Digital Tools and Solutions for Inquiry-Based STEM Learning

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Chapter 5
Wikigrams-Based Social Inquiry

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ABSTRACT

This chapter presents techniques that combine the productive activity aimed at creation of collaborative stories with the research activity based on the analysis of the relationship between the participants of the productive activity. The productive activity is delivered through a wiki site Letopisi.org, where all actions of the participants are recorded in an electronic log. Log records are used as a data source to build sociograms, which constitute the basis for the research activity. The chapter describes different cycles of collaboration based on the usage of social objects. The first cycle is creation of digital story. The second cycle is social inquiry.

INTRODUCTION

Social media attracts attention of researchers and widely used in various spheres. However, in education, dynamics of social networks, extensive data on interrelations between network participants, network analysis techniques are hardly used. It comes from the widespread belief that the network data is hard to access or that the network analysis is too complicated. In this chapter, we will demonstrate that the network provides a great platform for inquiry-based learning. We present a number of simple methods of learning analytics as well as on the methods of creating static graphs (Graphvz) and dynamic models (NetLogo), which many teachers are familiar with. The source material for the research is log records. The set of log-records is a by-product of a specific learning activity, which is a digital storytelling. Cycles of

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interleaving storytelling and research activities of the learners are interconnected by using the proposed approach. The by-product results of the learner's storytelling activities are used as a feed substrate for the network research based on the analysis of sociograms. It provides an advanced pathway to developing pedagogical means that utilize the science of complex networks as a vehicle through which students can acquire analytical skills for the network-oriented data analysis.

BACKGROUND

Science, Technology, Engineering, and Mathematics (STEM) are the driving force for worldwide economic and social advancements. The skills needed by the 21st century STEM workforce include the ability to interact with large amounts of data and the ability to understand the changing role of models. Educational systems worldwide are not keeping up with the explosion in the big data and data-driven sciences. However, exposure to these data-driven science skills is unavailable to most primary and secondary school students. Network science is a promising way to address data-intensive real-world problems (Cramer et al., 2015). Network science is an emerging, highly interdisciplinary research area that aims to develop theoretical and practical approaches and techniques to increase our understanding of natural and man-made networks(Börner, Sanyal, & Vespignani, 2007). We are surrounded by systems that are collectively called complex systems, capturing the fact that it is difficult to derive their collective behavior from knowledge of the system's components. Complex systems understanding, mathematical description, prediction, and eventually control is one of the major scientific challenges of the 21st century. Nature, science and technology are permeated with networks, and we will never understand complex systems unless we develop a deep understanding of the networks behind them (Barabási, 2016). A working definition of network science is the study of network representations of physical, biological, and social phenomena leading to predictive models of these phenomena (Committee on Network Science for Future Army Applications & National Research Council, 2005).

The network perspective allows us to address deep questions about different systems.

By postulating a friendship network in (say) a school classroom of 25 students, we have taken a theoretical step that is non-trivial. We have supposed that separate individuals are not an adequate representation, moreover that even separate dyads are insufficient; rather, that there is a unity within the classroom that makes it *proper to talk of 'a' network, not 25 children or 300 dyads. To conceptualize the classroom in network terms is an implicit (and strong) claim that connectedness across individual elements is fundamentally important so that the classroom can be thought of as one 'system'. (Brandes, Robins, McCRANIE, & Wasserman, 2013, p.5)*

To be successful in the 21st century, students must have a fundamental knowledge of complex networks which allows them to explore the interconnectedness of our world. Networks are pervasive across all aspects of life: biological, physical, economic, and social and our society continues to become ever more connected through the use of social media tools. This inherently interdisciplinary makes network science the perfect tool to engage students in STEM fields. Components of networks have been used as a tool for teaching math and computer science for many years. Scientists have expanded these efforts by developing and sharing materials to demonstrate how network science can successfully be used to engage students in STEM fields (Harrington, Beguerisse-Díaz, Rombach, Keating, & Porter, 2013; Sánchez & Brändle, 2014; Sheetz, Dunham, & Cooper, 2015).

As a rule, immersing school students in the field of network science begins with the study of maps that are based on data from different areas of research. For example, science maps for kids are based on the avalanche of data generated by scientific research today. These maps invite students to see, explore, and understand science (Börner et al., 2009).

We assume that introducing students and teachers to the network science may begin with mapping their own activities in the networked communities. The advantage of this approach is a network lens is used to understand situations in which students and teachers are drawn into. Consequently, the network science shows its strength in the areas of immediate experience and students and teachers become researchers of their own activity.

Inquiry-based learning attracts more attention and is expanding in Russia. Inquiry-based learning is one of educational concepts based on the constructionism philosophy. It is closely connected with learning by doing, project based learning or learning by design. The common ground for all these concepts has been the fact that they all form productive agency which there is scarce in Russia.

There is a need in contemporary society for citizens capable of acting as independent and self-sufficient agents under decentralized management. Contemporary education is intended to nurture citizens able to devise, create, use and share new products. Information and communication technologies support, facilitate and augment agent's activities. New economic models emphasize the importance of new knowledge, innovation, and the development of human capacity as the sources of sustainable economic growth. It is through education and human capacity development that individuals not only add value to the economy but contribute to the cultural legacy, participate in social discourse, improve the health of the family and community, conserve the natural environment, and increase their own agency and ability to continue to develop and contribute, creating a virtuous cycle of personal development and contribution (UNESCO, 2008).

The desired future of modern learning can be described as a situation where teachers and students are active agents that produce knowledge. Both society and education equally need participants with their own agency, because agency drives participation in the decision-making, knowledge production and collaborative learning. The concept of ‘agency’ reflects the individual’s ability to perform an ‘agent’, i.e. active protagonist, the driving force behind the action (Inden, 2000). For Russia, the problem of fostering agency is particularly acute, because of the extent to which individual agency has been historically foreign to our culture (Wierzbicka, 1992). A necessity of formation participant’s agency requires mentors of learning to put special attention to the problems of self-control and self-determination of behavior of participants. People have agency to the extent that they can alter their environment so that the environment affects them in adaptive ways. Schwartz (Schwartz, 1999) termed this formulation ‘productive agency’, because it emphasizes production through the environment. Schwartz defined productive agency as a recursive system where people take advantage of their available means to produce outwardly, and they see their ideas embodied and modified by the material or social world. Production distinguishes between situations that involve external production and those that do not and in this regard productive agency is akin to constructionism. Constructionism argues that learning occurs best when constructing a public artifact.

Constructionism shares constructivism’s connotation of learning as `building knowledge structures’ irrespective of the circumstances of the learning. It then adds that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it’s a sandcastle or a theory of the universe... (Papert & Harel, 1991, p.193).

Public entity or a public artifact can be not only examined or discussed but it can also be used by other people. That is to say a public artifact is inherently shareable.

Comparing the known learning communities close to the constructionism theory allows us to see that almost all of them use the idea of a cycle or a spiral of actions performed by agents over objects of actions:

- In the Globaloria Social Learning Network (Reynolds & Caperton, 2009) students perform the following actions with computer games: Play -> Plan -> Prototype -> Program -> Publish.

- In the Scratch Social Learning Network (Brennan, Hernández, & Resnick, 2009) students perform the following actions with Scratch projects: Imagine -> Create -> Play -> Share.
- In the NetLogo Modeling Commons (Lerner, 2014) NetLogo modelers perform the following actions with NetLogo Models:Create -> Run -> Share -> Comment -> Modify -> Create variations.
- In the StarLogo TNG Social Learning Network there are two linked circles (Klopfer, Scheintaub, Huang, Wendel, & Roque, 2009) and StarLogo TNG modelers perform the following actions with StarLogo Models. Research circle: Observe/Collect Data -> Generate Questions -> Test/Tinker/Play -> Observe/Collect Data. Design circle: Design -> Build -> Test/Tinker/Play -> Design.
- In the Looking Glass Social Learning Network (Kelleher & Pausch, 2007) 3D modelers perform the following actions with Alice Models: Create -> Animate -> Remix –> Share.
- In the CloudWorks Teaching Network (Galley, Conole, Dalziel, & Ghiglione, 2010) teachers perform the following actions with clouds (objects on the base of CompendiumLD map) Find -> Share -> Discuss.
- In the WebGrid Social Inquiry Network (Gaines & Shaw, 2012) researchers perform the following actions with grids (objects on the base of Repertoir Grid Test): Display -> Cluster -> Map -> Crossplot -> Matches -> Compare.

The circular consequence of agent's actions affecting an artifact is close to the theory of object sociality and its application to network communities organization defined by Engeström (Engeström, 2005). We draw in particular on the work of Engeström in terms of the concept of 'social objects' and his arguments for the importance of social objects as the key mediating artifacts. Engeström drawing on the work of Knorr-Cetina (Knorr-Cetina, 1999) puts forward an argument for the need to adopt an approach to social networking based on object oriented sociality. He provides examples of successful social networking sites built around social objects. three out of five for the inquiry-based organizational principles of design for the social networks singled out by Engeström deserve special attention as they are compulsory for learning communities:

- Clearly define the social object your service is built around.
- Define the verbs that users perform on the objects, so that is it clear what the site is for.
- Make the objects shareable.

The third principle (Make the objects shareable) means that an object created by one of the participants of the social network may be used or modified in any way by other participants of the social network.

In all the above-mentioned communities, there is a certain social object – a game, a story, a model or other ‘virtual chips’ over which agents perform their actions. Objects or actions can be different, but all agents are permitted to carry actions over one and the same object. If agents perform actions over one and the same object, they become indirectly connected by the social object. The links are similar to those between movie actors, or scientists creating an article, or Wikipedia editors working on a page together. The structure of these social connections is the subject of social network analysis and learning analytics. We agree with the definition of learning analytics as a collection of methods that allow learners to understand what is going on in a learning scenario (Schneider et al., 2012).

Learning analytics and diagrams methodology help to analyze and discuss situations that develop during a network collaboration in different domains. Analysts in this field have established Social Network Analysis (SNA) as an empirical method to study the ties between actors in the network (Wasserman & Faust, 1994). SNA uses various concepts to evaluate different network properties like centrality, connectivity, cliques, etc. A sociogram is a powerful analysis tool, helping researchers identify points of interest and other structural properties that otherwise would not be obvious in numeric data. The use of graphic imagery to represent relational information was key to the birth of sociometry. Depictions of social networks were invented by social scientist Jacob L. Moreno in 1934 (Moreno, 1934). As Freeman notes Moreno was the first to propose using sociograms to reveal important structural information about social linkage patterns and specified general rules for constructing sociograms (Freeman, 2000). We make maps not just of the physical world but also of our social worlds (Mehra et al., 2014).

The study of dynamic networks greatly benefits from visualizations that can illustrate ideas and concepts not immediately visible in a static sociogram. Moody and others’ research illustrates the need to visualize how networks develop and change over time (Moody, Mcfarl, & Bender-demoll, 2005). Among the tools developed in the complexity field, agent-based modeling and network analysis are very important in sustaining the process of bringing complexity to bear on the policy world. The combination of the two methods can increase enormously the potential of complexity-based policies (Fontana & Terna, 2015). Since agent-based modeling is inherently dynamic, the problems with static networks are overcome naturally. Agent-based modeling permits the desired richness of behaviors and attributes that might bridge the gap between agent-nodes and the real world.

Termites With Logs

It was mentioned in the previous section that actors perform actions over same objects becoming interlinked via this social object in many various situations. Simple actions that students perform over objects of actions in learning communities are very much alike the procedures performed by turtles in a famous Termites model (Resnick, 1997): search-for-chip -> find-new-pile -> put-down-chip. As Resnick (1997, p.76) wrote, each individual termite should obey the following rules:

If you are not carrying anything and you bump into wood chip, pick it up.

If you are carrying a wood chip and you bump into another wood chip, put down the wood chip you're carrying.

Each turtle performs a sequence of steps in procedures search-for-chip find-new-pile put-down-chip which leads to the result when chips scattered randomly over the screen are gradually gathered into one round pile. Termites model seems most optimal because it contains chips as objects for collaboration. Experimenting on this model we can get a deeper understanding of collaboration phenomenon. Let's imagine that termites record their labor actions over chips in a log. I.e. if an actor performs a meaningful action on a chip, he leaves a record on this in the log. To understand how we can benefit from collateral records we have modified the original text of Termites model by adding new variables and rules. We have inserted a variable called list WIKILOG where turtles make records of their actions. There also have been made some additions to the procedures *search-for-chip* and *put-down-chip.*

Procedures

```
to search-for-chip
ifelse pcolor = yellow [
ifelse 0 = [pagenum] of patch-here [
let newpage 1 + length pages set pages lput newpage pages
set t-pagenum newpage
set wikilog lput (se [who] of self newpage "create") wikilog ]
[set t-pagenum [pagenum] of patch-here ]
set pcolor black set color orange fd 20 ]
[ wiggle search-for-chip ]
end

to put-down-chip
```

```
ifelse pcolor = black
[
ask patch-here [set pagenum [t-pagenum] of myself] set wikilog
lput (se [who] of self [t-pagenum] of self "edit") wikilog
set pcolor yellow
set color white
set t-pagenum 0
get-away ]
[ rt random 360
fd 1
put-down-chip ]
end
```

A procedure to define links between actors having carried the same chip has been added to the model. It uses log records.

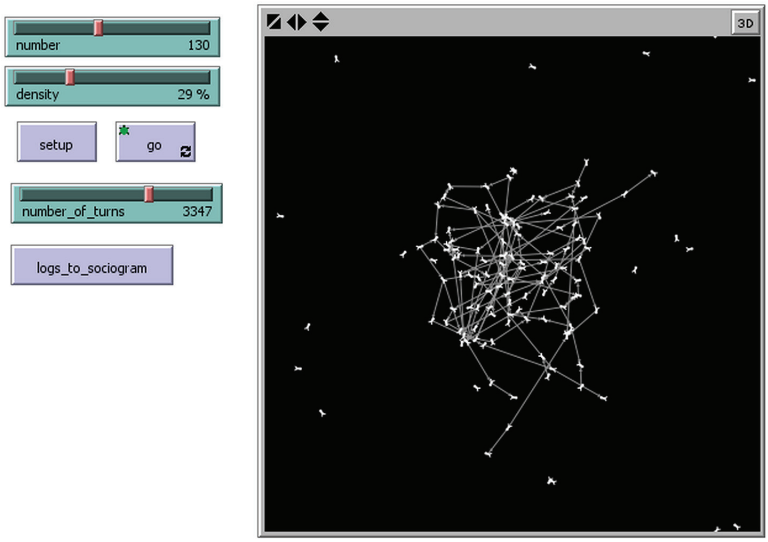
Procedures

```
to-report edits
report filter ["edit" = item 2 ?] wikilog
end

to logs_to_sociogram
ask patches [set pcolor 0]
foreach edits [
let friend1 item 0 ?
let p1 item 1 ?
let friend2 first first filter [(p1 = item 1 ?) and ("create" =
item 2 ?)] wikilog
if friend1 != friend2 [
ask turtle friend1 [ create-friendbond-with turtle friend2 ]]]
repeat 8 [layout-spring turtles links 1 5 7 ]
end
```

The interface for the modified model is shown in Figure 1. Logs_to_sociogram button switches all the chips off the screen and only shows linkage between agents carrying one and the same chip.

Figure 1. Interface of termites with logs model



Termites with Log Model was implemented in NetLogo language 5.2 and its source code is available on the Internet http://modelingcommons.org/browse/one_model/4749

This simplest model for sociograms creation based on the actions with social objects can be applied to various collaboration situations. In all cases when actors perform actions over shareable objects, the log for these actions can help build sociograms as well as conduct social research. This statement was used when we designed a learning social network Letopisi.org, which combines cycles of creative and research learning.

Letopisi.org: Creative and Exploratory Cycles

Initially the network Letopisi.org was regarded as a field for creative productive learning where learners create common stories about their teachers, schools and cities. As a medium for collaboration at the start of the project in 2006 we chose wiki. The majority of wiki software (also known as a wiki engine) is free and open source software and is developed collaboratively. MediaWiki is the most popular of these and is also used to run Wikipedia, the world's largest online encyclopedia, as well as many other (non-profit) educational projects.

We draw attention to the fact that wiki is a very simple and very quick way to create and deploy a new page in the network. In the same time, attention falls from the area that it strengthens with the interaction of wiki pages and the collaborative efforts. What has been created by one person, can be further used by other people. We can collect articles from the finished blocks, the same way as the program collects from Lego blocks. Lego blocks or a Wiki article are useful and powerful not because they are simple but because they determined the exact template, and they are always compatible with each other. Thanks to the template and transclusion mechanism, with MediaWiki it is possible to use articles as “building bricks” and from these we can assemble larger “building blocks” (Patarakin & Visser, 2012).

A wiki is the simplest online database that could possibly work. Users of wiki do not need to know the programming commands of the hypertext language. The text of any article or page of recorded items is interpreted by the program as hypertext. The special wiki checking agent looks through the texts of all the pages in search of patterns before they get to the browser. If a match is found, the agent checks whether a page of that name already exists in the database; in that case, it makes a reference on that page - if such a page does not exist then reference is made to the creation of a new page.

This example shows us how wiki can be used to elaborate a project in a variety of ways. We may select those words/concepts which we want to use as a basis and about which we wish to learn more, MediaWiki syntax imply that we include the key words in two square brackets. Following up on the example given we can use [[Sedum telephium]] or to [[Pustinskiy nature reserve]]. If a botanist has already written and placed an article about [[Sedum telephium]] in wiki, the reference will work immediately and will lead us to the text. If s/he intends to write an article in the future, there will be a deferred reference which can be activated in the future. The beauty of wiki is that we do not have to bother a botanist with questions about how to find the file containing his or her article on the Sedum telephium or to ask a geographer about the name of a swamp. We just abide by the way wiki works —the article is named and has a reference. And if a geographer then writes another article about the swamp in question, the link becomes activated automatically – nothing else has to be done.

In Russian education MediaWiki is represented first of all by Letopisi.org project and its regional clones in several teaching colleges and universities. Letopisi - http://Letopisi.org is the national educational project with international participation and has continued for more than ten years. Currently Letopisi.org is a huge multimedia archive and an experimental site, where everyone can find useful information and make an experiment with modern methods of collective storage, retrieval, editing and classification of texts, photos, audio, video. The leading idea of the Letopisi concept is that the collaborative network activity and the network cooperation of the learning agents are aimed at the creation of various types of learning products which in general could be marked by a widely recognized term “digital story”. The role of narration and the meaning of the practice of narration for various fields of activity were stressed by Bruner (Bruner, 2003) When the computer technologies started to be used multiple forms of digital storytelling emerged. More recent research (Gee, 2004; Grobstein, 2005) allowed for widening our understanding of the variety of the modern digital story modifications. The basic scheme of the concept is the following: the digital story and the constituent elements of it could be used by other participants of the collaborative activity in creation of new stories.

In the Letopisi.org Social Learning Network students perform the following actions with wiki pages:

Read -> Create -> Edit -> Connect -> Share -> Read

Read stories created by others -> create new page -> edit page -> put pages together into a story -> share the new story

This is a base cycle of actions in Letopisi where key objects are pages over which actions are performed. The learning design within the frame of the given concept structures not only the conditions for a separate learning agent activity within a limited time and space interval but also determines conditions for mid-term interrelation of the learning agents and the exchange of the activity products as well as the conditions for the development and long-term evolution of the whole collaborative activity system based on the selection of the most important stories.

In the focus of the learning design is not only the learning activity of a separate learning agent related to the creation of an individual product, but also a system of relations between all elements. Thus, the subject of the learning design represents not only social projecting of the system “agent-tools-product-outcome” in which digital stories are created, but also projecting of a system in which the interrelation and evolution of these digital stories occur as well as the interrelation and co-evolution of the digital stories authors who are the learning agents. Using the metaphor of chess school, we can state that the subject of the learning design is not just the playing board upon which a single game is being performed but also the whole network of relations which is formed “around the board” between the participants of the collaborative activity.

The MediaWiki environment in which the modern collaborative activity is carried out allows us to follow the links which occur between the agents and objects of activity. As a rule, modern socio-technical systems in which the collaborative activity is carried out, store the full history of all activities. In general terms, this history can be presented as a record of a chess or go game, consisting of many moves. Each move in the socio-educational project as a game contains three required elements:

Agent ID| Object ID| Type of an action (Writing, Editing, Voting)|

Every action of an agent towards an object leads to the formation of a link between them. If the agents perform action over one and the same object they become agents of the collaborative activity, indirectly linked with one another by the mutual object of activity. The collaborative activity network could be presented as the bipartite graph combining agents with objects of collaborative activity.

There is a variety of software tools that has been developed to support analysis of network structures. In our work, we have chosen a tool that allows us to easily identify the stable patterns in the field of collaborative work, as well as to track and analyze the dynamics of sociograms, to select the participants among stable patterns for their targeted management.

Our first learning analytics application is based on Graphviz - open source graph visualization software. Graph visualization is a way of representing structural information as diagrams of abstract graphs and networks. The Graphviz layout programs take descriptions of graphs in a simple text language, and build diagrams in useful formats. The use of GraphViz diagrams allows us to conduct express analysis of the position at the field of the collaborative network activity.

We have created a simple application for social network analysis that help to detect and visualize cliques of densely connected articles and editors in wiki - Collaboration Diagram or WikiGram - https://www.mediawiki.org/wiki/Extension:Collaboration_Diagram

The use of wikigrams allows us to conduct express analysis of the position at the field of the collaborative network activity, to determine the key units of the position – authors and articles, with which the majority of other units are linked, to evaluate the stability of a community according to the number of authors involved into collaborative editing of the collaborative pages.

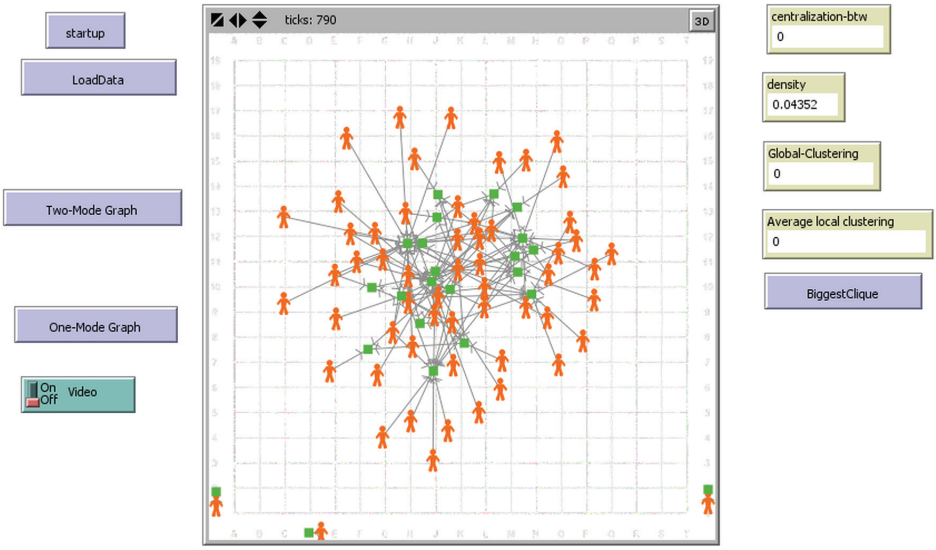
On the basis of this application we have developed the technique of the discussion of collaboration. With this application we have identified the typical configurations in the field of a collaborative work (single, paired figures, small groups, cliques, clusters, giant components, binder key players).

Our second learning analytics application was implemented in NetLogo language 5.2 and its source code is available on the Internet as Dynamic Wikigram Model http://modelingcommons.org/browse/one_model/4769

The use of NetLogo allowed us to present the collaboration as a dynamic diagram in which each actor can interact with each other tens of thousands of actors. The created model used NetLogo features such as breeds and agentset. Interface of Dynamic Wikigram Model presented in Figure 2.

Details of methodology, technology and a range of applications are best illustrated for the purposes of this chapter by a brief example as presented in the next section.

Figure 2. Interface of dynamic Wikigram model



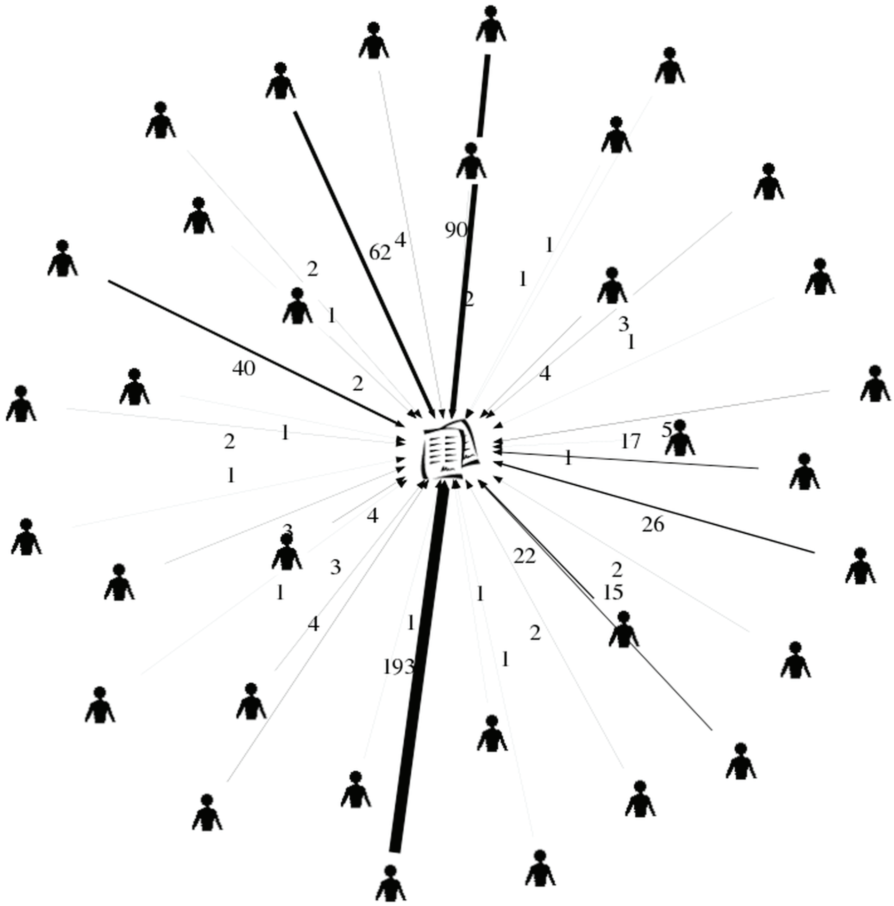
Wikigrams in Action

To illustrate wikigrams reflecting collaborative editing let us have a look at an example of a page and a category. Each page among working tabs has a wikigram tab. By clicking this tab a user opens a special page where Graphviz creates a bipartite graph – wikigram (Figure 3). The participants are shown as little figures and pages image represents an internet wiki page. The diagram is interactive, and you see the name of an author or a page when mouse on image on the diagram. If you click on the images, a relevant page for the author or the article opens.

Graphviz interprets the program, the code of which is placed under the diagram. The first lines determine the layout of a wikigram. Those lines with an arrow symbol –> are interpreted as links between units.

```
<graphviz>
digraph W {
layout = "neato";
node[fontsize="10", fontcolor="blue", nodesep=2, shape="none",
style=""] ;
edge [arrowhead=normal, arrowsize=0.4,len=2.5];
node [URL="/index.php?title=\N"] ;
"User:T Pirog" [tooltip="T Pirog"] ;
"User:T Pirog" [label ="", image="/CollaborationDiagram/user_
```

Figure 3. WikiGram of page




```
icon.png” ];
“UbiPlace” [image=”/CollaborationDiagram/article_icon.png”
tooltip=”UbiPlace” label=””];
“User:T Pirog” -> “UbiPlace” [ penwidth=1.18 label=4] ;
“User:Aygun Azizova A.” -> “UbiPlace” [ penwidth=1.47 label=5]
;
“User:Ljudmilla Rozhdestvenskaja” -> “UbiPlace” [ penwidth=0.30
label=1] ;
</graphviz>
```

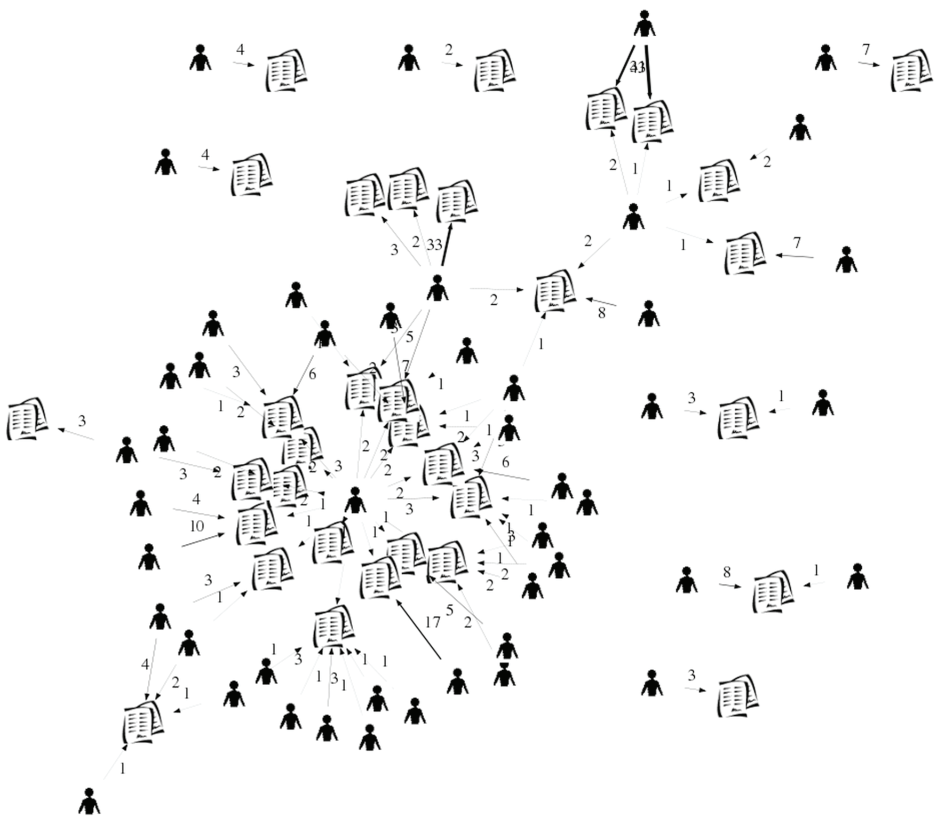
A wikigram is automatically built not only for a separate page, but for groups of pages under one category.

Categories, a software feature of MediaWiki, provide automatic indexes that are useful as tables of contents. You can categorize pages and files by adding one or more Category tags to the content text. These tags create links at the bottom of the page that take you to the list of all pages in that category.

As a rule, co-editors unite under one category those pages which are their collaborative work within one project. Thus, a category wikigram reflects interaction within a creative project (Figure 4).

Any participant can take graphs initial text and use it for personal experiments on a separate designated page. Available actions are:

Figure 4. Category wikigram



- Trying different layouts (neato, circo, sfdp, fdp) and choosing an optimal one for showing links between units in a way when links are not crossed. For example, layout = “circo”
- Changing diagram size for smaller or bigger to make objects clearly visible on a screen. For example, size=”10,10”
- Setting sizes for edges and arrows. For example, edge [arrowhead = normal, arrowsize = 0.4, len = 1.5]
- Changing other parameters – permit or forbid unit overlap. For example, overlap = false.

A more complicated and interesting task is connected with deletion of some units or breaking a graph into clusters. A researcher can visually identify a unit with the highest central concentration, and then delete all the lines bearing it in a word processor. The following figures show the example of such task. Complete project wikigram is shown in Figure 5. A key actor is in the center of the wikigram.

Figure 5. Complete project wikigram

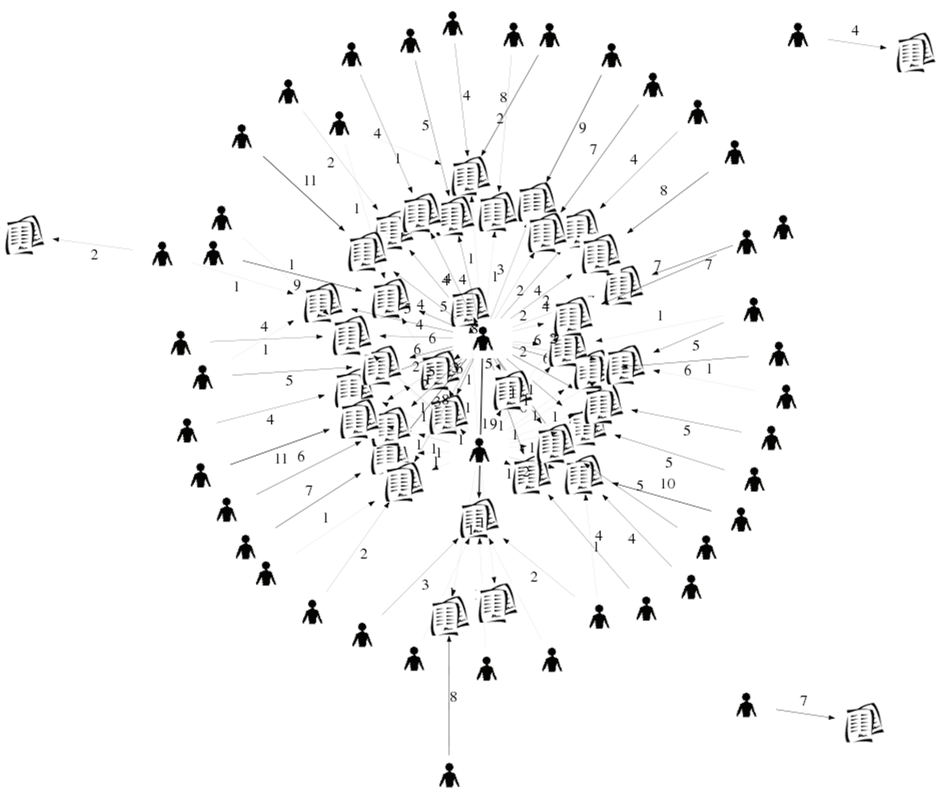
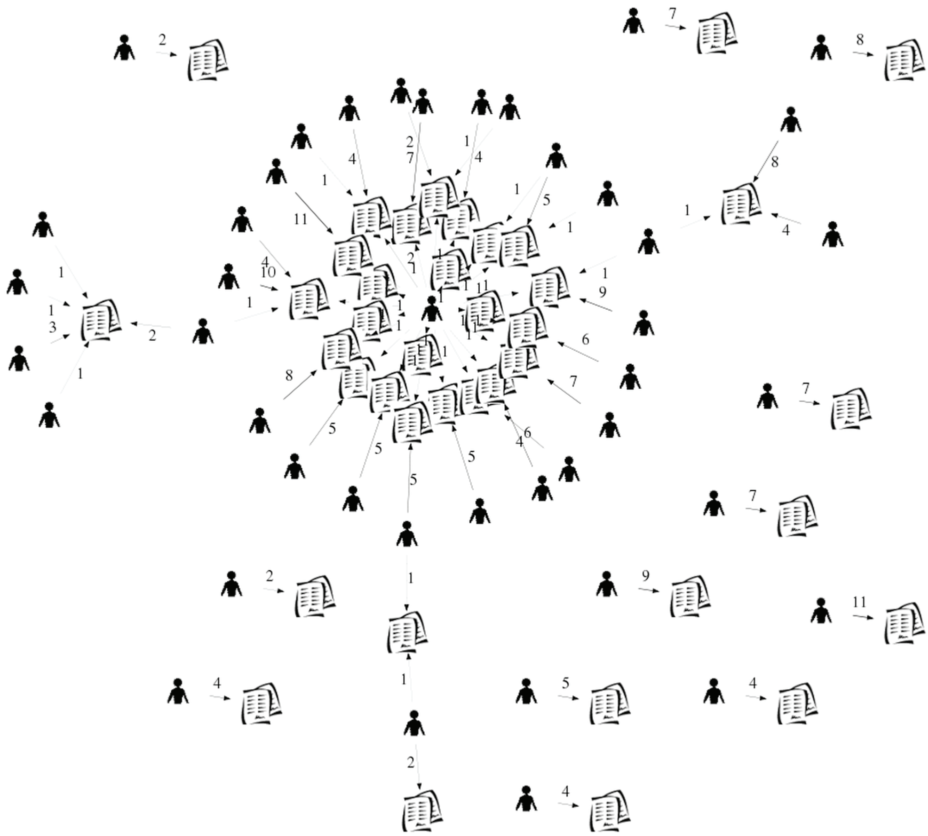


Figure 6. Wikigram after removal of a key actor



After removing from the graph all the rows, which mentions a key actor, the wikigram is transformed to the following form (Figure 6).

The next possible task is connected with the comparison and evaluation of wikigrams of different categories. To make it easier for teachers and students to compare and evaluate wikigrams we have created evaluation criteria shown in Table 1.

Dynamic Wikigram Model can be used as a simple and illustrative tool of analysis. During his/her research, a student uses the technique of dynamic agent-based sociograms to:

- Trace how and based on what objects' links between participants of collaborative production activity are formed.
- Identify key players and stable biggest cliques, which serve as cores that support the operation of network communities.

Table 1. Wikigram evaluation criteria

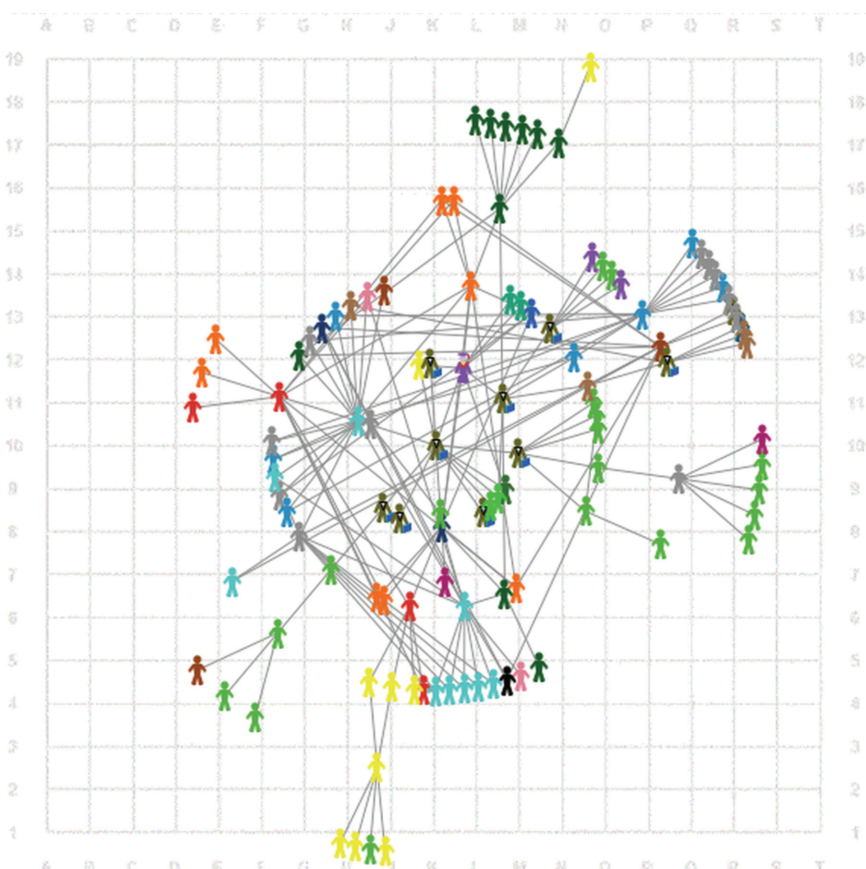
Criterion	High level	Medium level	Low level
Productivitya	A wikigram contains a variety of objects created by participants.	Participants have created digital objects. The number of objects is approximately equal to the number of participants.	In the project very few digital objects have been created. The number of objects is much fewer than the number of participants.
Action frequency	A graph shows that objects have been modified frequently (more than 5 times) by authors and editors	Some objects have been enhanced by the authors and other participants 3-4 times.	Objects created by participants have never been altered since being created and published in the system.
Connectedness	All actors and objects are connected in one graph.	Participants and objects are connected into small groups of components (3-4).	The graph of the project is broken into a number of non-connected components.
Cohesion	A wikigram depicts one cohesive clique, in which all the participants are connected to each other via pages.	Participants form several small groups.	There are no groups on the wikigram which proves lack of interaction.
Stability	A wikigram shows several key players, whose linking provides stability for collaboration.	A wikigram contains 2-3 main players, whose removal will lead to breaking the net into separate components.	A wikigram has one key player in charge of all informational processes. Removal of this unit terminates the net.

Key players are those elements in the network that are considered important, in regard to certain criteria. One of the most popular criteria is the betweenness centrality of vertex. The betweenness of an edge is the number of these paths running through it. It is clear that, when a graph is made of tightly bound clusters, loosely interconnected, all shortest paths between nodes in different clusters have to go through the few interclusters connections, which therefore have a large betweenness value. A node with high betweenness centrality is responsible for connecting many pairs of nodes via the best path, and deleting that node should cause many pairs of nodes to be more distinctly. The idea behind betweenness centrality is that being in between actors makes actor powerful because he may be able to control the flow of information between them (Borgatti, 2006). Nodes with high betweenness centrality are often called key-players. To calculate the betweenness centrality of a Netlogo turtle, you take every other possible pairs of turtles and, for each pair, you calculate the proportion of shortest paths between members of the pair that passes through the current turtle. The betweeness centrality of a turtle is the sum of these. Top ten key players are determined in NetLogo as

```
sublist reverse sort-one [norm-betweenness] users 0                    9
```

Key players are important in themselves and as nodes that connect communities. Qualitatively, a community is defined as a subset of nodes within the graph such that connections between the nodes are denser than connections with the rest of the network (Radicchi, Castellano, Cecconi, Loreto, & Parisi, 2004). The detection of the community structure in a network is generally intended as a procedure for mapping the network into a tree. For the divisive class of algorithms one starts with the whole graph and iteratively cuts the edges. The crucial point in a divisive algorithm is the selection of the edges to be cut. Girvan and Newman have introduced an "edge betweenness algorithm" where the selection of the edges to be cut is based on the

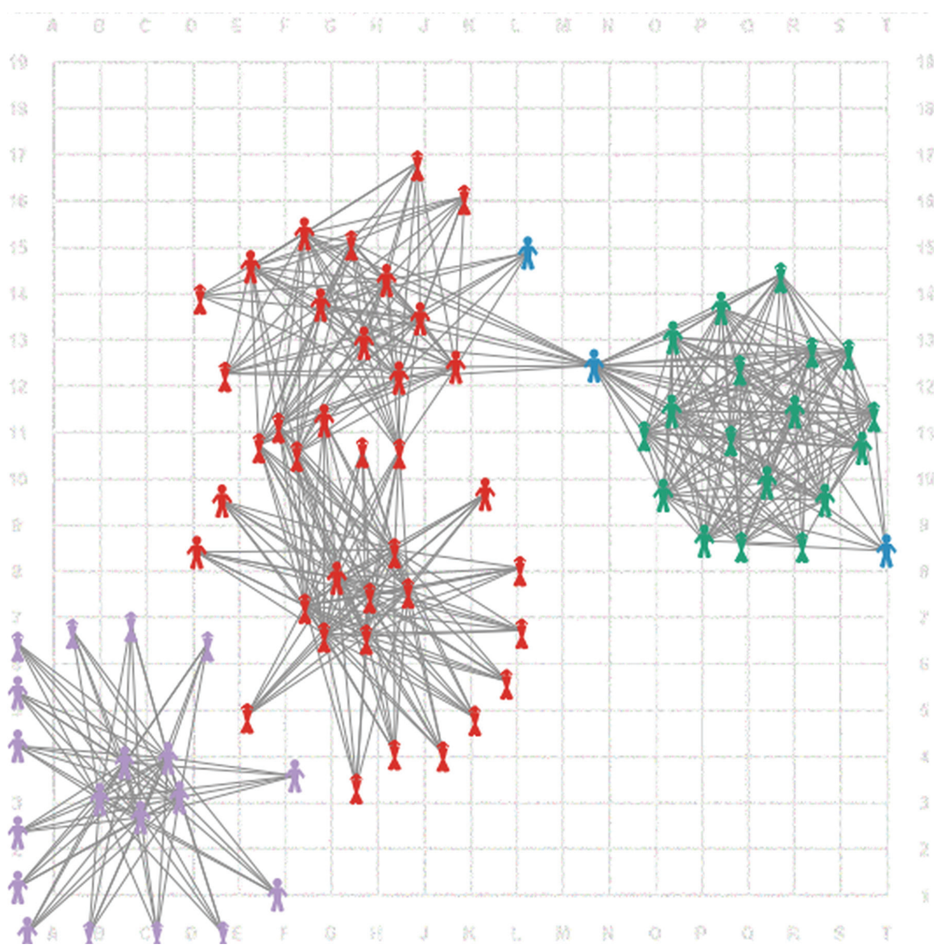
Figure 7. Wikigram with key player in the center



value of their edge betweenness centrality (Girvan & Newman, 2002). The single step of the edge betweenness algorithm consists in the computation of the edge betweenness for all edges in the graph and in the removal of those key players with the highest score. The iteration of this procedure leads to the splitting of the network into disconnected subgraphs, until the whole graph is divided in a set of isolated nodes. At each step of the edge betweenness algorithm NetLogo model created the sociogram, which was used to discuss the role of a key players (Figure 7).

A clique is a subset of a network in which every node has a direct link to every other node. A maximal clique is a clique that is not itself contained in a bigger clique. Cliques containing more than N members are determined in NetLogo as

Figure 8. Wikigram of maximal cliques



nw:maximal-cliques [if (count ?) > N

FUTURE RESEARCH DIRECTIONS

The projected system of the collaborative network activity gives extra possibilities not only for the productive activity but also for the analysis and reflection on the processes inside the system. The tools should open the possibility to assess from the network point of view both the position of each participant and the degree of the whole system development as the learning network. The analysis of the activity of each participant inside the acting community combined by mutual story or mutual game, allows us linking the act of activity and the development of one participant with the development of the whole community.

The point of the co-creative projects is not only the created product of the project, but also the social structure itself. The value is in the creation process of this social structure during collaborative work and the formation history of this structure. Usually the social structure and the history of its formation are hidden for the participants. In best cases the subject for participants' discussion is the number of created objects and the number of comments and ratings. Meanwhile a social structure is a significant characteristic in many respects determining the success of collaboration. We believe that visualization of the social structure can support the process of group reflection.

Reflexivity is defined as "the extent to which group members overtly reflect upon the group's objectives, strategies, and processes, and adapt them to current or anticipated endogenous or environmental circumstances" (West, 1996, p. 559). West distinguished between task reflexivity and social reflexivity. In teams, high in social reflexivity, team members often reflect and deal effectively with collaboration problems, and thus display a good quality of relationships and friendly attitudes. Social reflexivity is associated with the social functioning part of a team, deals with interpersonal relation, strengthens collaboration among team members, and therefore leads to better performance (Carter & West, 1998). While various studies have found that social reflexivity has significant positive relationship with team outcomes (Gurtner, Tschan, Semmer, & Nägele, 2007; Schippers, Den Hartog, & Koopman, 2007), little is known regarding the mechanisms underlying group social reflexivity in network collaborative projects. We start from the hypothesis that social reflection can be triggered by sociograms.

It's possible to use the approach and the applications described in this chapter not only inside Wiki or in learners' research activity, but for a wider field of productive activity to form productive agency. Productive agency formation isn't limited by learning or research communities where students work over project creation of simply educational value. This field of productive agency formation includes socio-pedagogical projects where citizens interact with each other, and artifacts are the documents influencing educational policies.

We have successfully used NetLogo wikigram application to support several socio-educational projects, where the number of participants was several thousand people.

CONCLUSION

Inquiry-based learning is most often connected with supervision and modeling of interaction within real flocks, swarms, anthills or termite nests. Digital technology development is now opening the door to research what Foucault defined as "a cet immense fourmillement de traces verbales" (vast swarm of verbal traces) (Foucault, 1969, p. 35). This being said, verbal traces, which turn into the subject of analysis, appear over the course of production of digital stories. The network of relationships between wiki pages collaborative editors is mapped in the same way as the network of relationships between dolphins, ants and termites. This does not mean that we suggest that our students study the process of creating digital stories in the same way as they would study building an ant-hill or a termitary. But we draw their attention that their own collaboration in creating digital stories is based on the same systemic rules as in forming flocks, building ant-hills or termite nests.

Do we really want to think of students as ants, each following the same simple rules in an almost mindless fashion? Certainly not. Students in a classroom are, of course, much different than ants in a colony—or roots on a walking tree. But in all of these cases, the behaviors of the overall system arise, often in unexpected ways, from interactions among the parts of the system. (Resnick, 2003, p.58)

We attract students' attention to the network science in the field of their own activity. In this field, they are the actors between whom digital stories edited pages mediated connections emerge. As a result, we get to unite the cycles of productive and research activities within one social network. The simple application for social network analysis described in this work is an experimental step to form a culture of open network research. The method of defining and visualizing the group participants, connected by editing the same articles, allows us to observe the groups connected by editing wiki-pages without leaving the wiki-media. The application and analysis methods under consideration serve as guidelines and can be used as invitation to conduct research. We have offered a methodology of wikigram demonstration on a gameboard with an alphabetical and numerical notation, which allows users to have discussions and analyze quality data on groups of participants of wiki-projects. Real cases analysis shows that the technology and methodology of wikigrams allows users to analyze and discuss situations which occur over the course of collaborative network activity.

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KEY TERMS AND DEFINITIONS

Clique: A subset of a network in which every node has a direct link to every other node.

GraphViz: An open source graph visualization software.

Key Players: Those elements in the network that are considered important, in regard to certain criteria.

Learning Analytic: A collection of methods that allow learners to understand what is going on in a learning scenario.

Log-File: A file of the transactions between a system and the users of that system.

MediaWiki: The most popular of wiki engines, which is also used to run Wikipedia.

NetLogo: A multi-agent programmable modeling environment.

Network Science: An emerging, highly interdisciplinary research area that deals with theoretical and practical approaches and techniques of analysis, synthesis and behavior of natural and man-made networks.

Network Analysis: An empirical method to study the ties between actors in the network.

Sociogram: A powerful analysis tool that provides researchers with the ability to identify specific points of interest and other structural properties.

Wiki: The simplest online database that could possibly work.