NETWORK SCIENCE

Genealogy

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Objective

The student will understand how network models are used by geneticists to better understand genetic inheritance.

The student will be able to visualize how traits flow (or do not flow) from generation to generation by using a model family tree network, discern the direction of flow in relation to inheritance, and practice modeling the flow of inherited traits with an inheritance tree.

The student will engage with NGSS Crosscutting Concept 4. *Systems/System Models.*

Vocabulary

Networks: 1) are a set of relationships, 2) show how things are connected, and 3) reveal hidden information. Examples of networks include social networks, or the people that an individual interacts with on a daily basis, such as their immediate or extended family.

Vertex (vertices): Also called a node, usually drawn as a circle; can represent different things in a network (e.g. people, animals, cells in the body, organizations, etc.). For example, vertices or nodes in our immediate family can include any siblings, parents, or even pets.

Edges: The lines connecting vertices in a network that represent a relationship. Arrows can indicate the direction of the relationship. The first example below shows an undirected edge; the second example shows a directed edge; the third example shows a bidirectional edge.

Background

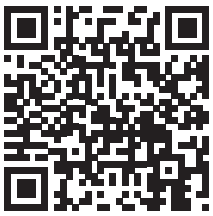
Genetics is the study of heredity and the variation of inherited characteristics. Heredity is the passing on of physical or mental characteristics genetically from one generation to another. In most cases, the inheritance of traits is dependent on probability.

Remember that family trees are a type of network. The network we create helps us understand which traits were passed down and who they came from. While humans can inherit traits like hair color and eye shape, sometimes they can inherit genetic diseases or be more likely to develop health issues because of their genetics. In most cases, inherited traits are based on probability, so tracing family networks can tell us how likely people are to have these types of diseases.

When tracing the genealogical flow of relatedness from one generation to the next one or two generations, it is easy to see how family members from different generations are connected by shared traits. When trying to trace the flow of relatedness on a larger scale - for example, across centuries or for a whole population - network science can help illustrate patterns of inheritance. For example, *why do some traits occur together?*

Genes and genetics explained:
https://www.betterhealth.vic.gov.au

"Mom vs. Dad: What Did You Inherit?" video by AsapSCIENCE and 23andMe:



Materials

Activity One – Emoji Game

Per pair

- 1 coin
- Washable markers
- Square slips of paper
- Clear tape
- Giant sticky note
- Yarn (optional—see Step 7)

Extension

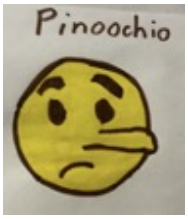
Per pair

- Hat
- Slips of paper (see Differentiation/ Extension section)

Procedure

Activity One – Emoji Game – Introduce Topic

1. Each participant should draw an emoji using markers and paper. They must have 4 traits (face shape, eyes, nose, mouth) and can take on any appearance. Encourage students to be creative. The sillier the emoji traits, the more fun this activity becomes. See examples:
2. Ask students to name their emojis, then have each student introduce their emoji to a partner. These are **Generation 1 Emojis.**
3. Hand out one coin and another paper square per pair and assign one partner "heads"



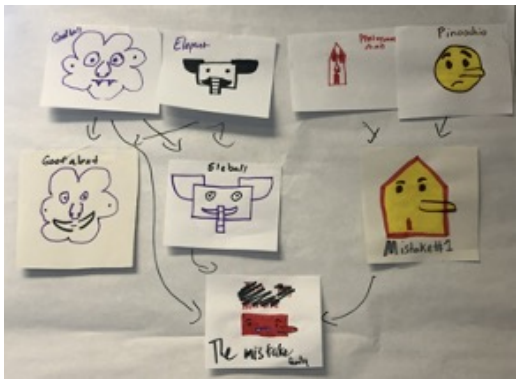
and another "tails" for the coin toss for the subsequent steps. *(NOTE: if there are uneven numbers of students, adjust the activity so that every student can participate – have some students create multiple emojis or involve facilitators within groups, etc.).*

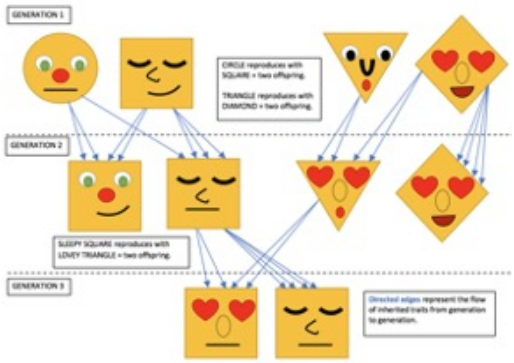
   a. Tell participants that their emojis are going to "reproduce." Youth will go through each feature (head shape, eyes, nose, and mouth) and flip a coin. Depending on which side the coin landed, that person's original emoji feature will now belong to its offspring.
   b. Repeat the process until participants have gone through all the features.
   c. Draw the offspring of the participant 1 and participant 2 "pairing" with the new features determined by the coin flips.
   d. Repeat this process to make a second offspring. These are **Generation 2 Emojis.**
   e. Each pair of participants should team up with another pair. Flip a coin to determine which of the Generation 2 Emojis will have offspring together. Repeat the steps above to create two **Generation 3 Emojis** per team.

Activity Two – Inheritance Tree

1. After the emojis have created **Generation 3**, teams work together to build the comprehensive emoji family tree on a larger poster board or sticky note.

2. Participants should identify how certain family members are related. For example, pick two of their emojis and ask how they are related to each other; pick a trait and see how it is passed down (or not) through generations.
3. Ask them to use a marker (or tape and yarn) to draw lines representing the genealogical flow of relatedness. This way the participants will draw the network of what "flowed" from emoji to emoji and what did not. Review vocabulary of network, edge, and vertex in relation to the emoji family tree created by the groups.





4. Ask the four participants in each team to figure out if any of the Generation 1 Emojis had more influence (more traits) on the flow to Generation 3 Emojis.

Whole Class Challenge

5. As the facilitator, choose groups at random and incorporate the features of their emojis into a **long lost emoji.** The class must work together based on the traits on display to decide what Emoji Family Tree (network) the newly-discovered emoji belongs to.
    a. Ask the students to use the terms network, vertex, and edge as they figure out the potential relationships of this long lost relative.

6. After the **Generation 2 Emojis** are made, have a hat/cup prepared with slips of paper that students can draw from to add variety to the family network.
    a. Examples may include not having children, having identical twins, additional siblings, step siblings, adopted offspring, genetic diseases, etc. Ask students – "How would genetic traits flow given these additions?"

Guiding Questions

- Did anyone have any features that stuck around until the very end of your family network?
- What do the vertices (nodes) and edges (lines and arrows) in this network represent?

  Vertices represent people, lines represent relationships and arrows represent direction of relationship
- Why do you think it's important to create family networks like the ones we just created?

  Ancestry and connection, genetic traits (hair color, eye shape), inherited diseases

Career/Future Application

Genetic counseling is a process to evaluate and understand an individual or family's risk of an inherited medical condition. A genetic counselor is a healthcare professional with specialized training in medical genetics and counseling.

https://www.nsgc.org/page/frequently-asked-questions-students#what

Genetic counselors interpret results of gene analyses and help people make sense of what their genes mean for their health and the health of their children. Websites like Ancestry.com, National Geographic, and 23andMe enable people to piece together their own family networks. People can even send a sample of their DNA to 23andMe and receive information about their genetic traits and risk for certain diseases.

References

Vocabulary terms were adapted from the following text:

Nooy, W. D., Mrvar, A., & Batagelj, V. (2005). Exploratory social network analysis with Pajek. Cambridge: Cambridge University Press.

Information about genetic counseling was taken from the following link:
https://www.nsgc.org/page/frequently-asked-questions-students#what

This activity was adapted from an activity done in Dr. Eileen Hebets' University of Nebraska-Lincoln Communicating Science Through Outreach class

Examples of diseases that can be inherited through genetics.
https://www.umdf.org/what-is-mitochondrial-disease/inheritance-and-genetics/

Article: Network Medicine: A Network-based Approach to Human Disease
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3140052/

Systems genetics is an approach to understand the flow of biological information that underlies complex traits:
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3934510/

Article (technical) about family trees/genealogy as "sparse" networks:
Batagelj, Vladimir and Andrej Mrvar. 2008. Analysis of Kinship Relations with Pajek. Social Science Computer Review. 26:2:224-246. <https://www.researchgate.net/publication/228978456_Analysis_of_Kinship_Relations_With_Pajek>

The background was written using definitions generated by Google dictionary.