Abstract: Learning Mathematics Through Networked Classroom Activities: 10 Years of Progress

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A landmark symposium, held at PME-NA in 2002, claimed "New theoretical, methodological, and design frameworks for engaging classroom learning are provoked and supported by the highly interactive and group-centered capabilities of a new generation of classroom–based networks." (Stroup et al, 2002). Since that time, researchers have used the new technology affordances of classroom networks to design activities, software, and pedagogies to structure productive learning experiences. These networks enable all students to contribute simultaneously to a group mathematical experience. In a basic scenario, each student in a classroom has a computer or handheld device to share mathematical contributions (e.g. points, graphs, algebraic expressions, etc.) and the network interconnect the mathematical contributions and communal experiences can be shared via a projected public display. As a result of multiple investigations, important journal papers and book chapters have been written; doctorates have been obtained on this topic; two large scale experimental studies have returned results; commercial products have been launched; and implementations have spread from the United States to Asia, Europe, and elsewhere.

The overall objective of this symposium, to be held approximately 10 years later, is to engage a diverse group of active investigators to consider the nature and extent of progress over the past 10 years. Specifically, we aim to:

1. Review and reflect on the major research findings.
2. Present and discuss refinements to theory.
3. Share and cross-fertilize emerging frameworks.
4. Raise and debate the important issues that lie ahead.

Active researchers will present diverse and contrasting perspectives from their work in the use of network technologies in mathematics education. The diverse perspectives focus on classrooms' discourse, creativity, participation and collaboration. They also focus on large scale research results measured both traditional empirical designs and innovative regression discontinuity designs. Questions are raised about missing resources and the use of classroom networks is extended to support deeper analysis of student mathematical thinking. The preparation of this session led to extensive discussion and debates among the researchers, suggesting that the session at AERA will be lively, controversial, and stimulating.

Our plan for the session emphasizes first bringing forward the multiple diverse viewpoints of the presenters and then engaging across these viewpoints via a panel discussion and through audience participation. The session chair will first provide a brief overview of the technological affordances of classroom networks for mathematics learning. Then highlights of each paper, emphasizing the four aims above, will be presented in about 10 minutes each. The presenters will then form a panel to address the questions of progress to date and directions forward. The session chair will engage the audience in

participating in the discussion with the panel, eliciting both Q&A and commentary from those attending. Collectively, we will use this format to highlight the significance of the session: a timely reflection among active researchers with diverse perspectives considering 10 years of research with an important strand of classroom technology for mathematics teaching and learning.

After preparing this session, we discovered too late that we had 8 presenters and only 6 were allowed by the AERA system. We thus positioned Hegedus and Abramson as discussants in the system. Their abstracts below can attest to their involvement in this field and ability to comment wisely.

Presenter #1

Discourse: Students engage in argumentation, comparison and discourse in personally meaningful ways

Stephen Hegedus, Kaput Center, University of Massachusetts Dartmouth
Corey Brady, Kaput Center, University of Massachusetts Dartmouth

For the past 10 years, the SimCalc project has made great advances in developing and implementing integrated software and curriculum into middle and high school classrooms (Hegedus et al, 2007). A recent 4-year longitudinal project tracked students throughout their high school, with some students being randomly assigned to SimCalc replacement units in their Algebra 1 and/or Algebra 2 classrooms. We evaluated their learning through repeated measures of standardized topics and more advanced topics in algebra and pre-calculus (e.g. slope as rate, systems of linear equations, modeling quadratic and exponential motion). We have combined integrated software and curriculum with networking hardware to allow the teacher to iteratively send more challenging activities to her students, and harvest their work allowing them to compare and contrast their work in mathematically meaningful ways due to the inherent algebraic structures embedded in the activities. This has had an impact on how students communicate their ideas both in small groups and whole class discussions when the teacher displays their work and navigates through the contributions of groups and individuals (Moreno & Hegedus, 2009). Students engage in important mathematical thinking such as argumentation, comparison and generalization in personally meaningful ways since they are examining their own work vs. mathematical objects borrowed from standard textbooks. We have observed that this not only impacts their learning in contrast to alternative instruction in our participating schools but also their motivation to engage in mathematical thinking and working in groups. Our statistical findings have directed our analysis of discourse processes that deepens our understanding of how the learning environment impacts students' motivation and learning. We will present some significant exemplars of these processes cast within a descriptive participation framework (Hegedus & Penuel, 2008) including:

- Increasing use of more mathematical expressive language (e.g. metaphors, gestures)
- Changes in flow of interaction (e.g. turn-taking) in contrast to control classrooms
- Enhanced identity through personal identification of work
- Shifting roles between and among students, teachers and the up-front display space

Paper #2

Creativity: Pedagogical moves in a generative classroom

Sarah M. Davis, Learning Sciences Lab, National Institute of Education, Singapore

This paper reports on research by the Generative Activities in Singapore (GenSing) (Davis, 2009) project to increase understanding of the pedagogical moves teachers make to foster creativity. GenSing is a four-year design study focused on students' developing understanding of function-based algebra using generative, network-based activities and the types of pedagogical practices needed to foster deep understanding.

For the GenSing project, a 12-week curricular unit composed of 10 different Generative Activities covering the algebra components of the Secondary 1 syllabus was implemented in all Secondary 1 classes at the research site. The curricular activities were created using the principles of generative design (Stroup, Ares, Hurford, & Lesh, 2007), incorporating function-based algebra (Kaput, 1995) and facilitated by the use of a classroom network (Roschelle, Penuel, & Abrahamson, 2004; Stroup et al., 2002). Our earlier studies found that the generative function-based approach to teaching algebraic concepts has the potential to improve students' understanding of the structural aspects of introductory algebraic concepts (Stroup, Carmona, & Davis, 2005).

We created a number of software visualization tools that transform the student-created digital artifacts from the various generative activities into representations that give insight into different facets of student activity. For example, Figure 1 shows the Spiral Visualizations of two different teachers' implementations of an activity where students are challenged to find expressions equivalent to y=2x. Using handheld devices connected to a classroom network, students enter their expressions and submit them to the public group display. The Spiral Visualizer uses this data to create a visualization depicting unique functions submitted, whether the student-generated expression is correct, and other information. Each of the spirals in Figure 1 represents approximately 10 minutes of classroom time. The first function submitted is in the 3 o'clock position and each subsequent unique function posts clockwise around the grey center. In the figure below, even absent any additional explanation, the visualization gives a strong sense that something very different occurred in Mr. Tan's and Mr. Lee's (pseudonyms) classrooms, even thought the student population in the two classes is quite similar.

We have been investigating the types of pedagogical moves used by teachers that foster creativity in student engagement in generative activities (in the example, "creativity" is defined as the wealth and variety of representations of functions equivalent to 2x). Using detailed field notes and video analyses of the pedagogical moves made by teachers during the time period covered by the spiral, we identify a variety of pedagogical moves and their role in fostering or inhibiting the diversity of responses in the group display. For example, two of the key moves used by Mr. Tan were: (1) Asking students to "surprise him" and (2) Highlighting and discussing different expressions in the display space. In the paper, we will present links between particular activities, pedagogical moves and related student creativity.

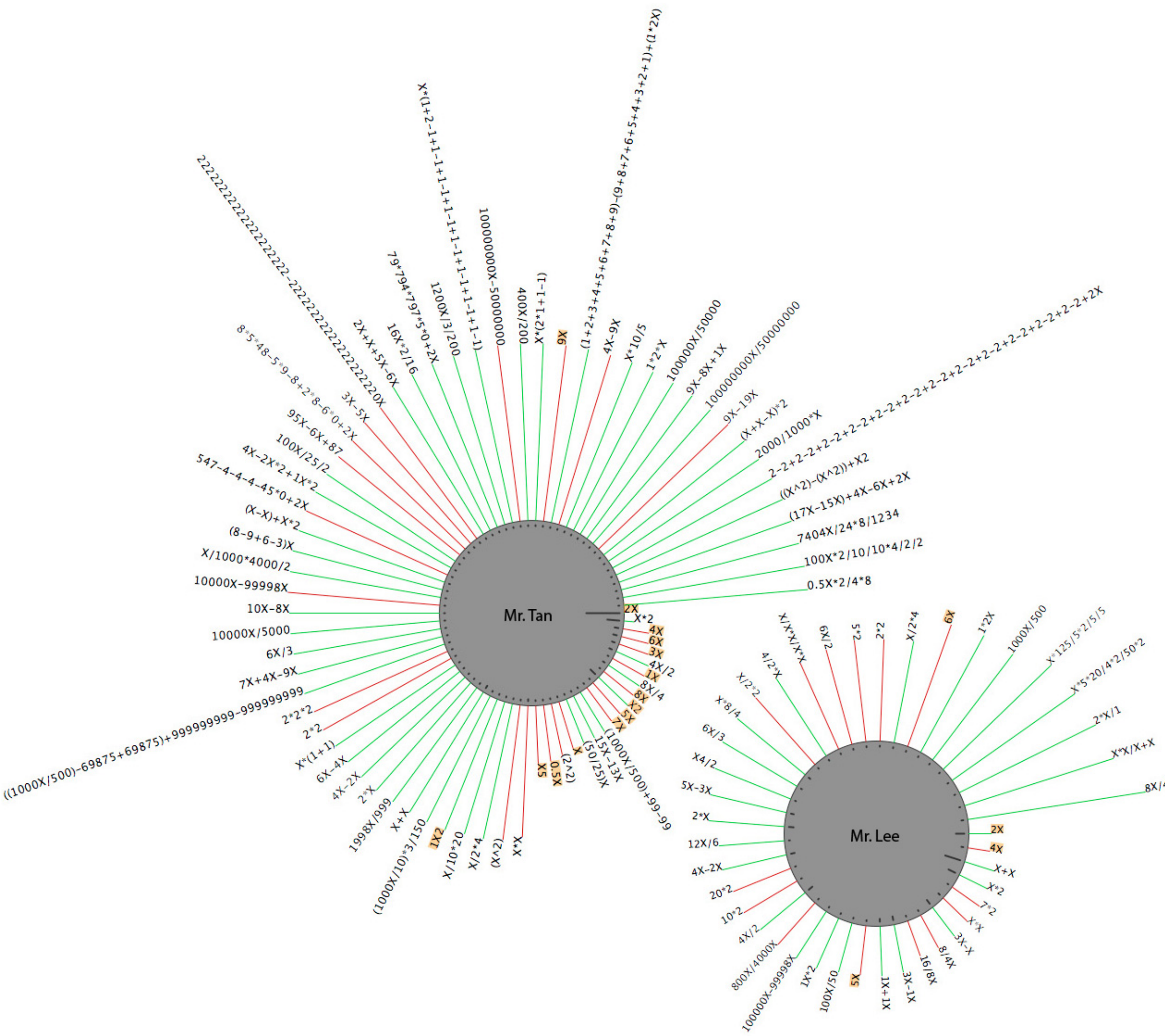

Figure 1: Mr. Tan and Mr. Lee

<u>Paper 3:</u>

Collaboration: Activity designs and pedagogy to enhance small group learning

Tobin White, School of Education, University of California, Davis,

Classroom networks afford novel forms of interaction among students and between students and teachers. Students can use locally networked handheld devices to jointly construct, examine, manipulate and exchange shared mathematical objects. These shared objects, displayed either on individual student device screens or in a public display at the front of a classroom, can in turn form the basis for groups of students to participate in a variety of investigations, problem-solving activities, or discussions aimed at cultivating understanding of important mathematical ideas. For much of the last decade, and over two different handheld device platforms, we have conducted a design research program to investigate the potential for supporting collective and collaborative forms of classroom activity with networks.

Our approach to classroom network design places special emphasis on small groups of two to four students. While instructional activity oriented toward student work in small groups has been effectively implemented in many settings, the shortcomings and challenges of facilitating classroom collaboration have also been well documented (Barron, 2003; Salomon & Globerson, 1989). Our learning activity designs investigate the potential to address these challenges by using classroom networking tools to distribute resources and responsibilities for collective action, and to create conditions for productive interaction and equitable participation within student groups. In a series of classroom-based design experiments, we have found that distributing mathematical objects across group members' devices can augment and enrich discursive interaction among participants (White, 2006) and support student learning about mathematical relationships (White & Pea, in press; White, Wallace & Lai, in press).

Importantly, though, collaborative learning in a classroom network does not simply replicate or enhance its offline alternative. The novel and dynamic forms of interaction afforded by network technology demand corresponding shifts in pedagogy, and present not only new opportunities but also new challenges for teachers seeking to implement them. Our most recent work seeks to unpack these issues through a researcher-teacher study (Ball, 2000) focused on examining the possibilities and subtleties of orchestrating classroom activity in a classroom network. We will report on both pedagogical and methodological insights emerging from this work.

Paper #4

Missing Resources for Learning in Network-Supported Mathematics Learning?

Nancy Ares, University of Rochester

This paper focuses on research designs and findings from studies in networked classrooms of non-dominant youths' social and cultural practices as resources rather than liabilities for learning. The findings reported here focus on equity of participation and contribution in mathematics classrooms using HubNet and Participatory Simulations (PartSims; Wilensky & Stroup, 2000). While there have been many studies of networked activity conducted in schools serving significant numbers of underserved students (Wilensky, 2003; Hegedus & Kaput, 2003), few have examined the ways that linguistic, interactional, and community-specific repertoires of practice are valuable resources for youth and teachers pursuing rigorous mathematical learning (but see Ares, Stroup, & Schademan, 2004; Ares, 2007, 2008). An important parallel focus is in Schorr and Goldin's (2008) work that situates students' affect and motivation in both networked classrooms and the larger social context of under-resourced schools. Recognizing the value students placed on being treated with dignity and respect among students, they demonstrate how networked activities (SimCalc MathWorlds, (Kaput & Roschelle 1997; Schorr, 2003) supported students' highly motivated, affectively engaged learning "conceptually challenging mathematics" (p. 135). Studies reviewed in this paper on students' use of culturally derived cognitive, linguistic and interactional resources that are often dismissed or ignored in classrooms under-served youth are complementary to that work in terms of settings: "where social conditions seem discouraging—for example, where relatively low institutional expectations prevail, where students' mathematical understanding and potential go unnoticed, or where school instruction is primarily directive, procedural, and/or test-oriented" (Schorr & Goldin, 2008, p. 133). They are also complementary in terms of assumptions about non-dominant youth as being rich in learning resources.

Findings from a family of studies in networked classrooms show how engaging in generative activities using Participatory Simulations can invite non-dominant youths' use of social and cultural practices as resources. They also pinpoint particular affordances of the system itself for broadening the space of participation beyond what is often found in conventional classrooms (Ares, 2008; Ares, Stroup, & Schademan, 2008; Stroup, Ares, & Hurford, 2005). Important for this panel discussion, such studies haven't gained much traction in the connected classroom research community as well as in mathematics classroom practice and grant funding. Further, the kinds of networked activities and technological affordances found in HubNet and PartSims are not used ubiquitously. This is problematic for our research community's efforts around equity. Also, the mismatch between many school curricula (and testing regimes) and these activities, as well as the lack of focus on "minorities' " resources (rather than deficits), militates against implementation of this kind of classroom activity. These and similar challenges will be addressed in the conclusion of the paper.

Paper 5:

Methodogy: Inclusive Regression Discontinuity Designs in Analyses of the Effectiveness of Middle-School Mathematics Intervention

Walter Stroup, Guadalupe Carmona, Vinh Pham and Celeste Alexander, Generative Design Center, The University of Texas at Austin

Ten years ago, we were asked about how we anticipated formally characterizing the learning outcomes or forms of student engagement related to the use these environments. At that time, our work was not, as yet, sufficiently rigorous and generalizable. As the papers in the session attest, our progress has exceeded what we might have reasonably anticipated. While some of this work builds on existing approaches, a number of innovations emerging from our work with the capabilities of network-mediated learning and teaching. This paper reports on one of these: Inclusive Regression Discontinuity Design as used to establish the effectiveness of a network-mediated middle school mathematics intervention for a district in central Texas.

Inclusive Regression Discontinuity Design is an extension of traditional regression discontinuity design. Traditional regression discontinuity uses a pre-test, post-test comparison of an experimental group below a cut score on some standardized scale to a group score above the cut score before and after a treatment. If, at the cut score there is a vertical discontinuity, or shift upward, in the regression line for the treatment group relative to the line through the results from the comparison group, this discontinuity is evidence of the success of the intervention (Cook and Shadish, 1994, Shadish, Cook, Campbell, 2001). Typically for education interventions, the treatment is a "pull-out" or self-contained program.

While we will report results from a successful year one mathematics intervention that used network supported activities as part of a pull-out intervention, our general approach to network-supported activity design is "inclusive" in ways that encourage heterogeneous grouping. Consistent with this inclusive stance, in year two of our study the network-based activities were used in classrooms comprised of students with scores both above and below the cut score. This hetrogeneous grouping was considered part of the "treatment". Then, just as with standard regression discontinuity analyses, the pretest-posttest results for students in the treatment with prior outcomes below the cut score could be compared with results from students above the cut score and not part of the intervention. All the conditions for internal validity can still be met with this inclusive regression discontinuity design (IRDD) and we will report our positive findings for students initially scoring below the cut score.

We will report on our similarly positive results for students above a cut score who used highly interactive, network mediated, middle school mathematics activities, in a heterogeneous classroom grouping. Unlike other forms of intervention for underperforming students that might be assumed to be harmful or limiting if also applied to higher performing students, this work formally extends the features of RDD to allow us to show that truly inclusive activity design as supported by next-generation network capabilities can result in significant improvements in outcomes for all students. And while this finding came from work based on using classroom networks, assuming similar internal conditions, IRDD should be able to be extended to a range of more fully socially situated accounts of learning, teaching and activity designs.

Paper 6

Results: Students in Large Scale Experiment Learned More Algebra – Other Benefits

A. Louis Abrahamson, The Better Education Foundation

A recently completed large-scale experiment on the teaching of algebra has shown significant results. These results are important enough to provide a new lens through which to view prior work, and to provide direction for future research.

The large-scale experiment was randomized clinical trial (RCT) with 127 mathematics teachers from 28 States. In June 2005, this study, which was funded by the US Dept of Education, randomized the teachers into two groups. That same summer all treatment teachers attended a week-long professional development (PD) institute at the Ohio State University. The purpose was to instruct teachers in the use of the technology chosen for the study – and necessary pedagogical ideas and principles. The PD was taught mainly by mathematics teachers, who were experienced users of the technology and pedagogy in their own classrooms. At the beginning of the academic year, all students in both groups (treatment and control) were given an algebra pretest, and teachers in the treatment group received TI-Navigator systems. These were available for use in their classes as they saw fit, for the duration of the ensuing academic year. There was no control by the project on how, why, or how often they used the systems. At the end of the academic year, all students were given an algebra post-test. In an HLM Analysis the project compared both groups. The result was that the treatment outperformed the control group with an Effect Size of 0.3 (Pape et al, 2008, 2010). This is roughly equivalent to the entire treatment group moving one-third of a standard deviation higher than control on the post-test. An effect of this magnitude is relatively rare in (so –called) “gold standard” educational experiments, where most such trials yield no effect. However, taken in conjunction with prior work, the composite picture is more exciting.

In 2004, Roschelle et al presented the results of a literature survey of prior work on networked classrooms, identifying 26 studies. Effects included promoting greater student engagement (16 studies), increased understanding of complex subject matter (11 studies), increasing interest and enjoyment of class (6 studies), helping students gauge their own level of understanding (5 studies), and teachers having better awareness of student difficulties (4 studies). Thus, the synthesis of the RCT with other studies shows that not only do students learn more, according to traditional measures, but also that classrooms appears to change in desirable ways.

This is significant from two perspectives. First, from a purely utilitarian aspect, classroom networks with appropriate PD appear to be a desirable innovation. Second, the results of this work pose additional questions. Clearly, the beneficial results are not pedagogy and teacher agnostic. Also, they are not technology independent in the sense that some classroom networking technologies are different from others. What are the principles behind the processes that lead to these results? What are the cause/effect relationships? Can researchers and theorists clearly articulate how and why they work? And, how might they be facilitated through teacher better professional development?

Paper 7

Assessment Design: Network-based environments as and for formative assessment and evaluation of student thinking

Guadalupe Carmona, The University of Texas at Austin

Different approaches are needed to better assess student understanding of math and science ideas, especially with deeper and qualitatively different way of teaching and learning math and science. Traditional assessments don’t reflect the complexity and diversity of student understanding. For example, two students that are assigned a similar score might have very different ways of reasoning about the same problem. For several decades, researchers have supported the use of authentic assessments to help better elicit, document, and interpret more valid evidence of student understanding. Yet, the systemic implementation of authentic tasks to assess student understanding at a large scale is challenging. Difficulties include: authenticity of interpretation of students’ work (focus on student mathematical thinking and measuring what counts), cost, time consumption, and fairness (inter-rater agreement between several evaluators).

We ask evaluators to provide a non-judgmental description of student thinking as elicited in students’ response to an authentic task, prior to assigning a quantitative measure of their performance. The technology allowed a large group of evaluators to assess, in real time, middle school students’ work on a type of authentic modeling task in mathematics called model-eliciting activity (Lesh, Hoover, Hole, Kelly, & Post, 2000; Aliprantis & Carmona, 2003). Evaluators were asked to describe student mathematical thinking by marking a 1 or a 0, depending on whether they assessed that a given set of descriptors well-depicted (or not) students' reasoning when they solved a particular model-eliciting activity. The descriptors were previously obtained by a systematic analysis of student mathematical thinking (Carmona, 2004). The aggregate of the group's assessment was displayed in a public space, generating discussion of the descriptors and providing pictorial representations of student thinking through a spider graph. Evaluators were asked to score students' work under two different conditions: (a) having previously depicted students' work using the descriptors and network environment, and (b) directly providing a numerical score without the descriptive assessment. Evaluators' quantitative scoring was not shared publicly. Inter-rater reliability among evaluators was calculated.

Results are as follows. First, students' diversity and complexity in thinking was expressed through differences in the generated spider graphs, which allowed a characterization of student work by capturing features that are difficult to express by a numerical value in a scale. (Carmona, Stroup, & Davis, 2006; Carmona, 2007) An example of the displays is provided in Figure 2. Second, this process of continuous display of ideas, reflection, and analysis allows for a quick and reliable way to pull forward multiple evaluators' ideas for discussion and negotiation of meaning. Third, changes in evaluators' inter-rater reliability showed a significant improvement after evaluators used this tool to first describe student thinking, leading to a more fair evaluation system. These findings support the conclusion that assessing student thinking first, and evaluating it afterwards, could have a very positive impact in improving student evaluation when compared to only evaluating without assessing first. Further research needs to be conducted to extend this assessment design that focuses on the diversity and complexity of student thinking to a larger scale.

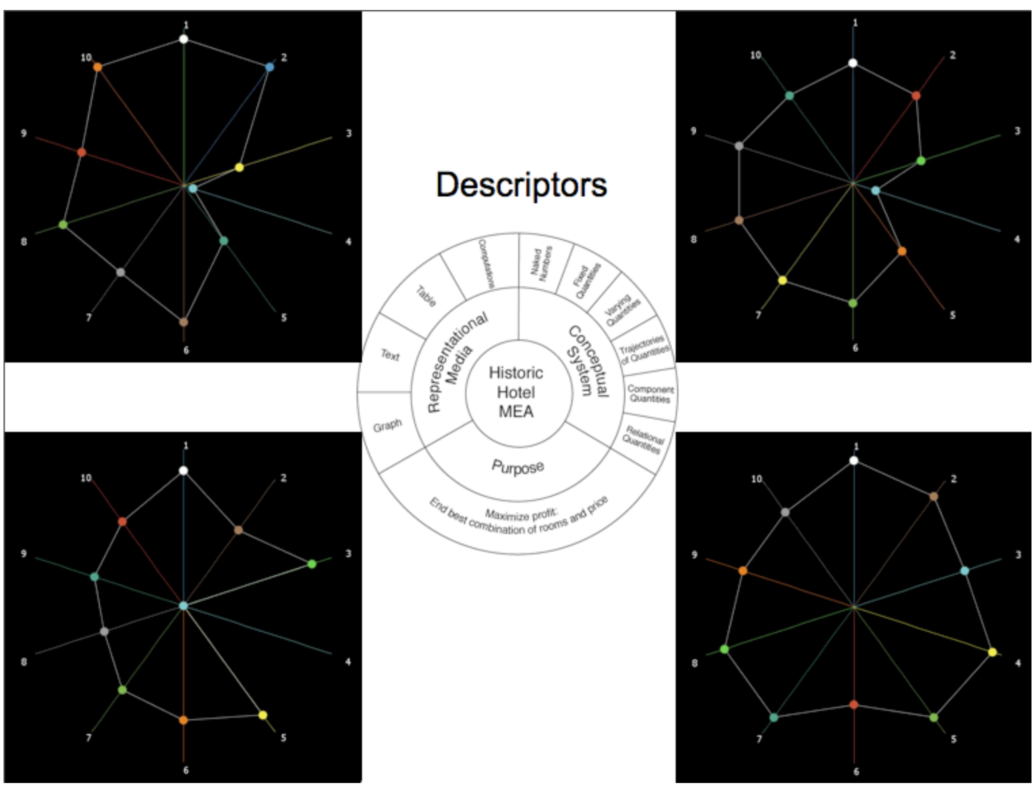

Figure 2. Students' different ways of thinking generate distinct displays.

REFERENCES

Aliprantis, C. D., & Carmona, G. (2003). Introduction to an economic problem: a models and modeling perspective. In R. Lesh & H. M. Doerr (Eds.) Beyond Constructivism: Models and Modeling Perspectives on Mathematics Problem Solving, Learning, and Teaching (pp.255-264). Mahwah, NJ: Lawrence Erlbaum Associates.

Ares, N. (2007). Challenges in operationalizing cultural practices in classroom and peer communities. International Journal of Educational Research, 45(6), 404-419.

Ares, N. (2008). Cultural relevance in design and use of networked classroom technologies. International Journal of Computer Supported Collaborative Learning, 3, 301-326.

Ares, N., Stroup, W., & Schademan, A. (2008). The power of mediating artifacts in group-level development of mathematical discourses. Cognition and Instruction, 27(1), 1-24.

Ball, D. (2000). Working on the inside: Using one's own practice as a site for studying teaching and learning. In A. Kelly & R. Lesh (Eds.), Handbook of Research Design in Mathematics and Science Education (pp. 365-402). NJ: Lawrence Erlbaum Associates.

Barron, B. (2003). When Smart Groups Fail. The Journal of the Learning Sciences, 12(3), 307-359.

Carmona, G., Stroup, W., & Davis, S. (2006). Introducing pre-service teachers to formative assessment: Improving assessment design and accountability in school mathematics through a network-based learning environment. Short research report. In S. Alatorre, J.L. Cortina, M. Sáiz, & A. Méndez, (Eds.). Proceedings of the Twenty-Eighth Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, vol. 2, pp. 190-2. Mérida, Mexico: Universidad Pedagógica Nacional.

Carmona, G. (2007). Improving assessment design and accountability in school mathematics: pre-service teachers' introduction to formative assessment through the use of technology. Paper discussion session in the Annual Meeting of the American Educational Research Association. Chicago, IL.

Carmona, G. (in press). Designing an Assessment Tool to Describe Students' Mathematical Knowledge. Saarbrücken, Germany: VDM Verlag Dr. Muller Publishing House Ltd.

Cook, T. D. & Shadish, W. R. (1994). Social Experiments: Some developments over the past fifteen years. Annual Review of Psychology, 45: 545-580.

Davis, S. M. (2009). Generative Activities in Singapore (GenSing): Pedagogy and Practice in Mathematics Classrooms. In B. Kaur, Y. B.H. & M. Kapur (Eds.), Mathematical Problem Solving: Yearbook 2009 Association of Mathematics Educators (pp. 136-158). Singapore: World Scientific.

Hegedus, S., Kaput, J., Dalton, S., Moniz, R., & Roschelle, J. (2007). *Understanding classroom interactions among, diverse, connected classroom technologies—Overview of the present findings of a 4-year study.*

Technical Report #1. Dartmouth, MA: Kaput Center for Research and Innovation in STEM Education, University of Massachusetts Dartmouth.

Hegedus, S., & Penuel, W. (2008). Studying new forms of participation and classroom identity in mathematics classrooms with integrated communication and representational infrastructures. *Educational Studies in Mathematics*, 68(2), 171-184.

Hegedus, S., & Kaput, J. (2003). The effect of SimCalc connected classrooms on students' algebraic thinking. In N. A. Pateman, B. J. Dougherty & J. Zilliox (Eds.), Proceedings of the 27th Conference of the International Group for the Psychology of Mathematics Education held jointly with the 25th Conference of the North American Chapter of the International Groupf or the Psychology of Mathematics Education (Vol. 3, pp. 47–54). Honolulu, Hawaii: College of Education, University of Hawaii.

Kaput, J. J. (1995). A research base supporting long term algebra reform? Paper presented at the Seventeenth Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, Columbus, OH.

Lesh, R., Hoover, M., Hole, B., Kelly, E., & Post, T. (2000). Principles for developing thought-revealing activities for students and teachers. In A. E. Kelly & R. A. Lesh (Eds.), Handbook of research design in mathematics and science education (pp. 591-645). Mahaway, NJ: Lawrence Erlbaum.

Moreno-Armella, L., & Hegedus, S. (2009). Co-action with digital technologies. *ZDM: The International Journal on Mathematics Education: Transforming Mathematics Education through the Use of Dynamic Mathematics Technologies, 41*(4), 505-519.

Pape S. J., Irving, K. E., Owens, D. T., Boscardin, C. K., Sanalan, V. A., Abrahamson, L., Kaya, S., Shin, H. S. (2008,March). The impact of classroom connectivity in promoting Algebra I achievement: Results of a randomized control trial. Paper preesented at the Annual Meeting of the American Educational Research Association (AERA), New York, NY, 50 pages.

Pape, S. J., Owens, D. T., Irving, K. E., Abrahamson, L., Sanalan, V. A. (2008,June). Classroom connectivity in promoting Algebra 1 & physical science achievement: Year 1 results. Paper preesented at the 2008 IES Research Conference, Washington, DC.

Pape S. J., Irving, K. E., Owens, D. T., Boscardin, C. K., Sanalan, V. A., Abrahamson, L., Kaya, S., Shin, H.S., Silver, D. (2010). Classroom connectivity in Algebra I Classrooms: Results of a randomized control trial. Manuscript submitted for publication.

Roschelle, J., Penuel, W. R., & Abrahamson, L. (2004). The Networked Classroom. Educational Leadership, 61(5), 50-54.

Salomon, G., & Globerson, T. (1989). When teams do not function the way they ought to. International Journal of Educational Research, 13, 89–99.

Schorr, R. Y., et. al., Students' expression of affect in an inner-city SimCalc classroom. Educational Studies in Mathematics v. 68 no. 2 (June 2008) p. 131-48

Shadish, W.R., Cook, T. D., & Campbell, D.T. (2001). Experimental and Quasi-Experimental Designs for Generalized Causal Inferences. Houghton Mifflin Company, Boston.

Stroup, W., Ares, N., & Hurford, A. (2005). A dialectical analysis of generativity: Issues of network supported design in mathematics and science. Mathematical Thinking and Learning, 7(3), 181-206.

Stroup, W. M., Ares, N., Hurford, A. C., & Lesh, R. (2007). Diversity by design: The what, why and how of generativity in next-generation classroom networks. Foundations for the Future in Mathematics Education. Mahwah, NJ: Lawrence Erlbaum Publishing Company.

Stroup, W. M., Carmona, L., & Davis, S. M. (2005). Improving on Expectations: Preliminary Results from Using Network-Supported Function-Based Algebra. In S. Wilson (Ed.), Proceedings of the 27th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education. Blacksburg, VA.

Stroup, W. M., Kaput, J. J., Ares, N., Wilensky, U., Hegedus, S., Roschelle, J., et al. (2002). The nature and future of classroom connectivity: The dialectics of mathematics in the social space. In D. S. Mewborn, P. Sztajn, D. Y. White, H. G. Wiegel, R. L. Bryant & K. Nooney (Eds.), Proceedings of the Twenty-Fourth Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education (Vol. 1, pp. 195-213). Athens, GA

Trochim, William (2006) http://www.socialresearchmethods.net/kb/quasird.htm

White, T. (2006). Code talk: Student discourse and participation with networked handhelds. International Journal of Computer-Supported Collaborative Learning, 1(3), 359-382.

White, T. & Pea, R. (in press). Distributed by design: On the promises and pitfalls of collaborative learning with multiple representations. Journal of the Learning Sciences.

White, T., Wallace, M., & Lai, K. (in press). Graphing in groups: Learning about lines in a collaborative classroom network environment. Mathematical Thinking and Learning.

Wilensky, U. (2003). Statistical mechanics for secondary school: The GasLab Modeling Toolkit. International Journal of Computers for Mathematical Learning, 8(1), 1-41.

Wilensky, U., & Stroup, W. (1999). Participatory simulations: Network-based design for systems learning in classrooms. Proceedings of the Conference on Computer-Supported Collaborative Learning, CSCL ’99, Stanford University.