

USING ACTOR NETWORK THEORY FOR DATA ANALYSIS

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ABSTRACT

The present study explores how the visualization of an actor network enables researchers to understand mediating processes better by investigating relationships and effects among elements and entities other than human-actor accounts. In particular, the study presents how visualization may facilitate an understanding of the dynamics and structures of an ecological classroom and thus provide insightful reflections for analyzing data and for drawing conclusions. In doing so, the study explores the possibility that object-oriented thinking guided by actor–network theory (ANT) may allow researchers to understand what data means when the initial design/theoretical conjecture does not work.

KEYWORDS

Visualization, Actor Network Theory, Data Analysis, Classroom Research

1. INTRODUCTION

When conducting classroom research, researchers must deal with complicated data and understand what is happening at a given moment (Stainback and Stainback, 1988; Cobb and Whitenack, 1996). One of the advantages of conducting classroom research is the possibility of uncovering new findings outside of the planned scope through retrospective analysis. However, it remains difficult for researchers to deal with the complex data involved, particularly when trying to decide what to do when the known data points not do what the researcher wants them to do.

The difficulty increases as the definition of *learning* is shifting from the acquisition of knowledge to changes in disciplinary practices. The interpretation of these changes in practice requires researchers to consider many things, rather than simply, for example, a test outcome. To handle this complexity, the understanding of the mediation process from a sociocultural perspective has received increasing attention. For example, the analytical triangle of cultural-historical activity theory has been used to understand several kinds of mediation processes among subjects, objects, rules, and divisions of labor. Typically, human actors are centralized to provide a kind of cause–effect explanation. Any kind of mediating process is, thus, delineated to suggest or direct what/why/how humans think, talk, and behave for connotating certain social and cultural meanings. Consequently, our awareness and consciousness of taking the social and cultural meanings of mediation artifacts into consideration from a given cultural frame may restrict our ability to observe and interpret other hidden meanings that may arise through the data.

In this context, this study suggests that a visualized actor network may help researchers understand the mediating process better by allowing them to expand different possibilities of relationships and effects among elements/entities beyond human actors. In particular, this study illustrates how object-oriented thinking for the mediating process helps researchers to understand what data mean.

2. BODY OF PAPER

The basic premise of actor–network theory (ANT) is to examine what makes and sustains links. Any element of the material and social world can be an actor in ANT. The role of mediation is to maintain or restore links among actors. ANT explores and describes how any elements (e.g., human, nature, technology, and social rules) come and hold together to describe forces and ties within a network. While researchers usually investigate how members in a group influence each other or struggle for power, ANT treats other interactions the same as human–human interactions (Latour, 2005). The establishment of a network (typically, either in a small group or in a classroom for educational research) is described as *translation* and consists of four phases: *problematization*, *interessement*, *enrollment*, and *mobilization*. Problematization is the phase in which a problem is defined. In this phase, there is an obligatory passage point that actors must perform to obtain their solution. The interessement and enrollment phases are those in which the actors recognize the solution and become part of the network. Finally, the mobilization phase is the moment at which the network works stably and as expected.

Pragmatically, when ANT is applied in a small group or in a classroom, researchers identify the elements of a network to examine how connections are established, which enables them to understand what sustains/mobilizes the connections. For example, the inclusion of all entities as part of mediation processes helps us to move away from a typical, holistic approach of the teacher-blamed or student-matter frames for the success/failure of argumentation. When innovative scientific argumentation-centered curriculum or a new technology (e.g., talking and writing [TW] maps) were introduced to classrooms, some groups/classrooms functioned better/worse than did others. In most cases, a presumption held by researchers was that there would be competence/ability differences among teachers and students, and this would be the main reason for the differences shown. In the following sections, this is explicated in more detail through a case in which something unexpected occurred beyond the teacher-blamed, student-matter frame in the mediating process.

2.1 Data Sources, Analysis, and Interpretation: Different Uses of Post-Its (Using ANT for Uncovering Data)

During two consecutive academic years (2017–2018), high school students in the ninth and tenth grade participated in a scientific argumentation design-experiment by dealing with five science-oriented issues, five socio-scientific issues, and two science experiment topics for each year (Table 1).

Table 1. Topics of TW activity and scientific argumentation

Subject	Topic	Questions
Chemistry and Biology Integrated	Regularity of matter Combination of matter “Natural or synthetic vitamin?”	<ol style="list-style-type: none"> 1. The iron and calcium around us are metal or ionic compounds. What does iron or calcium in vitamins look like? Do they exist in metallic or ionic form? 2. Can you design a scientific experiment testing your idea from 1? Let us describe your experimental steps to find the answer to 1 3. There are synthetic nutrients and natural nutrients. Investigate the differences between these two. Which is better? Please explain your choice (either natural or synthetic) based on scientific evidence
Physics and Life science	Interactive system “Design a ride that is both thrilling and safe”	<ol style="list-style-type: none"> 1. Investigate and introduce one of the world famous rides and explain the amount of momentum and impact applied to it 2. Investigate two or more safety issues related to the rides introduced in 1. Think about possible solutions to resolve these safety issues

		3. Assume that you're a world-renowned creator of play equipment. Design a ride that is both thrilling and safe. What aspects of your ride make it more thrilling and safer than other rides? Please explain why
Physics and Earth Science	Earth as system "Propose a new government policy to prepare for an unusual natural phenomenon"	<ol style="list-style-type: none"> 1. Can you think of an unusual natural phenomenon? What causes this phenomenon? Please explain the causes of this natural phenomenon scientifically 2. Interpret your answer to 1 in terms of the interactions of the components of the Earth system 3. Propose a new government policy to prepare for the unusual natural phenomenon selected in 1
Physics	Mechanics and energy "Design a ride that is both thrilling and safe"	<ol style="list-style-type: none"> 1. Investigate and introduce one world famous rollercoaster. Explain the mechanical energy conversion 2. Explain how the following are related to the safety of roller coasters: <ol style="list-style-type: none"> (1) Why does the roller coaster not fall off the rail during rotation? (2) Why does a person on a roller coaster not fall off the rail while rotating? (3) What is the role of the safety bar? Why should one wear a safety bar? (4) Why do you think an accident would happen despite wearing a safety bar? 3. Assume that you're a world renowned creator of play equipment. Design a ride that is both thrilling and safe. What aspects of your ride make it more thrilling and safer than other rides? Please explain why.
Chemistry	Language of chemistry "Design an experiment to test whether 90% of eggshell is made of calcium carbonate"	<ol style="list-style-type: none"> 1. Design an experiment to test the hypothesis that 90% of eggshell is made of calcium carbonate. Include the chemical reactions related to this experiment 2. Conduct your experiment. How does your result compared to your hypothesis? 3. Compare your group's experiment with the experiments of other groups. (If the result is different, please explain why.)
Earth Science	Changes in the earth's surface "What should we do when an earthquake happens and why?"	<ol style="list-style-type: none"> 1. In 2016, an earthquake with a magnitude of 5.8 and of intensity scale VII occurred in Gyeongju City. In 2017, an earthquake with a magnitude of 5.4 and of intensity scale IX occurred in Pohang. While these two earthquakes shared the same Richter scale magnitude, the intensity scale was greater in Pohang. Why do you think the intensity scale was greater in Pohang than it was in Gyeongju?

		<ol style="list-style-type: none"> When an earthquake occurs, the Korea Meteorological Administration sends out emergency disaster letters. Compare the emergency disaster systems of Korea and Japan. Improve the current emergency disaster system Refer to our school's manual on what to do when a disaster occurs. What should we do when an earthquake happens and why?
Physics	Electromagnetism	<p>Some people say that the electromagnetic waves generated from electric blankets are harmful to the human body. However, some people think that these electric waves are not harmful</p> <ol style="list-style-type: none"> Design an experiment to verify whether electromagnetic waves are generated by electric blankets Discuss the effects of magnetic fields and electromagnetic waves on the human body as caused by electric blankets As a scientist, what do you think about the use of electric blankets? What is your conclusion?
Earth Science	Air pollution	<ol style="list-style-type: none"> What causes fine dust? Explain the reasons scientifically How does fine dust affect the lives of young people? Design a manual that minimizes the adverse effects of fine dust on students' health
Physics	Sound and light	<ol style="list-style-type: none"> Describe the principles of making sound from an electric speaker Design a speaker that considers both performance and design
Chemistry	Structure of various molecules	<ol style="list-style-type: none"> Although water and ammonia have similar molecular weights, their boiling points are different. The boiling point of ammonia is -33.4°C, whereas the boiling point of water is 100°C. Explain the reason for this difference with regard to molecular structure If the structure of a water molecule were not curved, what phenomena would happen in the natural environment? What kinds of changes would happen in our lives?
Physics	Electrical energy	<ol style="list-style-type: none"> Explain the principles of generating various kinds of electric energy Discuss the most suitable energy generation method for our country. Consider various factors such as power generation, sustainability, the environment, and economic matters

Students used a modeling tool, TW maps (Figure 1), in which they came together to talk and then write down their arguments to develop a collective model. Our design conjecture was that group argumentation would occur if they were forced to write down their argument. After the completion of the group's TW map, a member stayed in the group as a representative to explain the group's map, whereas the other students in the group visited other groups. Students began to call this activity a *gallery talk*. By using 360° virtual reality cameras for each small group, verbal and nonverbal interactions were captured and observed. Interesting episodes (20% of all videos) were selected and fully transcribed.

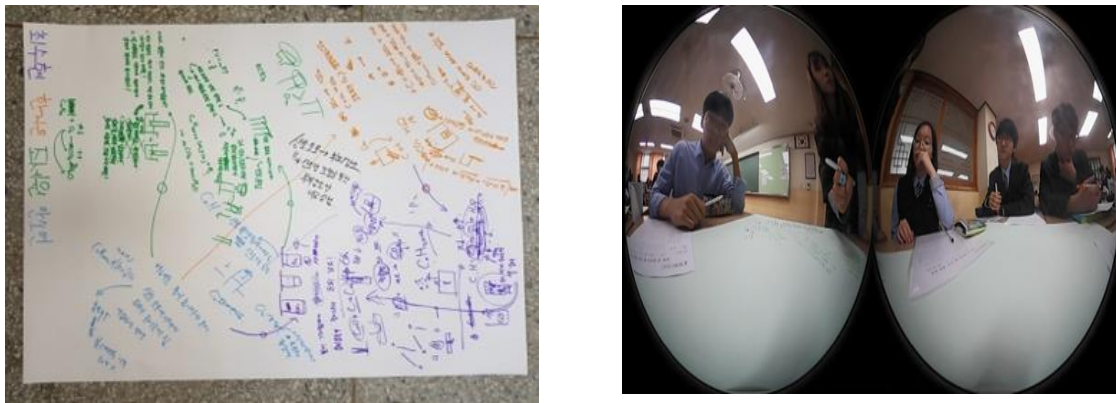


Figure 1. TW activity and 360 VR camera

After two months, a noticeable change in developing arguments was observed in one classroom across all small groups but not in other science classrooms. The change was that the classroom attempted to predict questions and reflections from other groups' members and prepared them ahead of time, which helped students develop arguments of better quality. Originally, our theoretical conjecture was that developing a TW map followed by a gallery talk would mediate students in such a way that they would demand evidence and justifications and discuss rules for good arguments more often to improve their argument quality. The gallery talks seemed to serve as a mediation process that produced better arguments by having students prepare questions and reflections from visitors.

However, an issue we faced from this data was why this occurred in only one classroom but not in the other four classrooms. The same science teacher taught all the science classes, and the classroom in which the students prepared questions was not a superior class. Using ANT, we examined the relationships between the tools and humans and their effects. In particular, we wanted to move beyond the typical expectation that some students are better participants than are others.

We first identified more actors in the network. While we were able to identify four actors at the beginning of this process (i.e., *students*, *TW map*, *small group discussion*, and *gallery talk*), we were able to add more actors as we began to include non-human elements, including *information resources*, *science practice experience*, *peer acceptance*, *experiment equipment*, *argumentation topics*, *assessment sensitivity*, and *communication competence*. Next, we described the relationships between the links among these actors. We traced how the claim was linked to the actors and found focal factors as well as obligatory passage points. When we analyzed students' work on the question "How can you design an experiment to determine whether the eggshell consists of 90% calcium carbonate?", we found a noticeable difference from the question-predicted classroom: post-it notes. While *post-it note* was not included as an actor in other classrooms, it was identified as one of the main actors in this classroom and was related to other actors, including *experiment equipment*, *argumentation topics*, and *peer relationships*.

A retrospective analysis was then performed. We traced how students in this classroom used post-it notes, and we compared this with the use of other classrooms. We also interviewed a few students and asked how they used post-it notes. Post-it notes were not an element used in the original design, which is the reason for our ignorance of their use during the initial observation. Students spontaneously began to use post-it notes because the space on the white paper was often limited, particularly during the gallery talk. To address this, the science teacher prepared and distributed post-it notes to each group. Students in this classroom took notes from the gallery talk, and the main part of the notes were composed of questions and reflections. Thus, when students visited other groups and received similar types of questions and reflections from others, they generated several more questions and reflections. Cumulatively, students became accustomed to asking and answering questions as well as giving and receiving reflections, all of which students had to prepare. It must be noted that post-it note-taking was also used in other classrooms; however, it was not identified as a main actor. The students used post-it notes in different ways. For example, students in one classroom used post-it note-taking as a way to summarize other groups' key claims. After taking notes from other groups, they came back to their own groups with these notes, enabling them to compare the differences and similarities between their writings and the claims of the other groups. In this way, the students scrutinized the accuracy of relevant science content knowledge by having the opportunity to compare arguments but did not necessarily reflect on and prepare questions in their argumentation practice.

2.2 Visualization of the Actor Network

While ANT provides core ideas and principles useful for analyzing messy and complicated data, ANT does not necessarily suggest specific ways in which to visualize a network. We came to think that a correlation measurement used in social network analysis can be useful in showing the relationships among actors within ANT. Thus, we applied some visualization techniques of SNA to identify the focal actors, the obligatory passage points, and the mediating processes in which actors interact with each other to produce effects. As the inter-node link in SNA represents social interactions, the line in ANT can be an intermediate currency in the network. Thus, in this way, the number, length, and intensity of lines correlate with the relationships between actors. The measurements of in- and out-degree lines and betweenness can be used to identify key actors and mediators in the network. The identification of in-degree lines for actors can be used to identify obligatory passage points. The map below (Figure 2) shows how *student-generated arguments* (A_number) related to other actors, such as *peer acceptance*, *science experiment*, *pre-existing knowledge*, *beliefs on claims*, *class topics*, and *TW tool*. The map shows obligatory passage points including *science experiments*, *peer acceptance*, *information resources*, *post-it note-taking*, and *task-proceeding remarks*.

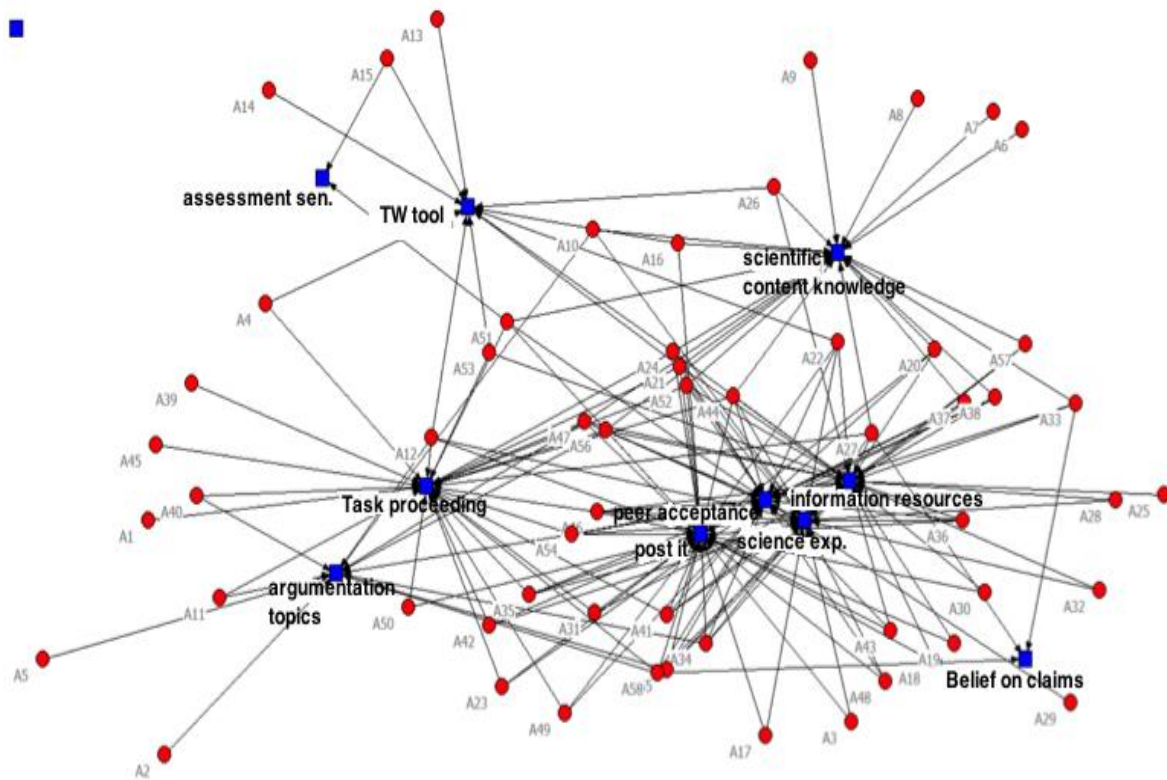


Figure 2. Key actors in student argumentation

It is quite interesting that *science experiments*, *peer acceptance*, *information resources*, and *post-it note-taking* are closely tied together, thereby increasing the eigenvector centrality, a measure of relative influence. For example, if two nodes have the same number of connections, a node connected to another node with many links maintains a higher eigenvector centrality than does one with fewer links. Although a more detailed explanation is required, the network suggested that the four actors were likely to be addressed simultaneously when argued.

3. CONCLUSION

A larger set of unexpected messy data is a common phenomenon in DBR. To handle this, we propose that using ANT with the visual technique of SNA may help researchers uncover the meaning of such messy data. In particular, focusing on ontological entities allows researchers to interpret the mediation process from other lenses, without adhering to the original theoretical conjectures, which often merely emphasizes human actors. The visualization of ANT enabled us to understand the structure and dynamics of classroom interactions. As a cultural resource, *post-it note-taking*—a way to record and provide questions and reflections, uniquely seen in one classroom—was identified as a mediator, which led to active feedback and discussion. If we did not use ANT, it would not have been easy to identify the role of post-it note-taking.

ANT provides fluid and complex—but extremely detailed—interpretations of the interactions between objects. From this multiplicity perspective, knowledge, learning, or practice is continuously produced and modified within webs of actors, which is consonant with the principles of DBR. Therefore, the flexibility and adaptability of ANT can be useful when conducting DBR for creating and modifying research plans as well as for data interpretation.

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