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Theoretical and Practical Framework for a Multinational, Precollege, Peer Teaching Collaborative

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Abstract: This paper discusses a formal peer teaching collaborative network of middle and secondary school students designing and prototyping science, technology, engineering, and mathematics (STEM) projects that they share in synchronous virtual settings and asynchronous settings. Funded primarily by the US National Science Foundation, the effort has involved students from five continents. The aims of the collaborative, called the International Community for Collaborative Content Creation, or IC4, include fostering STEM skills and intercultural competence. The practical framework for IC4 is replicable. It aligns closely with theorizing around intercultural competence formation. The practical framework relies on interest-driven creator theory as a confirmatory guide for formulation of the projects that students undertake. The theoretical framework involves the construct of participatory teaching and involves quantitative ethnography, a methodology that relies on techniques from social network analysis and from discourse analytics to create visual and statistical models for phenomena traditionally expressed through case study. The paper includes discussion of how activity theory provides an important descriptive tool for explaining how collaboratives such as IC4 mediate the formation of academic and intercultural competencies.

Keywords: Quantitative ethnography, discourse analysis, computer-supported collaborative learning, ICT policy, global competencies, intercultural competence, virtual communication, activity theory, interest-driven creator theory

1. Introduction

This paper discusses a peer teaching collaborative that organizes teams of 12-19 year-old students who create and share science, technology, engineering, and mathematics (STEM) projects in synchronous virtual settings and asynchronous settings. Funded primarily by the US National Science Foundation, the effort has involved students from five continents. Aims of the collaborative, called the International Community for Collaborative Content Creation (IC4), include fostering STEM skills and intercultural competence. The practical framework for IC4 is replicable and tracks well with theorizing around recognized patterns in intercultural competence formation (Deardorff, 2006; Ramirez R, 2016). The practical framework relies on interest-driven creator theory (Chan et al., 2018) as a confirmatory guide for formulation of the projects that students undertake.

The theoretical framework involves the construct of participatory teaching as a means for adolescents to take on responsibility for learning about and then teaching STEM content to peers and to school teachers. The framework applies quantitative ethnography, a methodology that relies on techniques from social network analysis and from discourse analytics to create visual and statistical models for phenomena traditionally expressed through case study (Wooldridge, Carayon, Eagan, & Shaffer, 2018). The paper provides a sample visual model of how students develop collaborative competences. It then segues into a discussion of how activity theory (Greeno, 2016) provides an important descriptive tool for explaining how collaboratives such as IC4 mediate the formation of academic and intercultural competencies (Hamilton & Espino, 2020).

2. International Community for Collaborative Content Creation (IC4)

IC4 began in 2017 as a network of school-based and independent clubs from different countries. It has since included students from Kenya, Namibia, India, Brazil, Finland, the US, Iran, Singapore, the United Arab Emirates, Uzbekistan, Mexico, and Cameroon. The projects around which students collaborate have been conceptualized as *makerspaces*, which are often defined by physicality and by the opportunity they provide learners to manually experiment and construct artefacts that embody social cognition and obligate or spur intellectual growth (Peppler, Halverson, & Kafai, 2016). Among the most prominent makerspace domains are robotics, circuit board experiments, and 3D printing. A subset of the makerspace movement, though, involves digital activities. Among the most popular creative outlets are video making, games, coding, and commercial products such as Minecraft (Ripper and Secondo 2018).

This more expansive view of makerspaces encompasses the past decade's revolution in user-created digital media content. Because it takes place over internationally distributed virtual spaces, IC4 projects primarily (but not exclusively) fall into this subset of the makerspace movement. Students and teachers meet in Zoom videoconference sessions called global meetups, and in asynchronous Slack groups. The interests of participating students drive the selection and formulation of projects. This approach to marshalling the energy and enthusiasm of the participating students reflects the premise of interest-driven creator theory (Chan et al., 2018), which posits that the entrée for learner immersion requires leveraging the learner's motivations and interests, and do so through activities that furnish agency and a way to progress beyond surface-level interest to more sustainable and resilient engagement in that area.

Online global meetups have emerged as a key component in building the IC4 community. The opportunity for visual, synchronous communication both motivated and built social trust among the participants, increasing the depth of interactions with time and experience. As more meetups have taken place, a shared understanding of the culture and behavior at meetups has emerged (Hamilton and Owens 2018). This includes a shared understanding of the roles within the meetups, such as a facilitator that guides the conversation and presenter(s) who share their project. As students develop social trust and comfort in their makerspace culture, they are able to interact more openly across cultural and national boundaries.

Makerspaces provide a rich context not only for innovative student learning experience, but also for uncovering valuable insight for the effective design of future learning environments. Learning environments of the future will include routine and flexible, internet-mediated synchronous and asynchronous project collaboration (Dede 2010). Collaborations around making, or artifact creation in cross-cultural settings, obligate a variety of constructs and practices likely to alter and reshape future conceptions of learning. Among these constructs are three that IC4 emphasizes as an internationally distributed collaboration: social cognition, participatory teaching, and help-giving(Hamilton & Kallunki, 2020) These types of phenomena are likely to emerge in dynamic and highly positive forms in the future.

3. Assessing IC4 Participation through Quantitative Ethnography

From the outset of the IC4 network, it was clear that assessment of student participation would resist traditional approaches. The cross-cultural, age, prior knowledge, internet access, and school context differences each undermined evaluating experience through normative or standardized frameworks associated with academic achievement. The complexity of the challenge does not diminish the reality of academic achievement, but rather the inadequacy of available instruments to model or document achievement. Additionally, overarching interests by the research in fostering cross-cultural competence remain elusive to measure, in part for the same reason (differences across all baseline variables) and in part because the literature on building intercultural competence does not explore the context of adolescents collaborating across international boundaries or cultures through virtual tools (Hamilton & Espino, 2020). Though the pandemic is likely to address that gap, the field of adolescent international collaboration in academic contexts and its impact on intercultural competence has yet to take form.

It was in this context of seeking a means to model or explain IC4 experience and the growth it might stimulate that quantitative ethnography (QE) and the related analytic tool of epistemic network analysis (ENA) emerged as a promising methodology.

3.1 Quantitative Ethnography Operationalized by Discourse Analysis

A core premise of QE is that ethnographic study entails observation of socio-cultural patterns that shape our world, patterns that entail multiple layers of interconnections. Careful observation and articulation of socio-cultural patterns and the interconnections between them – ethnography - is certainly relevant for understanding and building policy and practice around innovation in digital media in learning and education, including changes we sought to foster in the IC4 ecosystem.

One of the most prominent objects of ethnographic observation in such as ecosystem at IC4 is discourse: how people communicate, in oral or written form, for example. Other tools include project artifacts, asynchronous versus synchronous balance, or visual or prosodic cues in conversations. Our focus on written and spoken discourse has allowed entrée to valuable analytic software tools only recently available in social science research. Such discourse tools enable analysis and visualization of large data sets by dint of increasing computational speed and storage. "Big data" discourse analytics provide a previously inaccessible yet powerful way to suggest, expose, or clarify ethnographic patterns whose articulation has traditionally been constrained to labor-intensive case studies. Analytics cannot replace ethnography – but can scaffold and give more finely grained resolution to ethnographic inquiry.

An essential step in applying discourse analytics to qualitative research more broadly is to define the mediating units of analysis. One such mediating unit in the domain of learning science research is called an *epistemic frame*. Epistemic Frame Theory (EFT) (Shaffer, 2006) treats a student's configuration of knowledge, skills, and experience, coupled with the individual's beliefs and self-efficacy, as a unit of analysis, or epistemic frame (Nash & Shaffer, 2012). Epistemic frames may be loosely compared to the construct of funds of knowledge (Moje et al., 2004)– i.e., the totality of unique experience, enculturation, beliefs, experiences, expectations, etc., that an individual brings to a social setting.) Epistemic network analysis (ENA) software developed under NSF funding (Marquart, 2018) provides analytic tools for graphing and interpreting discourse patterns. ENA software detects or enables visual interpretation of shifts in epistemic frames. It helps to measure whether or how IC4's objectives are reached. Sample graphs appear in Hamilton et al (2020).

4. IC4's Rationale: The Future Global Workforce

Considerations of the nature of the future STEM workforce contribute to shaping the rationale for IC4 and its applied research. Computer-supported collaborative learning research communities deeply understand that the global workforce will evolve rapidly and require preparation that differs significantly from current career planning patterns that characterize virtually every country, independent of national wealth or development profile. A census of career areas in 2030 and 2040 will bear little resemblance to such a census reflecting 2010 or 2020 occupations. The number of distinct career areas will expand. Many or most workforce position descriptions—or whatever "position description" as a construct evolves into—will have short lifespans. The workplace that middle and secondary school students of today will occupy in the future will continuously cycle in new ways of thinking and new tools. The pandemic-caused shutdown will not last, but the need to adjust to rapidly changing macro-conditions is likely to typify daily life in the future, in other ways and in different contexts. The rhetoric and literature that anticipates future technology-induced trends has coined terms such as Industry 4.0 or VUCA (volatility, uncertainty, complexity, and ambiguity) (Wallner et al., 2016). Another term, upskilling, has been familiar for many years to the labor market research community, and the literature on future workplace trends has incorporated it as well (Baldini, Botterman, Neisse, & Tallacchini, 2018). Upskilling represents a form of adaptive expertise (Baroody, 2003). Szalavetz (2019) and Müller et al. (2018) are among future workforce forecasters stressing the importance of technological upskilling or adaptive expertise to sustaining innovation. Expressions such as Industry 4.0, VUCA, upskilling, and others form a terminology or jargon for market observers and

futurists. They point to the reality, that the future workforce will need to acquire complex competencies to take on relentless and unpredictable technological change.

What are these competencies? They include rapid conceptual migration ("rethinking") and entrée to important new technologies as they come online, interpreting multiple design and use paradigms, and developing the agility to size up and rapidly master emerging technologies, when the velocity of technological innovation will be significantly higher than it is in the early 2020s. These must take form in humane ways that attend to fairness, helpfulness, and well-being of all. The IC4 project is intended to immerse its participants in experiences that will help those competencies and humane dispositions take form and flourish, and its participants build confidence for career decisions.

4.1 Intercultural Competencies among Adolescents in the Future Workforce

Among these global competencies for the future, one of the most prominent is intercultural competency. The field of intercultural competence includes multiple definitions, though they are not applied in the literature to the field of adolescents engaged in collaborative academic activity over virtual communication media. That field is only now in early formation. We have conjectured a cascading sequence or taxonomy of dispositions and skills that correspond to what may become a ubiquitous pattern in precollege education for building international collaboration programs.

The taxonomy involves matching aspects of intercultural competence with gradations of involvement. The taxonomy represents a work in progress for amalgamating research on workforce and tertiary settings with observations we have documented in IC4.

One overriding dynamic that appears conspicuously absent from workforce and tertiary setting research on intercultural competence involves intrinsic curiosity and joy in collaboration, dynamics prominent in the precollege setting of IC4 (Hamilton & Espino, 2020). Research on intercultural competence explicitly specializes in what workforce literature often refers to as soft skills and dispositions (Singh & Sharma, 2014). It is puzzling that research in this area does not more fully reference and build on one of the most prominent and energizing factors routinely evident in IC4: people are curious about other cultures, and if they can function in a non-threatening forum that establishes norms around respect, appreciation, and scientific wonder, they take active pleasure in working with collaborators from other cultures.

This has been a consistent finding in the IC4 network. This network also aligns with observations about intercultural competence involving collaborations between so-called global south and global north partners. Holmes (2017) notes that intercultural competence literature "… requires complementary research, education, and training that gives voice to those in the "global South" who may be marginalized, disenfranchised, poor, and exploited." IC4 is in a unique position in that all of its core facilitators for global meetups represent low-income countries. Their voice in leadership neither highlights nor ignores north-south dynamics but rather deftly acknowledges those factors that may factor into any given collaboration.

4.2 Cultural Historical Activity Theory (CHAT)

ENA's underlying principle that discourse reflects the enculturation and cross-enculturation processes of international virtual collaborations can be interpreted through cultural-historical activity theory (CHAT) (Greeno, 2016). A common premise of the learning sciences is that activity mediates learning (Radinsky & Gomez, 2000). Rather than preceding or preparing for activity, in other words, learning is embedded in activity systems. This is a key tenet of CHAT, and it corresponds to IC4's emphasis on learning and problem solving while in collaborative makerspace-like activities. Various constructs of actors, rules and norms, instruments, community, and outcomes form the activity systems that mediate learning (Greeno, 2016). More importantly, treating internationally-distributed collaboration through a lens that focuses on cross-cultural, cross-national shared activity in a virtual space, in pursuit of outcomes (such as STEM challenges or other digital artifacts) changes terms by which school-age learners form perceptions of self and others in parts of the world that are remote to them. The virtual collaboration space, especially in synchronous video settings, enables visual communication with peers in other countries and cultures to take place from the familiarity of a student's own culture and context (Hamilton & Kallunki, 2020).

Table 1. *Stages of Involvement in Collaborative Network and Corresponding Intercultural Competences Invoked and Developed*

Stage of Involvement	Relevant Disposition or Skill Exercised and Developed
Responds to recruitment opportunity	Intercultural and intellectual curiosity
Reviews informed consent with information about intercultural and international interactions	Priming for intercultural adaptation, flexibility, and negotiation
Meets peers and teachers from own and other countries in introductory phase	Intercultural curiosity (Hamilton & Espino, 2020)
Observes interactions and presentations by others, commenting superficially. Comments explicitly in group reflection	Empathy, sensitivity, respect, good will to listen and to understand across culture (Sun, 2014) Acknowledged pleasure and joy in cross-cultural interactions (Hamilton & Espino, 2020)
Formulates projects either individually or by responding to interests of others in the meetup	Developing flexibility and early intersubjectivity and shared meaning; cooperation (Stahl, 2016)
Carries out project individually or in collaboration with others	Intersubjectivity is further refined through aware of cultural nuance (Daly, 2016)
Formulates and shares presentation	Increased communication competence Competency to demonstrate across cultural mindsets (Chen, 2017)
Facilitates peers and teachers working on other projects	Interculturally aware, sensitive, and adroit (Chen & Starosta, 1996); Integrated and naturally flowing persona representing cognitive, affective, and behavioral (Genç, 2018; Zelenková, 2020)

The types of virtual collaboration activity system that take place within IC4 strongly appear to neutralize uncertainty, anxiety, or mistrust about those who live elsewhere by hybridizing physical presence - where the student is enculturated and at ease - with virtual presence in a collaborator's country and culture (Hamilton & Kallunki, 2020).

5. Forthcoming IC4 Directions: Larger Grain Projects and VR/Volumetric Interactions

IC4 will progress in two directions. One is that projects that students formulate and elect to undertake will take on a larger granularity. For example, one new initiative involves South America's Pantanal rainforest, and government-funded efforts by IC4 partners in Brazil, to position atmospheric condition sensors through Pantanal regions most vulnerable to destructive fires. In the initial year of implementation (2021), sensor data provide a corpus for neural network analysis and AI algorithm development, enabling predictions of fire likelihood. IC4 students in Brazil, the US, Mexico, and Sub-Sahara carry out parallel analyses with mirror data. This is one of several examples of IC4's evolution to projects of larger grain size, to help students build high-end media and AI competencies in international collaboration.

The second area of future development involves intensifying the hybridization of presence experience, and evaluating the conjecture that hybrid presence scaffolds the development of intercultural competence and learning, especially as it applies to trust building over systems that include video communication This will take place through developing shared virtual reality artifacts including volumetric presence (Cho, Kim, Lee, Ahn, & Han, 2020).

6. Conclusion

This phenomenon is familiar to adults accustomed to international virtual collaborations. In a world where strife and mistrust can germinate in part because of geographical or cultural differences, there is

opportunity to invent fresh ways for school-age learners to understand those who do not live near them or do not live like them. This compelling dynamic applies both to geographic boundary-crossing and to cultural boundary-crossing that can occur within a country, a region, or even within a city (Hamilton & Kallunki, 2020). Displacing perceptions that originate in geographic, economic, cultural, or other differences with a productive and collaborative activity system as the primary basis for understanding those in other parts of the world is a different way to conceptualize intercultural competence.

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