Epistemic Network Analysis of an International Digital Makerspace in Africa, Europe, and the US

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Abstract

A digital makerspace community of fifteen clubs in Kenya, Finland, Namibia, and the United States involves participants, ages 10-19, who create videos and other digital artifacts to teach their peers science and mathematics. Each artifact represents a collaboration of participants from different countries. This paper reports on research on participants' socio-affective and academic development as they collaborate across cultural, economic, and international boundaries. Epistemic network analysis (ENA) is used to depict important malleable variables – and the relationships between those variables - such as self-efficacy, personal identity, confidence, awareness of others, and self-awareness. Our study demonstrates the efficacy of ENA to model and understand the salient aspects of international collaboration in digital maker spaces.

This study originates from an overarching conjecture that collaborations that cut across international, generational, cultural, and economic boundaries may have high potential at the individual level for promoting mutually reinforcing academic and affective growth in the collaborating students.

This project involves research on an international digital makerspace known as *International Community for Collaborative Content Creation* (IC4) shared by a network of fifteen elementary, middle and secondary school clubs in Namibia, Finland, Kenya, and the United States. The IC4 Media-Maker Clubs focus on cognitive, affective and social processes involved in creating digital media, building on work supported by both the State Department's Fulbright program and the US National Science Foundation (NSF). Our research group has observed profound changes in scientific and mathematical cognition and human creativity when individuals develop digital media representations science and math with the intent to impart knowledge and to teach others. These changes become even more consequential when students create digital media in collaboration with other students and with teachers. For example, *cross-generational dynamics* flourish when teachers and students plan and then co-create digital media such as videos, games, apps, and ebooks. These dynamics include altered perceptions of self-efficacy, personal identity, awareness of others, and self-awareness. Observation of these dynamics has led to the construct of participatory teaching. It has also led to broader attention to the value of help-giving in enriching neural connections and affective well-being while learning academic subject matter. Additionally, *intercultural dynamics* in pilot settings flourish when teachers and students

plan and co-create digital media with counterparts in other countries over the internet or wirelessly.

The current research involves two methodological advances. One is the development of a new inventory for observing change in intercultural competency among adolescents over international virtual collaborations, a construct surprisingly undeveloped in the assessment literature.

The second advance is the subject of this paper. It involves the adaptation and use of an important new tool in quantitative ethnography called Epistemic Network Analysis (ENA). ENA (Shaffer, 2017) is a method used to identify meaningful and quantifiable patterns in discourse or reasoning. ENA moves beyond the traditional frequency-based assessments by examining the structure of the co-occurrence, or connections in coded data. Moreover, compared to other methodological approaches, e.g., sequential analysis (see in Cress & Hesse, 2013), ENA has the novelty of (1) modeling whole networks of connections and (2) affording both quantitative and qualitative comparisons between different network models.

We examined the explanations provided by sixteen different exemplar IC4 club members. A thematic analysis found eight of the students' explanations focused on *Awareness of the perspective of peers and teachers*. This group of eight students will be referred to as the "Perspective group" throughout the rest of the paper. The other eight learners' explanations focused on *Increases in learners' confidence.* We will refer to this second group as the "Confidence group."

In order to understand the structure and texture of the differences between the themes represented in both groups, we used ENA to model the connections, or relationships, between constructs related to cognitive, affective, and social processes involved in creating digital media. These constructs include: Identity, Self-efficacy, Self-Awareness, Help-giving, Content confidence, Ability to see the perspective of others, Flow – High engagement, Motivation, Scientific rigor/stability/understanding interconnections in learner's conceptual models, Representational competence, Collaborative Dispositions, Cross-cultural disposition, Cross-generational disposition, Self-directed learning and knowledge acquisition, and Technical competencies.

However, in order to demonstrate the use of ENA in our context, we chose to hone in on a subset of these constructs to make the introduction of this method easier to comprehend. Our results mainly focus on the connections, between the five constructs of Ability to see the perspective of others, Content confidence, Identity, Self-Awareness, and Self-efficacy, which are explained in more detail in our code book (see Table 1).

A main theoretical assumption of ENA is that repeated connections between of two or more constructs reveal epistemic networks which characterize an underlying Discourse (Gee, 1999; Collier et al., 2016), e.g., in learners' descriptions of their motivation for participating the IC4 clubs. Here we aim to determine if ENA can reveal some characteristics of the differences between learners in the Perspective group versus those in the Confidence group. Furthermore, ENA provides the opportunity to quantitatively and qualitatively compare different epistemic network models with each other. Quantitative comparison is possible by using calculated centroids for every epistemic network generated by ENA. Such centroid values are determined

by the strength of connections between nodes in the epistemic network. Nodes are the constructs, while the strength of connections between them are generated based on their co-occurrences. These centroid values correlate and correspond with the plotted points which can be used for quantitative analyses. Furthermore, qualitative comparison of epistemic networks is possible using various options for visualization. One option is "subtracting networks," which means contrasting two network models by subtracting their nodes and connections weights from each other to create a *difference network graph*. The resulting difference network graph represents the difference between two discourse networks and therefore, can illustrate what makes discourse of one group of different from another.

Beyond comparing the networks of the two groups based on a subset of the constructs we are ultimately interested in, we created one network for both groups that contains the connections between all of our constructs of interest to illustrate the complex nature of the connections between the constructs related to participation in IC4 clubs.

Results

Figure 1 shows the plotted points which correspond to individual learners' construct network. The points for learners in the Perspective group are in red and the points for learners in the Confidence group are in blue. The squares are the means of the points and the boxes around the squares are 95% confidence intervals. There is a statistically significant difference between the location of the mean of the plotted points for the Perspective group compared to the Confidence group along the x-axis of the ENA space, $t(14)= 5.13, p < 0.001$ (See Table 2). To understand what these statistically significant differences mean we must consider their corresponding networks (see Figures 2, 3, and 4) and the qualitative data itself.

Figure 2 shows the mean ENA network for the Perspective group in red. Figure 3 shows the mean network for the Confidence group in blue. Figure 4 shows the subtraction, or difference network, where the network is red, the Perspective group made stronger connections, where the network is blue, the confidence group made stronger connections. The thicker the lines and stronger the color, the greater the difference. These networks allow us to interpret the statistically significant difference between the mean discourse networks of the groups.

We can interpret the ENA space based on the layout of the nodes (constructs) in the network. By examining Figures 2, 3, and 4 we can see that networks that are more weighted to the left, based on the weight of the edges (lines) will have the strongest connections between Ability to see the perspective of others and other constructs. In contrast networks that are more weighted to the right have the strongest connections between Content confidence and other constructs. As a result, the plotted points that are further to the left correspond to networks that have the strongest connections to Ability to see the perspective of others and plotted points further to the right correspond to networks which have the strongest connections to Content confidence. Therefore, we can interpret the position of the plotted points in terms of their position on the x-axis as the Ability to see the perspective of others vs Content confidence axis. This gives us one way of interpreting the meaning of the statistically significant difference between the two groups represented in Table 2 and Figure 1.

Examination of Figure 4 shows that the connections between the construct Ability to see the perspective of others and all other constructs is stronger for the Perspective group, particularly between Ability to see perspectives of others and Identity, as well as Self-awareness. In contrast, the connections between Content Confidence and Self-awareness, Identity, and Self-Efficacy are all stronger in the Confidence group. These differences are driving the statistically significant difference along the Ability to see the perspective of other vs Content confidence axis (x-axis) we observed in the means of the plotted ENA points for the groups.

Figure 5 shows the mean network for all individuals in both groups using all the constructs we are interested in relation to participation in IC4 clubs. Here we can see that the strongest connection is between Identity and Self-awareness. The network is complex with connections occurring between all fourteen constructs in a variety of patterns.

Discussion

ENA allows us to measure and discriminate readily between the two groups based on the connections between constructs. Specifically, we can *see* how participation in the clubs impacts learners' self-perception in terms of how they relate to other and what they are capable of doing.

This analysis differentiated between the two groups showing that one group mainly explained their participation in terms of appreciating the perspective of others and how that related to how they understood themselves. In contrast, the other group's explanations focused on their confidence with in STEM and how that related to their self-understanding. We do not need to claim that either of these types of explanation is better than the other, but simply that ENA helps us measure and understand different constellations of constructs as they relate to participation in the international maker space cultivated in IC4 clubs.

We have built generations of tacit and explicit knowledge about the experience of students whose educational setting involves sitting at desks, exposed to commercially published curriculum by which they are judged in the form of standardized tests. Until recently, these settings provided no digital affordances, and where international connections form no more than a miniscule percentage or a single percentage of experience, if at all. The body of knowledge about these traditional learning settings has an enormous gravitational force that resists new ways of learning and communication. In fact, of course, learning environments of the future will take us further and further from those traditional settings. This particular research is one such ecosystem. It involves long-term virtual collaboration across international, cultural and economic boundaries among adolescents. It explores not only international collaboration, but student-generated rather than published commercial content, inventiveness in media-making, an ethos of help-giving by which students take stock of their own success in part by the success they help their peers achieve, a blend of multiple digital tools and communication modalities, and versatile intercultural competencies. The IC4 network is one example of an approach that differs from traditional settings in ways that involve virtually every aspect of a student's academic, emotional, and social growth. Such future learning environments will require researchers and policy makers to re-chart their understandings of the spectrum of student experience and collaboration. Epistemic network analysis, increasingly adopted as a methodology in other research settings, appears to be proving valuable in helping to create visual maps not only the

constructs that will come into greater play in future learning environments, but the complex relationships between those constructs. Such analyses can be applied at both the individual level and group level for exploring other complexity represented in the mean ENA network for all learners with all constructs (see Figure 5). As such we advocate for it's further adoption and development.

References

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Gee, J. P. (1999). An introduction to discourse analysis: Theory and practice. *London & New York: Routledge*.

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Tables and Figures

Table 1.

Construct	Definition	Example
Ability to see the perspective of others	Statements that convey an understanding of the view point of other individuals	As a student, what surprised me the most from this experience was that **I got to see the point of view from my teacher** on how they teach us, the students.
Content confidence	Statements which express and ability in a particular area of study or domain.	I have gained a better work ethic. This **experience has given me the confidence to take on calculus.**
Identity	Statements about how an individual perceives themselves, particularly in relation to others.	The way I see it, it's like a flip and switch situation he's the teacher and **I'm the student**...and then one time he'll be the student and **I'll be the teacher cause I get to teach him about things that he helped teach me**.
Self-Awareness	Expressions of self-perception	**I notice that I can see how other students are thinking** about these math concepts when I give them feedback.
Self-Efficacy	Expressions of belief in one's own abilities.	And, itÍs really great, just working with a teacher, to know that wow, like **I am working with my teacher to improve this class and this subject**.

Table 2. Comparison of plotted points between the Perspective group and the Confidence group, $p < 0.001$, $t = 5.13$.

	N	*Mean*	*SD*
Perspective group	8	-0.420	0.251
Confidence group	8	0.332	0.261

Figure 1. Plotted points – Perspective group red, Confidence group blue.

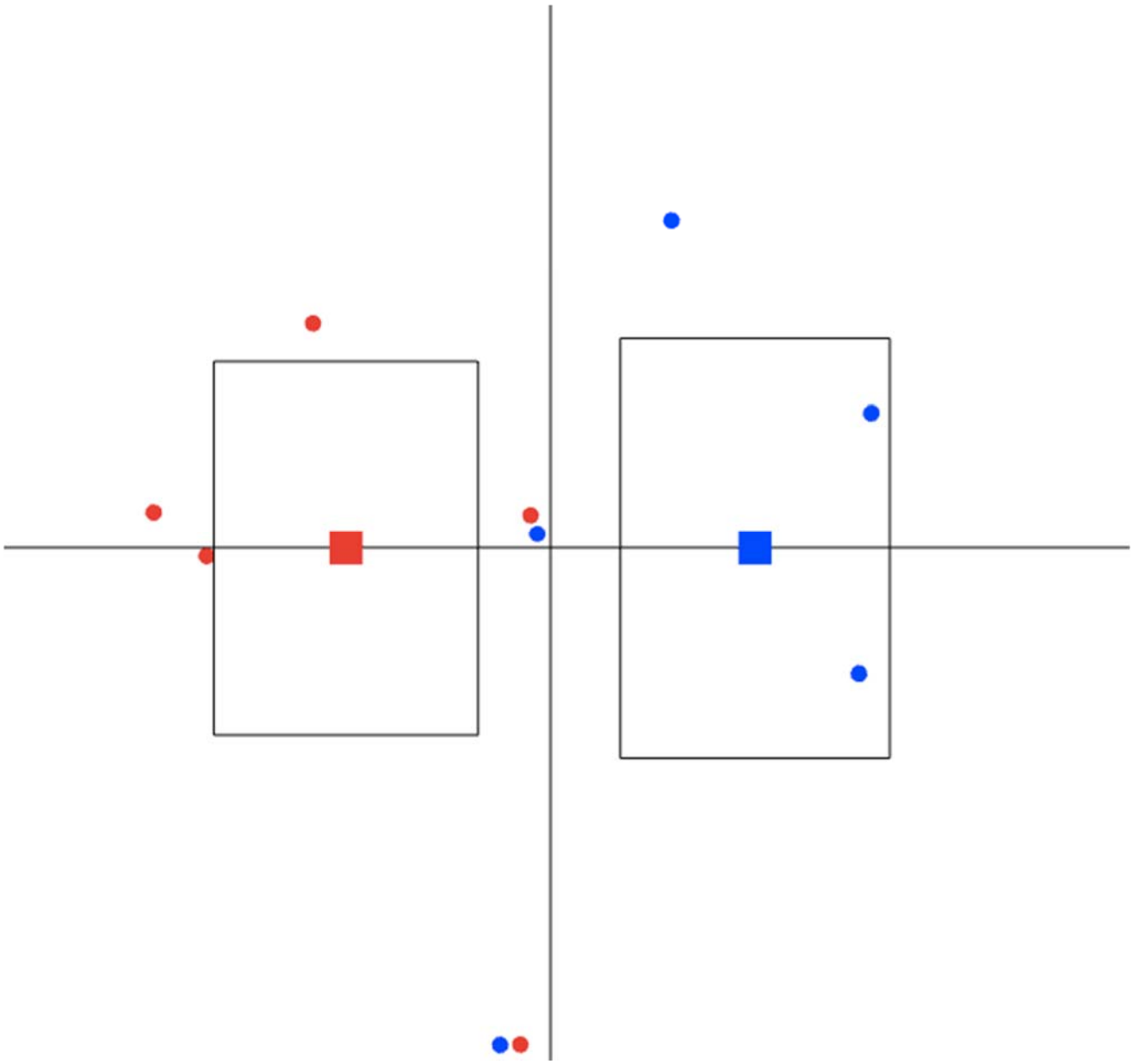

Figure 2. Mean ENA network for the Perspective group.

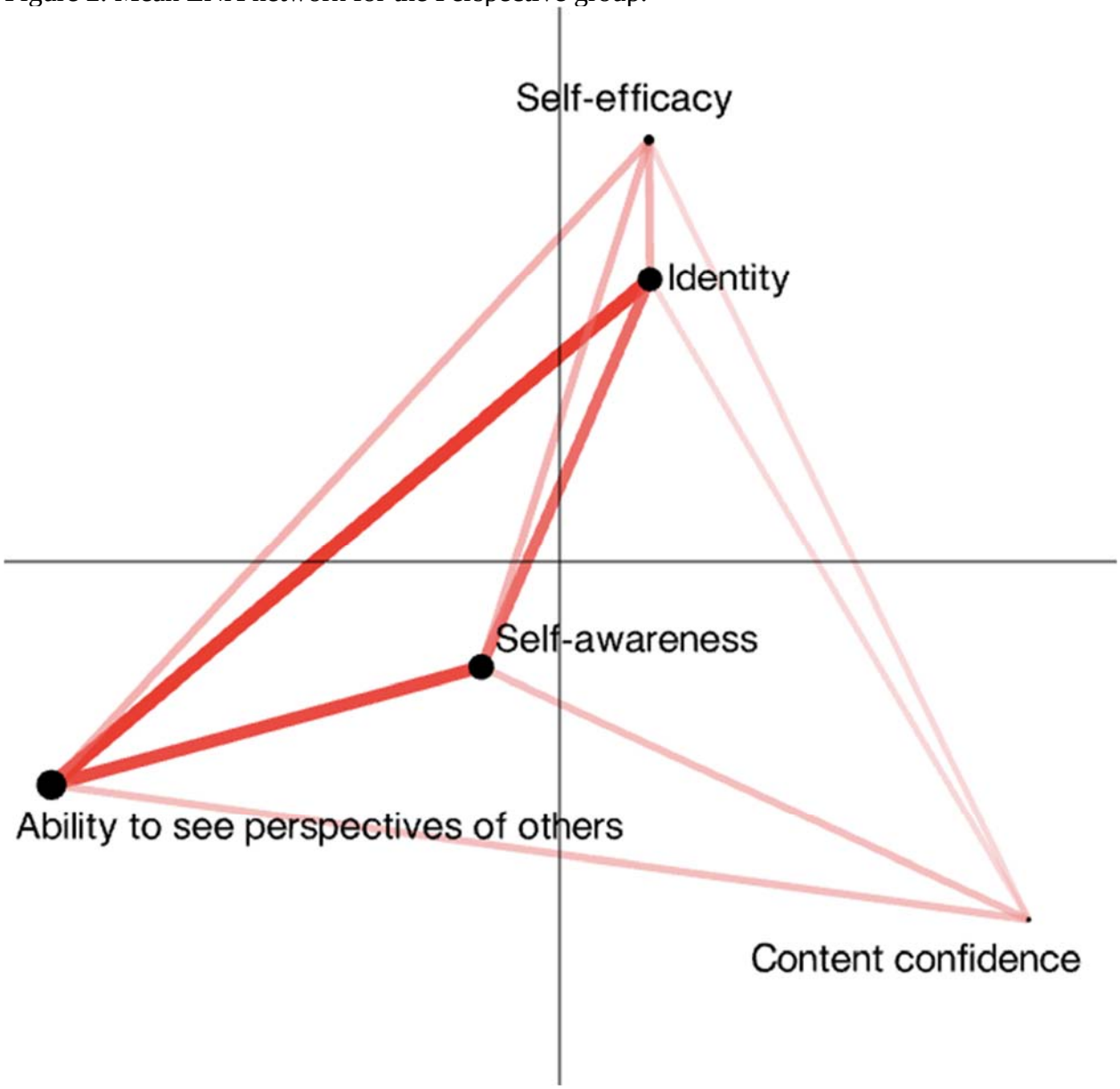

Figure 3. Mean ENA network for the Confidence group.

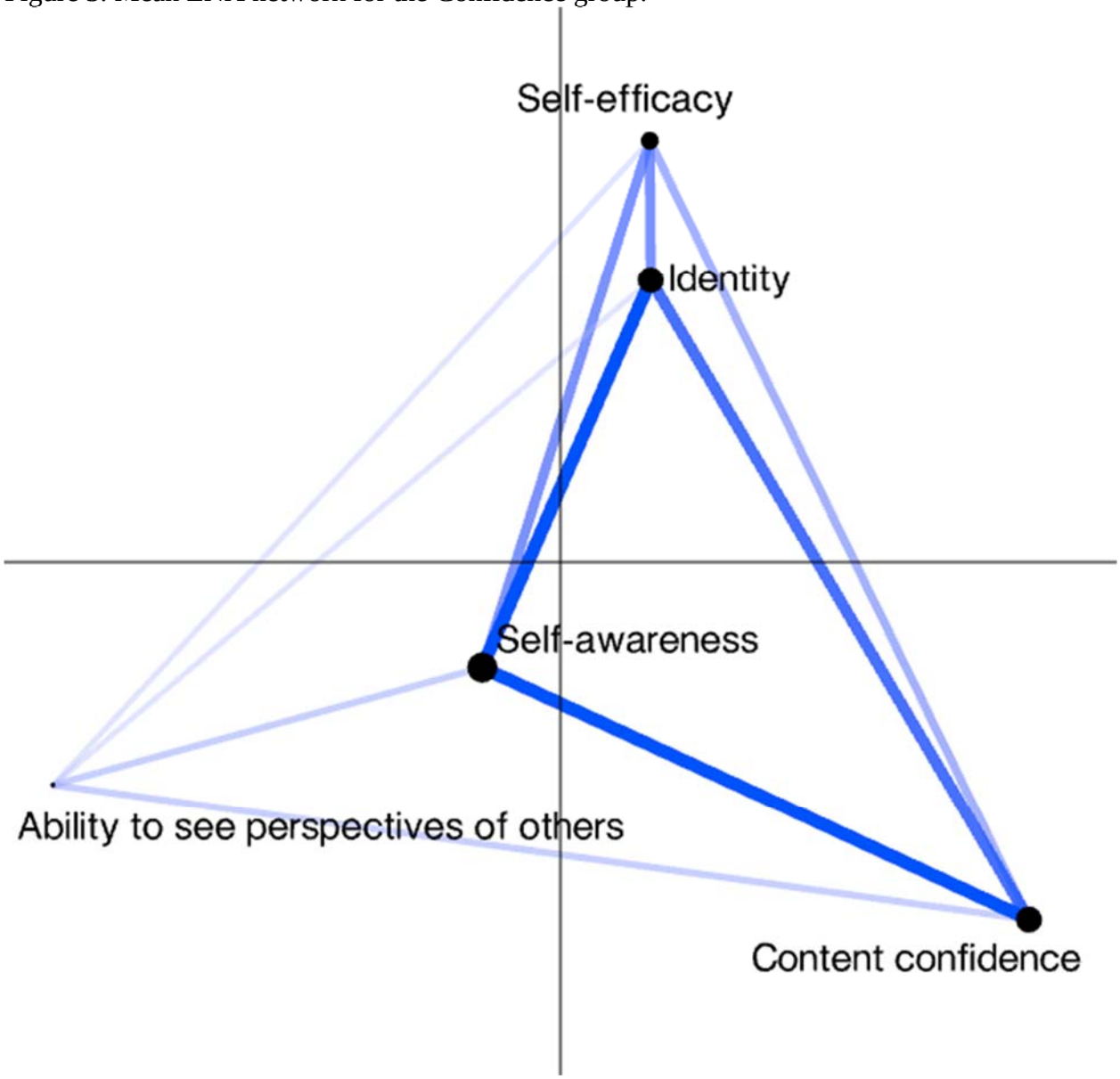

Figure 4. Difference ENA network – Perspectives group red, Confidence group blue.

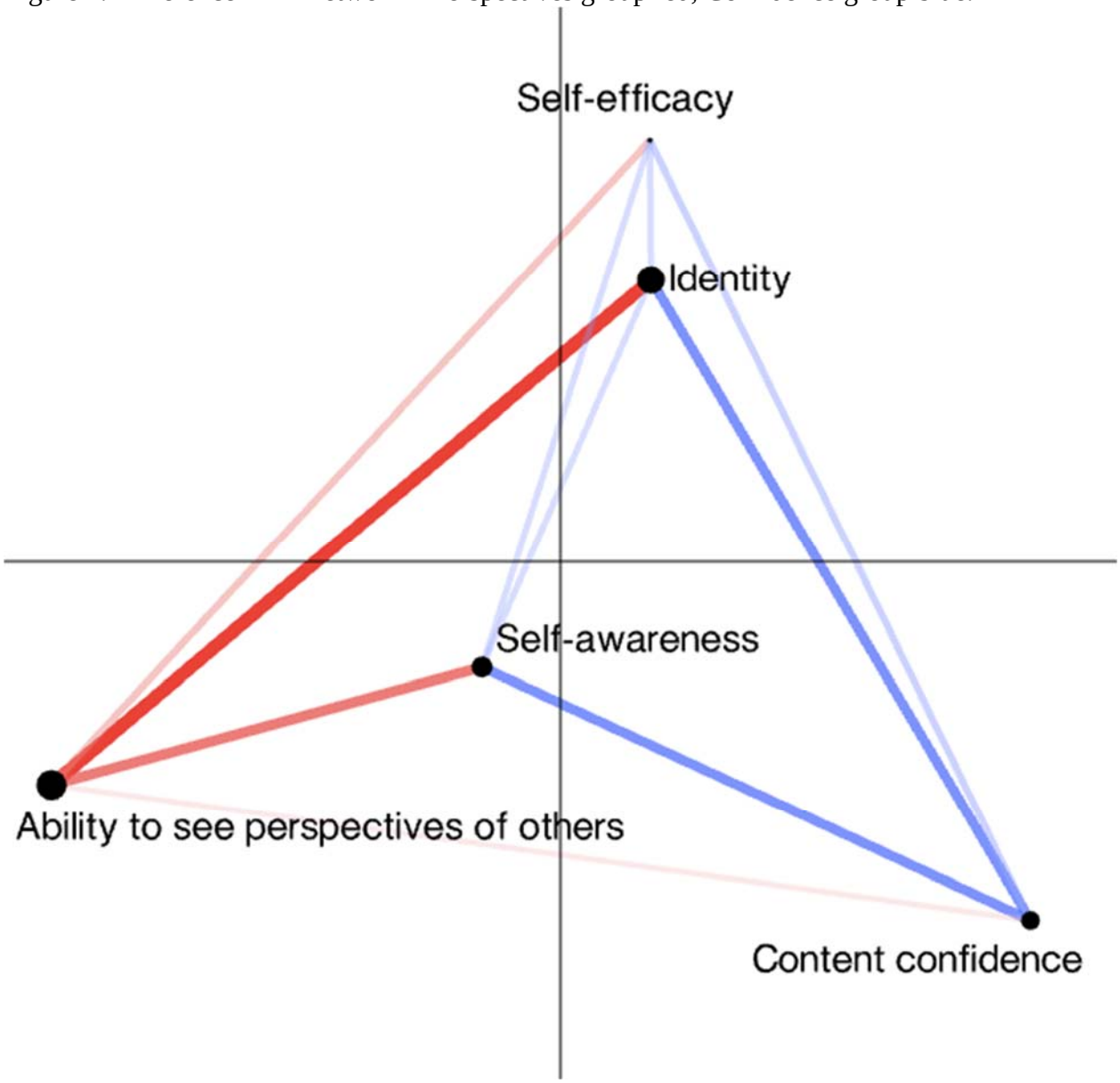

Figure 5. Mean ENA network for all learners with all constructs of interest.