Using Social Network Analysis to Examine Player Interactions in *EvE Online*

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Abstract: Network analysis is an increasingly popular tool for the analysis of rich telemetry data from digital game environments. In this paper we apply social network analysis techniques to the massively multiplayer online game *EvE Online* in order to examine patterns of player interactions in the game. Data were collected from a 1-month period of player-versus-player (PvP) interactions in a specific region of the game. In our analyses we conduct analyses of key actors relying on different centrality measures to identify patterns of play in the region. We examine the features and implications of being a "key actor" across these centrality measures in this context as well as explore applications of this methodology toward game design and research.

Introduction

Network analysis and theory constitute important methodological and conceptual tools that help highlight structure among seemingly chaotic relationships. With the proliferation of geocoded, transactional, and digital game data related to education, researchers have started applying and using network principles to explain patterns and highlight structures among relationships. In a recent study, González Canché (2018) relied on geographical network analysis to measure states that were central providers and receivers of nonresident students (e.g., students who attended high school in state A but enrolled in college in state B). The use of this conceptual and analytic framework enabled inclusion of all geographical facets of the higher education system in the United States. While straightforward, no previous study dealing with student migration patterns and behaviors was capable of including all such components. Similarly, González Canché and Rios-Aguilar (2015) applied network principles to measure the effects of one's peers on credit accumulation in community colleges and found that minority male students were affected more by their peers than nonminority students and minority female students were.

One particular subset of network analysis that is well suited to the types of data being produced by modern digital systems is social network analysis. In social network analysis individuals are modeled as nodes, and the relationships between individuals are modeled as edges. These relationships can include things such as Facebook friends (Backstrom & Kleinberg, 2014; Hristova, Musolesi, & Mascolo, 2014), Twitter followers (Myers, Sharma, Gupta, & Lin, 2014), or academic coauthors (Zare-Farashbandi, Geraei, & Siamaki, 2014). Social network analysis highlights connections between individuals and can shed light on the types and structures of formal and informal communities that take shape around specific practices, such as digital games.

Using Networks to Study Games

Network analysis and theory have been previously applied to educational game domains. Game environments can provide a rich mix of play possibilities combined with robust data logging and capture that facilitates the construction and analysis of player-system and player-player interaction networks. In short, network analysis enables the possibility of identifying complex patterns of interaction that

can arise from rich digital games, simulations, and other contexts. Once these patterns are identified, researchers and designers can more confidently discuss the meaning and importance of centrality measures in this environment and offer recommendations and implications toward game design and research. For instance, Shaffer et al. (2009) developed a method of assessing learner performance and knowledge—epistemic network analysis (ENA)—based on network analysis principles. ENA considers the number and quality of the connections that bind together an *epistemic frame*—the "skills, affiliations, habits, and understandings" (p. 4) that define a given community. Using the games *Digital Zoo* and *Urban Science*, Shaffer and colleagues assessed the relationship between students' values, affiliations, and interactions over time through the construction of network graphs. Once these graphs were constructed, it became possible to assess the relative *centrality* of each component of the epistemic frame—the relative importance and structure that each component lent to the overall structure of the process of gameplay.

Other forms of network analysis can be used to evaluate game characteristics as well. For example, Kirman & Lawson (2009) applied methods of social network analysis to the social collection game *Familiars*. They evaluated players' interactions with one another to construct a social network graph of overall participation and found that players could be subset into three player typologies: the "hardcore" player, the "casual" player, and the "peripheral" player. These analyses focused on the participation of groups within the game and did not attempt to identify specific actors in the game or their contributions to and importance within the network.

In this study we apply analytic and conceptual tools of social network analysis to study player interactions in the complex digital environment of the space sci-fi massively multiplayer online (MMO) *EvE Online*. In our social network analysis, we treat individual players as nodes, and we evaluate the relationships between nodes based on the interactions that individuals have with one another in the game. We identify central actors in this network and discuss the implications and significance of being a central actor in the context of the game.

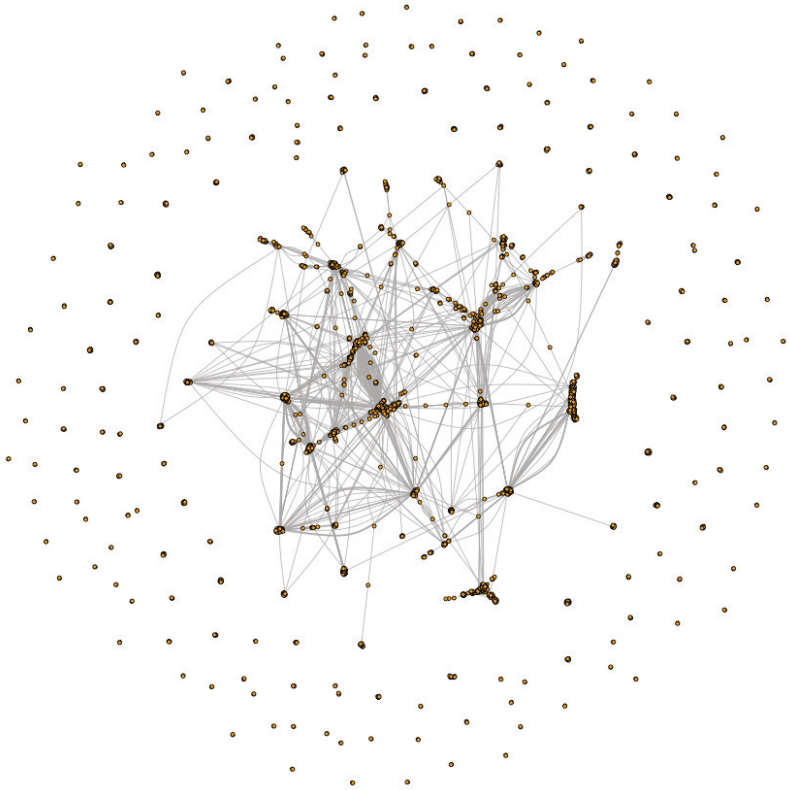
Why *EvE Online*?

EvE Online (CCP, 2004) is a massively multiplayer online space-based science-fiction game. In *EvE*, players assume the role of an immortal capsuleer, piloting spaceships to extract resources, claim territory, and broker the sale of goods between players. *EvE* features regions of space that can be claimed by player organizations, and fights over resources and territory in these regions are a frequent source of conflict in the game. The player-versus-player (PvP) nature of *EvE* is strongly emphasized, and conflicts between players and player organizations are a major draw for the game. *EvE* features a comprehensive application programming interface (API) that allows players to obtain data on many events that take place within the game, and this API has given rise to a number of prominent fan sites in the community that feature their own APIs as well. The availability of detailed, public-facing APIs makes *EvE Online* relatively unique among MMOs and was what made this particular analysis possible.

Methodology

Data were obtained from the community website *zKillboard.com* (Caphinator, 2015). When a pilot in *EvE* destroys another pilot's ship, the game generates a "killmail" for the aggressor(s) and the victim—all pilots who attacked the victim are listed. *zKillboard* aggregates these killmails and makes them available publicly for pilots to track their kills, efficiency, value destroyed, and other statistics.

Using *zKillboard*'s API, data were obtained for 5,523 unique pilots and 8,654 unique pilot/pilot interactions. In order to appear in the data set a pilot must have been present on at least one killmail (either as an aggressor or as a victim) during the month of October 2017 in the "Placid" region of space within *EvE Online*. An aggressor pilot is defined as being listed as a contributor on a killmail (by dealing damage or otherwise impairing the victim's ship), while a victim pilot is defined as losing his ship. We constructed two different networks from this data set. In one, we modeled a network of aggressors acting on victims as a *directed*, unweighted network. In the other, we modeled a network of aggressors acting alongside one another as an *undirected*, unweighted network. By using these two graphs we could identify not only patterns in interactions between aggressors and victims, but also patterns of which aggressors commonly played with one another. Graphical representations of both networks are presented (see Figure 1).



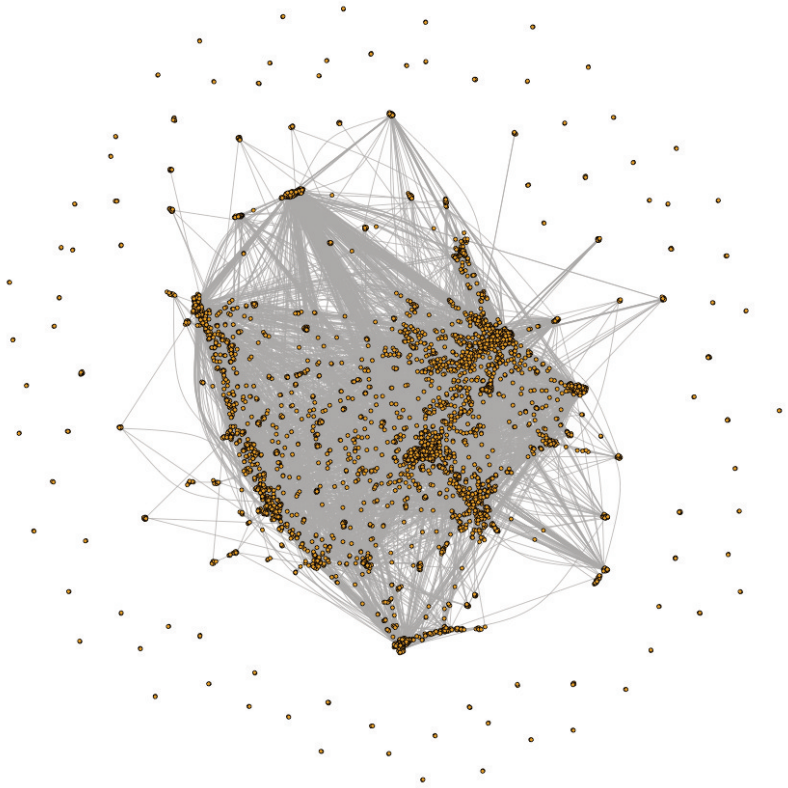


Figure 1. Aggressor–aggressor network (top) and aggressor–victim network (bottom).

Analysis

Aggressor–Victim Network

The aggressor–victim (A->V) network contained 18,190 unique aggressor/victim edges connecting 5,523 pilot nodes in the data set. We constructed a directed network from these data, with individual aggressors acting on victims. That is, if pilots A, B, C, and D are all listed as aggressors on pilot Z's killmail, the network contains edges for A->Z, B->Z, C->Z, and D->Z.

From this network we calculated four measures of network centrality—betweenness centrality (the number of shortest paths that pass through a given node), closeness centrality (the inverse of the sum of the length of each path), degree centrality (the number of edges that a given node has), and eigenvector centrality (the degree of "importance" of a node's edges; see Table 1).

Rank	Closeness Centrality	Betweenness Centrality	Degree Centrality	Eigenvector Centrality
1	BoomBangGone	BoomBangGone	BoomBangGone	Nina Glutdrache
2	Carnelio Riraille	JEK ROO	dirk boos	Xel'lotath Tier
3	Xel'lotath Tier	Xel'lotath Tier	Carnelio Riraille	Daemon Koabd
4	Lt Lunar Lazair	dirk boos	Ildar Nabiullin	oh crap BEARS
5	kado'tempestas	Carnelio Riraille	oh crap BEARS	Nina Fyrerdrache

Table 1. Central actors in the Placid region in EvE Online in the aggressor–victim network.

For all pilots identified among the central actors in the region, we aggregated some of their public

statistics that *zKillboard* tracks, such as their kills (number of ships destroyed), efficiency (their ratio of ships destroyed to ships lost), and value destroyed for October (across all regions of *EvE*, not just Placid; see Table 2).

Name	Average[a]	Min[a]	Max[a]	St Dev[a]
Ship Kills	383	115	477	111.8
Efficiency	86%	71%	98%	10.3%
Value Destroyed[b]	15.35	5.40	41.82	11.38

[a] JEK ROO recorded no ship kills for the month of October and is omitted from these statistics
[b] values are in billions of InterStellar Kredits (ISK), *EvE*'s in-game currency. 1 USD ~ 80m ISK.

Table 2. Central actors' aggregate statistics from zKillboard, aggressor–victim network.

While several pilots appear multiple times as central actors in the A->V network, there are some notable exceptions. For instance, the only common actor between degree centrality and eigenvector centrality is the player "oh crap BEARS." The difference between degree centrality and eigenvector centrality is one of *importance*—degree centrality assesses the number of edges between nodes considering these edges to be equal, while eigenvector centrality assesses the importance of each edge based on which nodes it connects. In this network, then, a higher eigenvector centrality suggests that the actor in question is listed as an aggressor on the killmails of other pilots who are themselves central actors. By comparison, degree centrality is a raw measure of the number of killmails on which the pilot is listed as an aggressor, regardless of the pilot's position and involvement of the victim in the overall network. Therefore, oh crap BEARS is unique in the high degree and eigenvector centrality—this pilot shoots at and is shot at by many different pilots, and those pilots are themselves central actors in the network.

Betweenness centrality is another interesting measure of network centrality for the A->V network. While BoomBangGone is a central actor by multiple measures, JEK ROO is a central actor only in terms of betweenness. JEK ROO was omitted from Table 2 because this pilot has never destroyed another player's ship before. JEK ROO recorded 0 kills and 152 losses in Placid in October, and each ship JEK ROO lost was completely unfit—it had no guns, armor, shields, or any other modules equipped. It is most likely that this pilot was an automated bot account for farming resources, and the amount of time that the bot was online and active led to its being attacked and destroyed by a wide range of pilots. This sort of behavior would lead to a high betweenness centrality, even with no recorded kills, because the pilot serves as a bridge linking two aggressors that may otherwise have not shared any common kills. Examining the connections in the data showed that kado'tempestas, dirk boos, and Jos Manar—all central actors themselves in either the A->V or A-A networks—were listed as aggressors against JEK ROO during October.

Aggressor–Aggressor Network

The aggressor–aggressor (A-A) network contained 8,692 unique aggressor/aggressor pairs for 3,038 nodes, less than half the connections of the A->V network. This suggests that the network of PvP interactions in EvE is not mutual; many of the pilots who appear in the network appear only as victims, not as aggressors. The A-A network has a much higher density than the A->V network: 0.0009 for the A-A network compared to 0.0005 for the A->V network.

As we calculated for the A->V network, we also calculated centrality measures for the aggressor–aggressor network (see Table 3).

Rank	Closeness Centrality	Betweenness Centrality	Degree Centrality	Eigenvector Centrality
1	Quark Dallocort	Lt Lunar Lazair	Nina Glutdrache	Nina Glutdrache
2	petosorus	Meatwave Heatwave	dirk boos	Nina Fyrerdrache
3	Pippinthehobbit	Nassen Leto	rus B2K	AlexeyTier Haizenberg
4	Dancness Aldebaran	Jos Manar	Tainted Nightmare	rus B2K
5	Sith Sarum	Enderas Tsero	AlexeyTier Haizenberg	Bongo Linvor

Table 3. Central actors in the aggressor–aggressor network.

We also generated summary statistics for these pilots' number of kills, efficiency, and value destroyed for the month of October (see Table 4).

Name	Average	Min	Max	St Dev
Ship Kills	148	10	477	122.2
Efficiency	94%	70%	99%	7.3%
Value Destroyed	58.05	1.41	379.17	114.39

Table 4. Central actors' aggregate statistics from zKillboard, aggressor–aggressor network.

There are several differences present among central actors in the two networks, primarily in that the A->V network and A-A network share almost no common actors. Being a central actor in the aggressor–victim network is typical of pilots who shoot at many different targets; this network represents who is shooting and who is being shot at. For the aggressor–aggressor network, however, a central actor is a player who flies with many different allied pilots; this network represents who you shoot *with*. This is evident in the difference between ship kills and value destroyed between central actors in the two networks. The average central actor in the A-A network recorded 148 ship kills for the month of October, totaling 50 billion InterStellar Kredits (ISK) in damages. In the A->V network, however, the average central actor recorded 383 ship kills with just 15 billion ISK in damages. These differences are likely due to the types of players present in both networks—central actors in the A->V network tend to be focused on PvP content specifically in the Placid region, with most of their ship kills coming from that area of space (but not necessarily being expensive, valuable kills), while central actors in the A-A network appear to travel much farther distances in search of players to fight and in larger, more organized groups, and they end up accruing fewer but more valuable kills.

Interestingly, many of the central actors in terms of closeness in the A-A network are not local to Placid at all. For instance, the pilot Quark Dallocort recorded just two kills in Placid for the month of October, but both of these kills involved a group of 31 players from more than one dozen different player organizations. Another of the central actors in terms of closeness, petosorus, recorded just four kills in Placid, but all of these were with a group of players from the corporation "EvE University," a corporation devoted to training and tutoring new players from across EvE. By comparison, Xel'lotath Tier recorded more than 50 kills and 20 losses in Placid during October—usually in a group of four or fewer players, and frequently by himself.

Both networks are relatively sparse and contain many player participants who are not well connected to the rest of the network. However, the implications of these connection patterns are very different. In the A-A network there are 2,741 pilots who have a degree centrality less than 20 (90%). While this could indicate low overall activity (the fewer kills you have, the fewer opportunities to connect to others on the network), it could also indicate small, tightly knit groups of players who fly together very frequently, but

rarely with people outside of their community. On the other hand, in the A->V network, there are 5,083 pilots who have a degree centrality less than 20 (92%), and 1,599 pilots who have a degree centrality of 1 (just one connection in the graph). For the A->V network, where edges are a player destroying another's ship, a low centrality suggests a player who is relatively disengaged from PvP content in *EvE*.

Interpretation

In this paper we used social network analysis to construct two networks from pilot interaction data in the MMO *EvE Online*. One network assessed directed connections between pilots listed as aggressors and victims from killmails obtained from the website *zKillboard*, while the other assessed connections between pilots listed as aggressors on mutual killmails. We calculated multiple measures of centrality for each graph and found that each centrality measure produced different sets of pilots considered to be central actors. Different centrality measures identified different types of play styles that may be used by each pilot.

In the A-A network, measures of closeness centrality identified pilots who appear to participate in large-scale PvP fleets. These pilots appeared with relative infrequency in Placid, our region of interest, and recorded fewer kills overall than central actors identified by other methods. The defining feature of these pilots was participation in fleets numbering 15–50 pilots, especially fleets from PvP–focused corporations and alliances such as EvE University. In these large fleets, pilots rapidly become connected to other active pilots in the region, moving them closer to the center of their respective networks. On the other hand, in the A->V network, pilots with a high closeness centrality were frequently also high in betweenness centrality and degree centrality. Central actors in the A->V network, by their measures of closeness, were often some of the most active and successful (in terms of scoring kills and destroying ships), while this did not necessarily hold true for the A-A network.

Measures of betweenness centrality identified pilots with a high diversity of kills and losses in both networks. These pilots were indiscriminate in whom they aggressed or were aggressed by, and whom they aggressed with. *EvE Online*'s political landscape is dominated by nonaggression agreements between corporations and alliances, so pilots with high betweenness centrality were likely to be from smaller corporations and groups, or from groups without these nonaggression agreements in place. Additionally, betweenness centrality identified JEK ROO as a central actor despite this pilot recording no kills in the entire data set, something that other centrality measures did not identify for the A->V network.

Degree centrality and eigenvector centrality, as raw measures of connections, identified pilots in the A->V network who are prolific in the amount of targets that they find and destroy in the game. Pilots with a high degree centrality are identified as some of the most active pilots using *zKillboard*'s own metrics of performance (such as ship kills, value destroyed, and efficiency). In the A-A network, on the other hand, degree centrality and eigenvector centrality represent pilots who play with many different people. For example, two of the most central actors in the A-A network in terms of degree centrality are the pilots dirk boos and Tainted Nightmare. Both of these pilots, at the time of data collection, were a corporation named "Toxic Uprising." In looking at these pilots' *zKillboard* histories, and other pilots in Toxic Uprising, we found that members of this corporation rarely played with anyone outside of the corporation. While Toxic Uprising has since disbanded, during the month of October it contained around 70 pilots. This high coherence between pilots in the corporation contributed to the degree centrality of dirk boos and Tainted Nightmare, while the low out-group participation contributed to much lower

betweenness centrality and closeness centrality. Members of this corporation shared many common links with one another but relatively few with the broader network of all players within the Placid region.

Central actors in terms of their eigenvector centrality are best characterized as "hunters of hunters" in the A->V network. Eigenvector centrality weights the relative importance of connections in the network based on who is connected to them. While a pilot high in degree centrality may have aggressed many different pilots, that pilot will be high in eigenvector centrality only if the aggressed pilots themselves were more central within the network. Pilots such as JEK ROO seem to be primarily outliers, and the vast majority of pilots identified as central actors are quite proficient at PvP. Therefore, pilots high in eigenvector centrality are pilots who frequently aggress and are aggressed by other central actors in the network. In the A-A network, this interpretation is slightly different—pilots high in eigenvector centrality are pilots who frequently fly with other central actors. As with degree centrality, the central actors for eigenvector centrality are almost all in the same corporation. In this case, the pilot Nina Glutdrache is the CEO of the corporation Conoco, a member of the Caldari Armed Forces alliance, and the pilots rus B2K, AlexeyTier Haizenberg, and Bongo Linvor are all members of this corporation as well. Nearly 2,400 pilots are members of Conoco, and the sheer size and activity of the corporation appears to drive its most active members to a central position in the network in terms of their degree and eigenvector centrality measures. In *EvE Online*, however, shooting at members of the same corporation is generally frowned upon. This, combined with possible nonaggression agreements that Conoco has in place, could explain why its pilots are not similarly high in betweenness or closeness centrality—while they share many connections with one another, they share fewer connections to the rest of the network by virtue of having fewer people that they are allowed to shoot at. In the case of Conoco, large sections of the A->V network are off-limits because a substantial number of actors in the network are in the same corporation.

Discussion and Implications

We believe that the topography and structure of these networks has implications for thinking about game design as well as game assessment. Network analyses are a popular form of analysis in game environments, and while the literature on the analysis of player-system interactions is rich (Kim, Almond, & Shute, 2016; Shaffer et al., 2009), the literature on player-player interactions is significantly smaller. These analyses offer a template for constructing meaningful analyses and inferences about player-player interactions from rich log data. We hope that by showing how these analyses can be used to interpret players' interactions with one another, more games (especially in the education sphere) will afford students opportunities to interact with one another and record this data for analysis.

From a game-design standpoint, these analyses raised several interesting questions. First, pilot JEK ROO appears to be a bot-controlled player, which is against *EvE Online*'s terms of service. In fact, this account may have already been banned—JEK ROO has not recorded a loss since September 1, 2017. However, this account also held a central position within the network in terms of its betweenness centrality—many of the shortest node-node paths between aggressors and victims passed through this pilot. Whether betweenness centrality is important to the overall health of the game environment, and whether bot accounts play a role in supporting *EvE*'s PvP community or the communities of other online games, is an open question.

Additionally, we intend to further examine the role that large player groups have in shaping the PvP landscape in *EvE Online*. Two corporations contain nine of the 10 most central actors in terms of their

degree centrality and eigenvector centrality (and it is quite likely that the pilot Nina Fyrerdrache is also Nina Glutdrache, based on naming similarities and shared killmails). While Conoco and Toxic Uprising are not sufficiently large to dominate the entire network, this may not be the case in smaller or newer games with less developed communities of players. There are similar questions about the influence that a large number of bot accounts could have in these environments as well.

With its robust API and large player community, *EvE Online* is uniquely situated to facilitate these kinds of analyses. In future work we hope to examine differences in network structure across multiple different regions of space in the game, as well as weight edge connections with different attributes (such as total number of kills rather than number of unique kills, or with value destroyed by aggressing). Additionally, we plan to apply these analyses to education-focused games and digital environments as a means of studying the associations between status as a central actor and position in a social network with learning gains and outcomes.

References

Backstrom, L., & Kleinberg, J. (2014, February). Romantic partnerships and the dispersion of social ties: A network analysis of relationship status on Facebook. *In Proceedings of the 17th ACM conference on Computer Supported Cooperative Work & Social Computing* (pp. 831–841). New York, NY: ACM.

Caphinator, S. (2015). *zKillboard.* Retrieved from https://zkillboard.com/

CCP Games. (2004). *EvE Online* [Video game]. Reykjavik, Iceland: CCP Games.

González Canché, M. S. (2018). Geographical network analysis and spatial econometrics as tools to enhance our understanding of student migration patterns and benefits in the U.S. higher education network. *Review of Higher Education, 41*(2), 169–216.

González Canché, M. S., & Rios-Aguilar, C. (2015). Critical social network analysis in community colleges: Peer effects and credit attainment. *New Directions for Institutional Research*, *2014*(163), 75–91.

Hristova, D., Musolesi, M., & Mascolo, C. (2014, June). Keep your friends close and your Facebook friends closer: A multiplex network approach to the analysis of offline and online social ties. In *Proceedings of the Eighth International AAAI Conference on Weblogs and Social Media* (pp. 206–215). Palo Alto, CA: The AAAI Press.

Kim, Y. J., Almond, R. G., & Shute, V. J. (2016). Applying evidence-centered design for the development of game-based assessments in physics playground. *International Journal of Testing*, *16*(2), 142–163.

Kirman, B., & Lawson, S. (2009). Hardcore classification: Identifying play styles in social games using network analysis. In S. Natkin & J. Dupire (Eds.), *Entertainment Computing—ICEC 2009* (pp. 246–251). Berlin and Heidelberg, Germany: Springer.

Myers, S. A., Sharma, A., Gupta, P., & Lin, J. (2014, April). Information network or social network?: The structure of the Twitter follow graph. In *Proceedings of the 23rd International Conference on World Wide Web* (pp. 493–498). New York, NY: ACM.

Shaffer, D. W., Hatfield, D., Svarovsky, G. N., Nash, P., Nulty, A., Bagley, E., & Mislevy, R. (2009). Epistemic network analysis: A prototype for 21st-century assessment of learning. *International Journal of Learning and Media*, *1*(2), 33–53.

Zare-Farashbandi, F., Geraei, E., & Siamaki, S. (2014). Study of co-authorship network of papers in the Journal of Research in Medical Sciences using social network analysis. *Journal of Research in Medical Sciences: The Official Journal of Isfahan University of Medical Sciences, 19*(1), 41–46.