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GIFT ARTICLE

Building Resilience: An Exercise to Create Network Structures and Assess Resilience with Marshmallows and Spaghetti Noodles or LEGO® Pieces

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Abstract

Scholars, practitioners, and society at large are becoming increasingly interested in how resilience works (Coutu, 2002). This activity gives students the opportunity to build a network structure and assess its resilience, while learning the concepts and calculation steps of basic network metrics including density, reachability, and centralization. The article provides guidelines for preparing necessary materials (e.g., marshmallows and spaghetti noodles or LEGO® pieces), detailed procedures and worksheet for the activity, and debriefing questions for connecting the experiences from the activity with real world examples of communication networks and resilience.

Courses

Resilience, Network Analysis, Organizational Communication, Interpersonal Communication, Family Communication, or Management Communication.

Objectives

- Define resilience as a trait and as a process.
- Describe how resilience exists or is enacted in various interpersonal, organizational, and management communication contexts.
- Identify the structural characteristics of networks that are resilient to varying forms of external shocks.

- Explain and calculate three basic network metrics introduced in the exercise.

Introduction and Rationale

Resilience is related to the ability to endure and/or the process of bouncing back from adversities. It is often defined as either an internal, measurable, and relatively static trait of individuals and systems (e.g., hardiness of an individual; robustness or redundancy of a system) or a demonstrable process such as how one reacts to and recovers from crisis (Harms, Brady, Wood, & Silard, 2018; Janssen et al., 2006). Overcoming difficulty can be seen in human behavior and in nature, like when neighborhoods and ecosystems engage in recovery after natural disasters. Resilience is argued to be "developed, sustained, and grown through discourse, interaction, and material considerations" (Buzzanell, 2010, p. 1). With this dialogic conceptualization, resilience exists in multiple ways and multiple places, from refugee families facing hardships to organizations undergoing crisis.

Resilience has become a hot topic in popular press (e.g., Friedman, 2018) and academic conversations (e.g., Buzzanell & Houston, 2018; Servick, 2018; Underwood, 2018). A forum in the *Journal of Applied Communication Research* (Buzzanell & Houston, 2018) provides a description of why exploring the enactment of resilience at multiple, intersecting levels (e.g., individual/relational, family, organizational, community, and national) is beneficial. Courses in a variety of disciplines may benefit from conversations about what it means to be resilient in their area of study.

One useful approach to the study of resilience is through network theory and methods. Network research focuses on examining how nodes (i.e., actors) are connected by a set of links (i.e., relations), and the implications of those connections for various social and physical phenomena (Borgatti et al., 2009; Hanneman & Riddle, 2005). Networks can represent friendship ties among students, social support among residents in communities, knowledge sharing among team members in an organization, and other relationships among entities. According to the communication theory of resilience, an important process of resilience is using and maintaining communication networks (Buzzanell, 2010, 2018), which can occur between people, organizations, or other networks with multiple types of nodes (i.e., employees, departments, and databases in a network). Building and sustaining resilient networks is essential to designing effective organizational communication and collaboration systems.

Predictors of resilience, or cushioning factors that enable adaptation or recovery (Servick, 2018), can be found in a person or entity's network. Further, levels of density, reachability, and centralization can be related to resilience processes and outcomes (Janssen et al., 2006). Density is defined as the number of actual links divided by the number of possible links (Monge & Contractor, 2003). Reachability refers to whether it is possible to trace from a source node to the target node through a set of connections (Hanneman & Riddle, 2005). Both density and reachability can provide insights to the level of connectivity in a network. Centralization measures the extent to which there are a small number of highly central nodes. In other words, a centralized network will have a large variation in node centrality (Monge & Contractor, 2003). Dense structures can usually better withstand external shocks and reachability may facilitate rebuilding after disturbances (Janssen et al., 2006). Networks with high centralization will usually break into a larger number of pieces if carefully attacked (e.g., a hub or central nodes being disrupted).

Both resilience and network concepts can be difficult to understand without personal experience. This activity gives students a hands-on experience building networks and assessing resilience. The following sections list the materials and preparation necessary, explain the activity, describe how the activity can be debriefed, and present an appraisal of the activity.

Description of the Activity

In this 30 to 50-minute activity, students will create their own networks relevant to their interest area. Consider discussing various definitions of resilience and what the concept means to students. The initial (in)ability of a network to withstand external shocks as a function of its built structure might represent resilience as a *trait.* The rebuilding of networks after an external shock might represent individuals or organizations engaging in resilience as a *process*.

Materials and Preparation

Before the day of the activity, the instructor should think about how they want to connect network ideas or resilience into their class level and course materials. For undergraduate classes, instructors might ask students to create their networks in a specific context (i.e., everyone builds a job-seeking network). In graduate classes, where students have diverse areas of expertise, students could create networks relevant to their research interests. In an organizational communication class, networks might represent an employee communication and knowledge-sharing network or a business partnership network. Students could also think about the transfer of goods within a manufacturing plant's network of customers and suppliers when struck by a material shortage. In an interpersonal communication class, networks might represent family connections or friendships among students. Biologists might consider the implications of a keystone species being endangered in ecological networks, while computer scientists might evaluate the influence of a virus on a computer network.

Resilience is also an essential element of students' personal well-being and collegiate and career success. Students could create and evaluate their own personal social network and think about their own ability to deal with adversity. Instructors may consider what contexts would be most meaningful to students in the class and discuss how network thinking might help map out the meaningful relationships in these contexts.

In the activity, students will be asked to conduct three attacks on the networks they create. Be sure to brainstorm what these attacks could be ahead of the activity if everyone in the class is building the same type of network. Examples of a node-level attack could be a coworker being fired or a store going out of business. On the other hand, a link-level attack might be an intradepartmental conflict among coworkers, a malfunctioning enterprise social media tool used by coworkers, or a closure of a road that connects a business to their supplier. Natural disasters and terrorism are examples of events that would present a global shock to the overall network structure, including both the nodes and links in a given system.

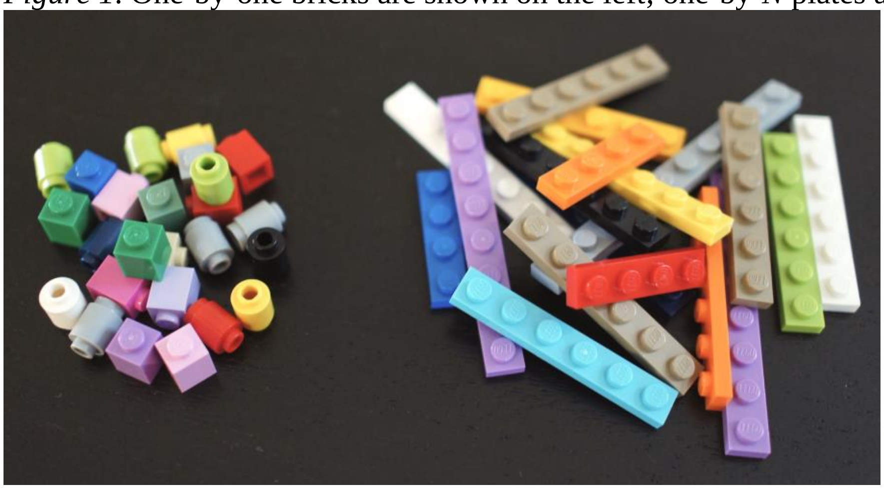
Reading Materials

To prepare students for the activity, instructors might consider assigning an introductory reading on resilience (e.g., Buzzanell, 2010; Coutu, 2002) and/or network ideas (e.g., Borgatti et al., 2009; Krackhardt & Hanson, 1993). Instructors could also explain these concepts in class either before or after the activity.

Model Materials

On the day of the activity, instructors need the following materials: 1) supplies for the networks (i.e., marshmallows, spaghetti noodles, and markers OR LEGO® bricks and plates), and 2) worksheets. First, instructors should gather the supplies for the networks. Each student needs six mini-marshmallows and eight spaghetti noodles of varying lengths. If spaghetti noodles and marshmallows are used, instructors should bring markers of different colors to be shared among students to give each marshmallow a designated color. Instead, six LEGO® bricks and eight LEGO® plates may be used. Bricks are one-by-one; plates are one-by-*N* (see Figure 1). Using marshmallows and spaghetti noodles or LEGO® bricks and plates produces similar results. Instructors should take their budget and available resources into consideration when selecting materials.

Figure 1. One-by-one bricks are shown on the left; one-by-*N* plates are shown on the right.



Worksheets

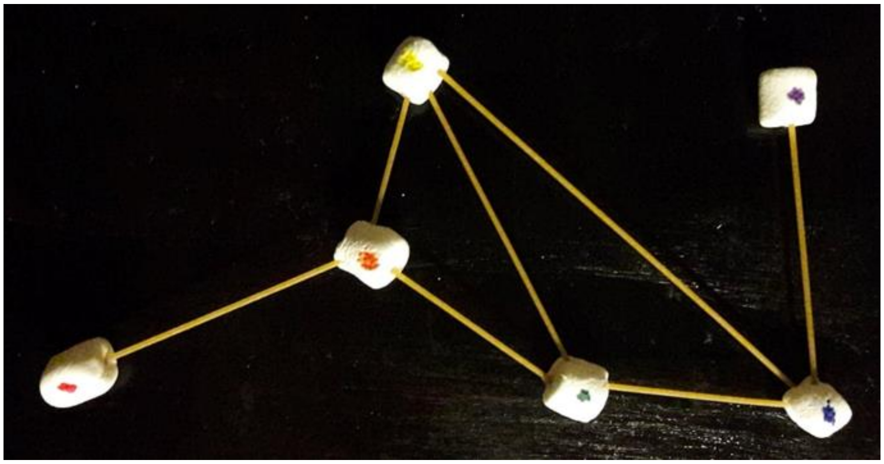
Second, students will be given a worksheet (see Appendix A) for calculating network measures and recording the results of “resilience tests” (i.e., tests of vulnerability in response to node-level, link-level, and global-level disruptions to the network). Instructors should make sure each student has their own worksheet.

Procedure

1. Pass out six marshmallows/bricks *(i.e., nodes*) and eight spaghetti/plates (*i.e., links*) to each student in the class (3-5 minutes). Ask students to place a colored dot on each of their marshmallows (see Figure 2). If using LEGO® pieces, instruct students to assign their bricks a label (by color, if possible). Make sure to keep a set of nodes and links for demonstration. Have students think about what nodes and links represent in their networks.

For the purposes of this activity, students will be asked to create an information sharing network, where the nodes are college students and the links represent students exchanging information relevant to their schoolwork and everyday life. Students could visualize their own network of friends from classes, student organizations, or other social contexts.

Figure 2. Marshmallow bricks are connected to spaghetti links. In this network example, density is .467; mean distance is 1.8; and centralization (based on variance of degrees) is .889.



2. Ask students to connect the nodes and links in any way they would like to make a network (3-5 minutes). Instructors can demonstrate how to connect the nodes and links, so students can observe an example of constructing an appropriate network. Students do not have to use all the links but should not use more than eight links and should be able to lay their network down flat. In other words, the structure should not be more than one node high. If using marshmallows and spaghetti, students should break apart their noodles into the desired link lengths and stick their spaghetti into the marshmallows. Link lengths are often indicative of the proximity of two nodes (e.g., employees who work together in the same brick-and-mortar business might be connected with short links, while their teleworking coworkers might have longer links), but do not have to be a crucial factor in this activity.

3. Have students calculate network metrics for their structure (10-15 minutes). These include density, reachability, and centralization. The worksheet includes detailed definitions and step-by-step calculation guidelines. It is a good idea to demonstrate how to calculate the network metrics based on the network built by the instructor to help students complete the worksheet. An online variance calculator like Alcula (Arcidiacono, n.d.) should be used to compute centralization. Ask students to report their metrics and record them on the board, or on a shared online document if the class size is large (see Appendix B). The class can discuss similarities and differences in students' numbers after each calculation or wait until all metrics have been calculated. Students can look at each other's networks to understand how the metrics reflect the visible structure.

4. Pair up students and have the partners conduct resilience tests on their networks (5-10 minutes). The resilience tests represent adverse scenarios that might be experienced by a

network. A node-level attack would represent a student being removed from the network, like if they left an organization. A link-level attack would represent the loss of a communication channel between two students, or if one student intentionally keeps another from receiving useful information for some reason. An example of a global attack to the structure of the network could be if a pandemic prevented the students from seeing each other at school and only few pre-established alternatives that would act as channels of communication existed. Be sure to demonstrate what each attack would look like before asking students to conduct them. For the node removal test, ask students to give their network to their partner. Each student should remove two nodes from their partners' network. Have students count how many pieces their own network is broken up into and then put their network back together. Record their metrics on the board. For link removal test, repeat the above process, but instead remove two links. Count the links and record the number. For the global shock test, have students stand up and drop their network from shoulder height. When using marshmallows and spaghetti, if the networks do not break, try holding the networks perpendicular to the ground, so a weak spot in the network (like a wishbone shape) is pointed down. Seeing how the network breaks allows students to evaluate points of strength and weakness in their network and allows for richer comparisons across networks with varying structure. Count the broken parts and record the number.

Debriefing

Debrief the activity with the class using the Think-Pair-Share technique (10-15 minutes). Everyone will think about resilience and networks concepts, along with Appendix B on the board. First, ask students to think on their own about one or more of the questions below for two minutes. Second, instruct them to talk with their partner about the questions for three minutes. Third, have students share their thoughts in an all-class discussion for 5 to 10 minutes. Questions to ask include:

a. How does network structure impact resilience? How will the relationship between network structure and resilience vary across contexts? For example, think of contrasting contexts of information/communication flow versus disease spread. Building resilience involves constructing, maintaining, and reactivating information ties (e.g., adding links to enhance reachability or designating central nodes who can bridge information across subgroups in the network) in the former context. Contrarily, in the latter context, building resilience involves configuring and reconfiguring network ties (e.g., decreasing density and reachability, and also decreasing centralization if the hub can be easily infected) to be able to slow down and stop contagion.
b. How could each network be rebuilt to be more resilient? Why would the proposed changes make the network more resilient?
c. How are networks' resilience tested in real-life? How does the breakdown of interpersonal or organizational ties relate to the resilience of individuals and systems?

The calculation of metrics is optional. If step three is skipped, the class might discuss how the qualitative differences in their networks impacted the resilience tests. It may also be beneficial to assign students different conditions when creating their network (e.g., highly robust or vulnerable networks). A limitation of this activity is that many network metrics may be relatively similar when using only six nodes and eight links. If the instructor decides not to calculate metrics, using more pieces will increase the variation in possible structures and may better mirror students' envisioned networks.

The results of this activity will vary depending on how much students think strategically about resilient structures when creating their network (e.g., are they trying to create a "strong" network in anticipation of the attacks) and disrupting other's network (e.g., are they diagnosing "weak" parts of the structure). Instructors can facilitate thinking about networks and resilience by assigning the readings mentioned above or introducing the concepts prior to the activity. It is important to emphasize that the consequences of external shock depend on whether the network faces a random failure or a targeted, coordinated attack (Barabási & Bonabeau, 2003), as well as which real world phenomena the nodes, links, and the overall network represent.

Instructors can further facilitate discussions about the processes by which resilience can be actively enacted. Networks offer support mechanisms that can facilitate resilience, but networks can also enact resilience. Resilient people have an ability to improvise (Coutu, 2002); and resilient systems (e.g., families, teams, organizations, social movements, etc.) can reactivate functional but inactive nodes and links in specific situations like crises (Janssen et al., 2006). Resilient systems can also fill in the empty space where missing nodes or links used to exist, like nonprofits connecting to new funding sources after a donation is depleted.

Appraisal

This activity provides students with a fun opportunity to explore network ideas and resilience. The activity has been used in both graduate and undergraduate class sessions. Prior to class, students discussed resilience and read relevant articles. In a graduate-level class, students were given the option of creating a network relevant to their research interests. One student created their own personal social support network, while another considered their model a community facing a hurricane. The process of defining their nodes and links helped think about all the people, groups, and organizations that could be represented in their network and the many relationships that could link those entities together in different ways. In undergraduate-level classes on disasters and society, students were encouraged to think about networks relevant to disaster situations. Some students considered physical networks such as roads connecting townships or flight networks that could be disrupted by snowstorms. Others imagined their models being social networks in which residents share information about evacuation warnings or rebuilding procedures after disasters. Across all classes, conducting attacks on each other's networks and simulating a global shock were the highlights of the activity. Students enjoy the competition aspect of the activity, where they debate who conducted the most strategic attacks and whose networks were the most and least resilient. Students had limited knowledge of networks concepts, but quickly grasped the definitions, calculation steps, and implications of density, reachability, and centralization. This activity gives students the opportunity to explore the foundational concepts of network structure and connect them to resilience.

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Appendix

Appendix A. Worksheet for exercise.

Building Resilience Exercise

Step 1

You have 6 nodes and 8 links. Name your nodes using color for convenience when calculating network metrics.

Node 1: ___________

Node 2: ___________

Node 3: ___________

Node 4: ___________

Node 5: ___________

Node 6: ___________

Step 2

Connect the nodes and links in any way you want. You need not use all of the links, but your structure should be able to lay flat (= *generate a network of 6 nodes and X links*).

Step 3 – Calculate Network Metrics

A. Level of connectivity measured by Density: What is the proportion of all possible links that are actually present? Use the formula below, where N is the # of nodes (N is 6 here) and X is the # of links. _____

$$\frac{X}{N(N-1)/2}$$

B. Level of connectivity measured by Reachability: Can the nodes reach each other? How close are the nodes to each other? Or are there subgroups in the networks that are not connected to each other? Count the # of steps (i.e., distance) between each pair of nodes. Mean distance = _____.

Node 1 & 2: _____	Node 1 & 6: _____	Node 2 & 6: _____	Node 4 & 5: _____
Node 1 & 3: _____	Node 2 & 3: _____	Node 3 & 4: _____	Node 4 & 6: _____
Node 1 & 4: _____	Node 2 & 4: _____	Node 3 & 5: _____	Node 5 & 6: _____
Node 1 & 5: _____	Node 2 & 5: _____	Node 3 & 6: _____	

C. Level of centralization: How equal is the distribution of **degrees** (= # of direct connections) among nodes? The larger the variance (i.e., level of dispersion), the higher the centralization. Calculate the population variance by inputting the below degrees into an online variance calculator. _____

Degree of Node 1: _____	Degree of Node 3: _____	Degree of Node 5: _____
Degree of Node 2: _____	Degree of Node 4: _____	Degree of Node 6: _____

Step 4 – Conduct Resilience Tests

A. Node-level attack by a classmate: Have one partner take out 2 nodes from your model. How many parts (=connected components) does your model (=network) break into? _____

B. Link-level attack by a classmate: Have another partner take out 2 links. How many parts does your model break into? _____

C. Global shock: Stand up. Drop your model from shoulder height. How many parts does your model break into? _____

Appendix B. Measures calculated from the instructor's and each student's network.

	Network Metrics			Resilience Tests		
	Density	Reachability	Centralization	Node Removal	Link Removal	Global Shock
Instructor						
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
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