008), the perception of students about their own collaborative attitudes (Martínez et al., 2003), and the evolution and differences observed in the structure of the network at different stages (Lee & Bonk, 2016).

Nevertheless, a recent literature review emphasizes that most of the existing research on the effectiveness of social media is based on self-reported data (Tess, 2013) questioning its empirical validity. Still, web based information systems also facilitate data acquisition, manipulation and analysis. Social network analysis can then be used to study the structure of the network and the influence of positioning on each participant. To our best knowledge there are a limited number of studies that analyze the structure of the social network in educational settings or that study the position of individual students in the network and its influence in learning outcomes. Previous research suggests that the position in the network is positively related to learning performance in computer supported collaborative learning (Cho et al., 2007; Maglajlic & Gütl, 2012). In terms of the structure of the network, network properties impact in social learning (Paredes & Chung, 2012) and