A Network Context for Observing and Mapping of Ghana Mathematics Classroom Interactions

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Abstract

Ghana faces tremendous challenges in education with a national focus on replicating the conditions and processes for improving student learning throughout the country. High drop out rates, low scores on international tests, and lack of resources plague the educational system, contributing to quantity producing educational practices instead of quality. A network analysis approach and assessments of classroom climate provided the means to map and determine conditions and processes that can be replicated for quality educational improvement. Applying ontological modes of network complexity compositionally, structurally, and functionally allowed for organizing classroom interactions and processes into fundamental relational properties of learning environments, which include instructional, emotional, and behavioral interactions. The classroom network structures supported a positive environment and high number of instructional and emotionally supportive interactions, as well as demonstrated how classrooms can be complex in substantially varied ways compositionally, structurally, and functionally.

Keywords: Ghana education, classroom climate, network analysis, interactions

1. Introduction

Out of the 57 million primary school children who do not attend school worldwide, over half reside in sub-Saharan Africa (Federal Ministry for Economic Cooperation and Development,2015). Despite a national focus on education in countries like Ghana, student dropout rates canbe as high as 15% at the primary level and 35% at the junior high-level (Akyeampong&Ananga, 2014). Irregular school attendees usually come from the lowest income households. Studentsoften stay out of school because of economic issues. Adding to the challenge is many familiessimply cannot afford the cost of fees for their children to attend public schools. Many irregularschool attendees withdraw transiently and end up as permanent dropouts. Studies on the causesof student drop out in Ghana have also been attributed to poor quality in teaching methods(Akyeampong&Ananga, 2014, para. 1; Kadingdi, 2006). Additionally according to Apaganda,the Northern Regional Director of Education, the quantity of students in Ghana classrooms rangefrom 80 to 120 causing poor performance on year-end achievement tests (GhanaWeb, 2014).

Claims of poor student academic performance are supported by international test results. For example, Ghana was the only sub-Saharan African country to be included in the last Trends inMathematics and Science Study (TIMSS, 2011) for eighth grade in mathematics.[1]

Ghanaianstudents scored the lowest of the 45 countries participating. However, the Ghanaian scores arenot considered reliable due to the percentage of students with scores too low to estimate. Yet,according to Carnoy and Rothstein (2013) international tests show achievement gaps in allcountries when data is disaggregated in relation to poverty.

[1] Botswana and South Africa participated in the TIMSS 8th grade mathematics with 9th grade participants onlyscoring significantly below the TIMSS Centerpoint.

Concerning is there is littleagreement on how to fix the problem of the achievement gap in Ghana or globally. So how canthere be transformation from a "quantity producing education system" into a high-quality systemthat benefits Ghana and other nations as a whole? (GhanaWeb, 2014, para.1). Or how canquantity and quality be mutually achieved in education? Hadžikadić (2014) warned if you do notunderstand enough about a problem to solve it, intervening is meddling. Not only do we notknow enough about achievement gaps to eradicate them but also we know little about what reallygoes on in classrooms, in relation to network interactions and their impact on achievement.According to Carolan (2014), "relationships matter" and network science is the "new way" toapproach educational research in order to solve problems (p. 10). Networks can add tounderstanding how individuals, the environment, and various processes interrelate in context andhow systems can be strengthened and sustained (Scott, 2009; Westaby, 2012). The prevalentapproach in educational research has been to treat students as isolated statistical entities(Carolan, 2014) or subsume student outcomes into group averages. This approach does not takeinto full consideration that classrooms are nested, complex systems comprised of networks.Furthermore, the there is the critical role of relationships in classrooms and how the patterns inwhich they are embedded, impact individuals, performance, and achievement. A system like aclassroom is sustained by the means of mutual interactions of individuals that revealscharacteristics not shown by any one individual (Bellinger, 2014).

Westaby (2012) further argues, "goal achievement and performance results from network interactions" (p. 205). So in turn, classroom interactions have variable effects on studentperformance and achievement (p. 56). Mapping classrooms with teachers and studentsrepresented as points or nodes with varying levels of volition, then connect them by paths or links representing interactional causal sequences, represents unique patterns of interdependenciesin the social space classrooms occupy (Carolan, 2014; Westaby, 2012). Interactions are definedas "mutual or reciprocal action or influence" (Merriam Webster Online, n.d.), as well as "thequality, state, or process of two or more things acting on each other (Biology Online, 2014).Salmon (1984) defined processes as entities that display a consistent organization of structureover time (p. 144).

If you do not know why a classroom is the way it is a network approach offers a unique strategy to understand what causes a classroom to be the way it is (Bellinger, 2014; Carolan, 2014) andalso how to better understand how classroom processes relate to interactions and causality atvaried levels of analysis. Determining an accurate architecture of reality allows for rigorousunderstanding of the interdependent actors and environment because teachers and students "bothshape and are shaped by the context in which they interact" (Carolan, 2014, p. 10). A networked relational approach has the "potential to reveal new patterns of behavior not captured through traditional means" and underlying determinants of high performance and low performance (Westaby, 2012, p. 208).

2. Research Context

Whereby interactions in classrooms have been extensively researched in developing countries, with even a specialized research focus in the *Journal of Classroom Interactions*, there is still limited knowledge about the structure, interdependencies, and complexity of interaction processes in classrooms. Social network analysis provides a means to further examine teacher-student interactions, student-student interactions, teacher-whole classroom interactions, and also linkages to essential instructional, emotional, and behavioral processes. In additional to modeling network structures of agents, network processes can provide specific insight into the characteristics of network dynamics, potential causality, and can allow focus on vital patterns of interactions that create desired outcomes. Consequently, identifying the characteristics of various classroom network structures and corresponding processes can guide educators into more effective use of network theory application in determining the relationships between classroom environment, educational opportunity, and achievement.

Networks are ubiquitous and are the glue that holds the universe and its social systems together whether in a physical state, abstract, visible, or invisible form (Johnson, 2015). Networks operate in a constant state of dynamism and flux. They are not fixed and continually evolve adding new parts. They are found in biological, social, and technological systems, as well as throughout educational systems. They provide the means for communication, infrastructure, production, and feedback for complex adaptive systems like classrooms.

Networks can show relational states of similarities between location, participation, and attributes, as well as relational roles (Borgatti, Everett, & Johnson, 2013). Relational cognition of affect and perceptions can be represented along with relational events of interactions and flows (Borgatti, Everett, & Johnson, 2013).

There has been progress in the understanding of complex adaptive systems and the critical function of networks; given their structures are emergent phenomena. Additionally there has been progress in educational research on social network analysis in relation to social capital, diffusion, and peer influence (Carolan, 2014). Still social capital, diffusion, and peer influence research can benefit further from knowing about the elemental processes of all educational interactions, which include instructional, emotional, and behavioral interactions.

Furthermore according to Hadžikadić (2014), you can never understand inherent complexity unless you map out and understand the network behind the system. Networks are defined as interactions between components with social configuration with distinct and discernable structures (Scott, 2009). A school classroom, characterized as a complex adaptive system, is first contextual depending on the environment and possible outcomes and secondly, subsumed by "the nature of the ever-changing interactions among the constituent parts" (Obrien, Hadžikadić, &Khouja, p. 11). Behind each system in a classroom is complex intricate wiring of networks that define the interactions between actors and impact behavior. A network is one means to characterize a complex adaptive system like a classroom (Hadžikadić, 2014).

Yet a complex adaptive system like a classroom "can be more or less complex in substantially different ways" (Rescher, 1998, p. 9). Therein lies an opportunity to assess levels of complexity in classrooms and their interrelated effect on student achievement and outcomes. In order to address this opportunity, I propose the ontological modes of complexity as a means to capture classroom networks compositionally, structurally, and functionally. For example, compositional complexity includes a constitutional component, whereby the number of parts can be represented in a network, and in turn, heterogeneity can be represented in the constituent parts. This approach is commonly used in educational network research (Carolan, 2014). Structural complexity can be determined by the level organizational and hierarchical complexity in networks. This is also used in educational network research (Carolan, 2014).

However, it is the functional complexity comprised of operational complexity and nomic complexity, which has not been adequately addressed in educational network research. First, operational complexity can be defined as the dynamism in the temporal sequences of systems' processes (Rescher, 1998, p. 12). Secondly, nomic complexity can be defined as the working interrelationship of a network's elements, as well as the complicatedness and entanglement of laws governing the network (p. 12). Taking into account classroom instructional, emotional, and behavioral interactional processes over time can shed light on functional complexity, thus insight into the nature of relationships between the structure of a classroom and dynamics of change.

Furthermore, a classroom, examined as a whole system of relations, has properties distinguishable from those of individual students and teachers, which further determine the behaviors of the interrelated parts (Scott, 2009). Consequently, not only does a field of social forces determine aggregate behavior but also it is the perceived environment that really matters to the group behavior (Lewin, 1936; Scott, 2009, p. 11). For example, social meaning in a classroom is co-constructed by teachers and students based on their perceptions and experiences of the contexts in which they act (Scott, 2009, p. 11). It would seem critical to assess classroom environment in addition to compositional, structural, and functional complexity, which is assessed in this research.

3. Research Problem

Research suggests in order to improve educational outcomes; a researcher should focus on investigating the nature and effectiveness of teacher-student interactions (CASTL, 2013; Mashburn et al., 2008). In other words, research has not adequately addressed classroom processes of change and how patterns of change and stability limit success in how processes collectively impact student performance outcomes (Carolan, 2014: Freiberg, 1999).
Developmentally, middle school and high school students report interactions with teachers as "frequently" unsatisfying, unmotivating, and lacking as a supportive relationship (CASTL, 2013, p. 1). One consequence is student dropout, which is considered at crisis level in Ghana (Akyeampong&Ananga, 2014). Greater understanding of interrelating classroom climates and interactions are needed to improve classroom-level learning environments, outcomes, and adolescent withdrawal from educational pursuits (CASTL, 2013; Rolland, 2012). Detailed student-level data is necessary, as well as data on classroom interactions between teachers and students and students and students are necessary. Though, there is, very limited research conducted with precise and timely student-level data in Ghana and in developed countries like the United States (Data Quality Campaign, 2013).

The goal of this research is to identify and measure the structural forms of relations among actors in Ghanaian classrooms as a means to add to traditional variable-centric research (Knoke& Yang, 2008) and group average traditions with precise, detailed student-level data. Given the major national educational focus in Ghana is "improving the quality of learning and teaching," as well as reducing the dropout rate to raise national achievement scores (To Be Worldwide, 2011, p. 6), this research examines the potential for change at the classroom level to determine agent and process dynamics, as well as collective network forces that impact academic environments and outcomes

4. Research Questions

1. Given classroom climate, what are the interrelated network structures of agents and processes in classrooms?
2. What can network analysis add to the understanding of classroom environment, agent-level interactions, educational opportunities, and improving student academic outcomes?

5. Methodology

On order to meet criteria of detailed student-level data both a survey of classroom environment and observations were conducted. The 90-question survey provided an assessment of standardized classroom experiences from students and teachers from the Classroom Environment Scale (CES) Survey. The tool evaluates the effects of interactions and characteristics of the classroom environment (Trickett& Moos, 2002). CES has been used extensively in the US and internationally to ascertain classroom climate (Trickett& Moos, 2002). Though CES can capture aggregate scores on classroom characteristics; it can also capture how a student or teacher experiences the classroom and their place in it (Trickett& Moos, 2002). CES is based on the perspective a classroom is a dynamic system that includes the following domains:

Relationship Dimensions	
1 Involvement	the extent to which students are attentive and interested in class activities, participate in discussions, and do additional work on their own
2 Affiliation	the friendship students feel for each other, as expressed by getting to know each other, helping each other work with homework, and enjoying working together
3. Teacher Support	the help and friendship the teacher shows toward students; how much the teacher talks openly with students, trusts them, and is interested in their ideas
Personal Growth/Goal Orientation Dimensions	
4 Task Orientation	the emphasis on completing planned activities and staying on the subject matter
5. Competition	how much students compete with each other for grades and recognition and how hard it is to achieve good grades
System Maintenance and Change Dimensions	
6 Order and Organization	the emphasis on students behaving in an orderly and polite manner and on the organization of assignments and activities
7 Rule Clarity	the emphasis on establishing and following a clear set of rules and on students knowing what the consequences will be if they do not follow them; the extent to which the teacher is consistent in dealing with students who break rules
8. Teacher Control	how strict the teacher is in enforcing the rules, the severity of punishment for rule infractions, and how much students get into trouble in the class
9 Innovation	how much students contribute to planning classroom activities, and the extent to which the teacher uses new techniques and encourages creative thinking

Figure 1: CES Subscales and Descriptions (Trickett& Moos, 2002)

Additionally, the Classroom Assessment Scoring Systems (CLASS) was used, as a basis for the Observation Mapping Checklist of classroom interactions is the second source of data collection (see Appendix 1). The CLASS instrument is based on the assumption classrooms are complex and interactions are powerful impacting students and their performance (Pianta, 2012). CLASS was selected as an instrument to measure the effectiveness of teacher-student interaction because of its standardization, extensive use in the US and worldwide, and has been validated in thousands classrooms in the US (Hamre, Goffin, & Kraft-Sayre, 2009). CLASS has categorized teacher-student interactions across different domains and dimensions, as to directly observe verbal and non-verbal markers of behaviors. The three major domains include emotional support, behavioral support, and instructional support.

In each CLASS domain there are dimensions, which include a set of indicators of effective teacher-student interactions, as well as behavioral makers as the means to assess them. The CLASS instrument was adapted into an Observation Mapping Checklist in order to capture single interactions based on objective behavioral markers, instead of measuring the subjective experience of the whole class during an observation session (see Appendix A). Two researchers scored the Observation Mapping Checklist in classrooms during the half hour oberservationssessions. Also, the observations sessions were videotaped via IPad as not to be intrusive and for verifying scoring of the Observation Mapping Checklist.

The combination of a subjective and objective classroom environment assessment instruments provided in-depth nuances and feedback on interactions, in order to break down the black box of complexity in classrooms. This type of detailed individual and classroom feedback is usually hidden, invisible, or unavailable to teachers, yet is key increasing the strength of interactions, relationships, and achievement scores (Teachstone Training LLC, 2012). The combined instruments of CSE and CLASS provide intricate interaction data from surveys and observations of evidence-based data. This is significant because changing classroom environments into positive ones has shown to improve average achievement scores as high as twenty five percent (CASTL, 2013).

6. Sample

The research used non-probability sampling. North Ghana rural schools were selected from a large rural area on the basis that the known and unknown characteristics of the sample would best represent the population of rural junior high and high school mathematics classes (O'Sullivan, Rassel, &Berner, 2008). The sample included two junior high and two high schools with a total of one hundred and sixty students and four teachers participating.

All students and teachers were administered the CES classroom environment survey the second week in July of 2014, a week before year-end achievement tests. School principals approved the assessments. Teachers were not given advanced notice of survey administration and observations. All four teachers willingly agreed to participate even though the assessment period took away from scheduled test review time. The administration of the CES survey took place before the CLASS classroom observations, as to not bias the survey with any influence from the observation phase of the research. Students were given instructions in both English and their native language and could opt out of participation. Student participants in the 90-question CES survey took longer than the standard time of fifteen minutes (Trickett& Moos, 2002) with some students taking up to twice as long. This can be attributed to the fact English is the second language of the students and the CES format posed challenges in translating. Observation sessions in the four schools were conducted for a half hour.

7. Results

The results are presented in three phases. The first phase includes results and analysis on classroom climate from the CES results from students and teachers and from CLASS observations. In addition, results are compared to international norms in mathematics classes (Trickett& Moos, 2002). The second phase includes a network analysis of each classroom. The third phase incorporates quantitative and qualitative analysis of agent and process interactions for the Observation Mapping Checklist of classroom interactions based on CLASS.

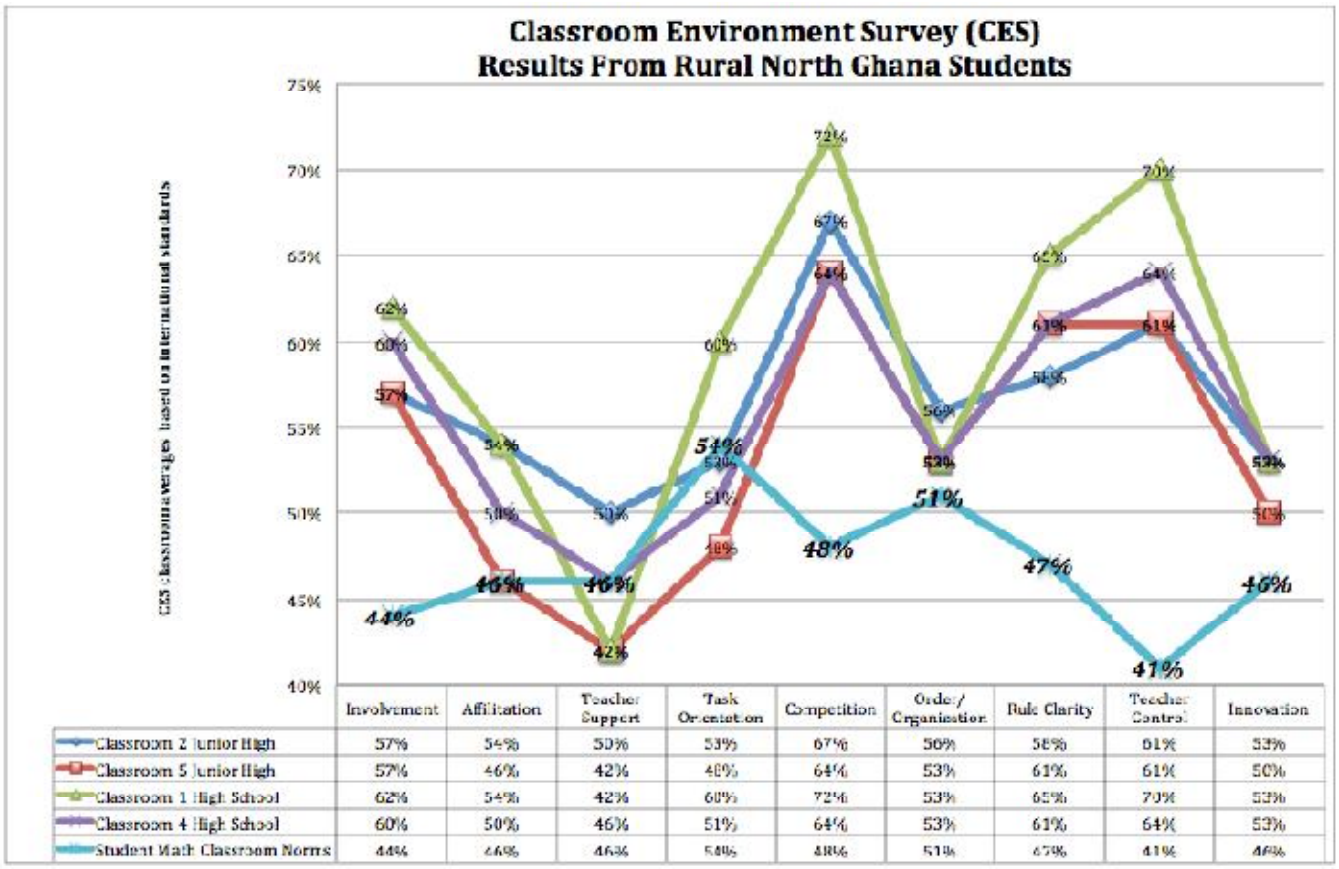
7.1. Phase One

An analysis of the four classrooms was conducted on CES in the first phase of the research. According to CES developers Trickett& Moos (2002), when students are together in a social grouping they bring their own norms and values creating a distinct aggregate in the form of a classroom. The aggregate of the students' abilities and attributes create a "suprapersonal environment" that partially defines the classroom culture that influences performance and attitudes toward performance (Trickett& Moos, 2002, p. 27). CES is comprised of subscales of relationship dimensions, personal growth/goal orientation dimensions, and system maintenance/change dimensions (see Figure 1 above). According to the CES Manual, mathematics classes tend to be very task oriented and well organized (Trickett& Moos, 2002). The results show the assessed classrooms were above average mathematics classroom norms in both task orientation and class organization.

The classroom environments assessed by students scored average or above average mathematics classroom norms in the areas of affiliation, teacher support, and order/organization. See Figures 2 & 3 below (see Appendixes B, C, D, & E for individual Classroom Environment Scale Profiles). The classrooms were scored substantially above average in the areas of involvement, competition, rule clarity, and teacher control. The classrooms were slightly above the average in innovation and both blow and above the average in teacher support and task orientation.

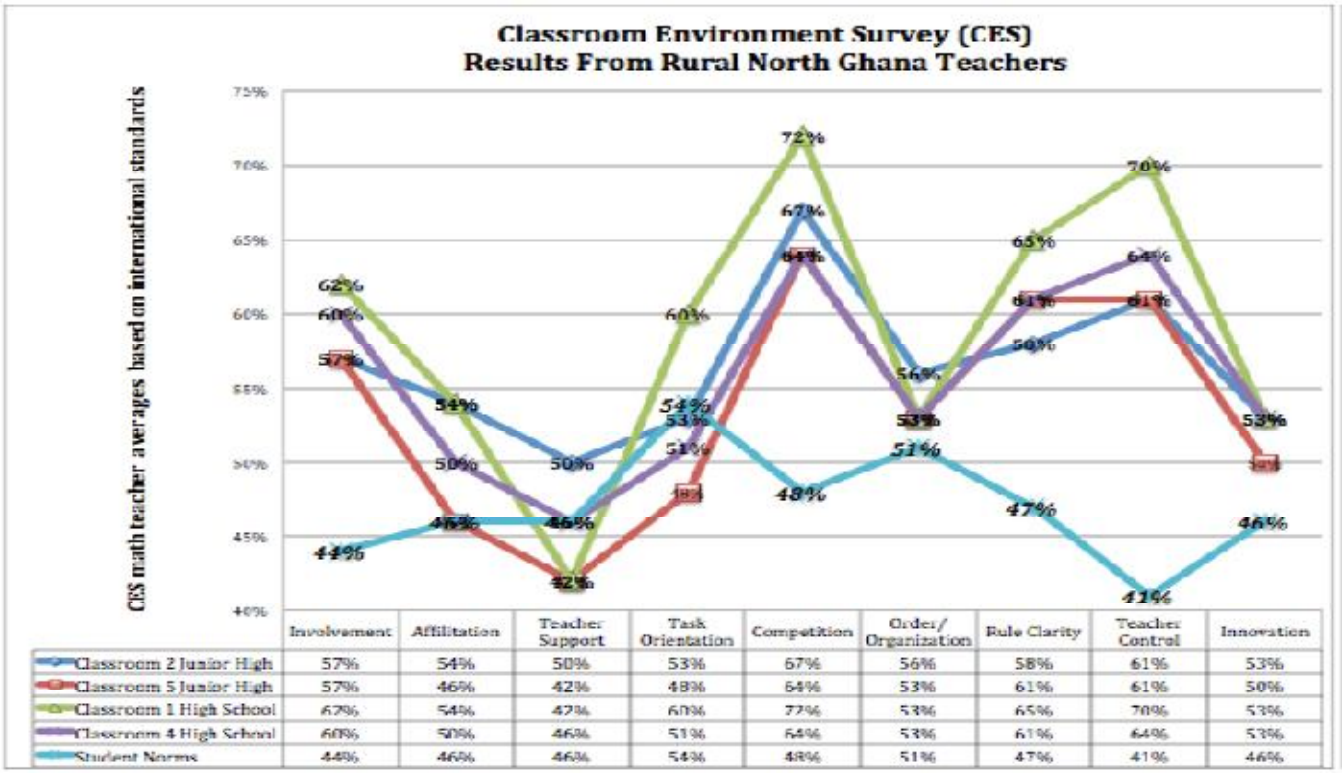
Teachers scored their classroom environments as average or above average in involvement, affiliation, task orientation, order/organization. The teachers scored their classrooms above average in competition, teacher control, and innovation. Teacher support, task orientation, order/organization, and rule clarity had scores ranging from below average, average, and above average. Competition and innovation were scored above average.

From the students' perceptions, the classroom environments were characterized as highly competitive, with high teacher control enforcing rules, and a major emphasis on students following rules. Still, there was a high level of student involvement, whereby students reported being attentive and actively engaged in class activities. Teachers also characterized their classrooms as competitive and high in teacher control. From CLASS observation measures, the classrooms exhibited a positive climate reflecting a positive emotional connection between teachers and students and students and students. For example, teachers and students consistently showed respect for one another and there were frequent positive communication between teachers and students. The teachers communicated positive expectations to students. Positive affect was demonstrated via teacher enthusiasm, smiling, and laughter (Teachstone Training LLC, 2012; Trickett& Moos, 2002). The results reveal the context, whereby "both (students and teachers) shape and are shaped by the context in which they interact" (Carolan, 2014, p. 10).



	Involvement	Affiliation	Teacher Support	Task Orientation	Competition	Order/ Organization	Rule Clarity	Teacher Control	Innovation
Classroom 2 Junior High	57%	54%	50%	53%	67%	56%	58%	61%	53%
Classroom 5 Junior High	57%	46%	42%	48%	64%	53%	61%	61%	50%
Classroom 1 High School	62%	54%	42%	60%	72%	53%	65%	70%	53%
Classroom 4 High School	60%	50%	46%	51%	64%	53%	61%	64%	53%
Student Math Classroom Norms	44%	46%	46%	54%	48%	51%	47%	41%	46%

Figure 2: Classroom Environment Survey CES Outcome Graphs from Aggregate Student Data



	Involvement	Affiliation	Teacher Support	Task Orientation	Competition	Order/ Organization	Rule Clarity	Teacher Control	Innovation
Classroom 2 Junior High	57%	54%	50%	53%	67%	56%	58%	61%	53%
Classroom 5 Junior High	57%	46%	42%	48%	64%	53%	61%	61%	50%
Classroom 1 High School	62%	54%	42%	60%	72%	53%	65%	70%	53%
Classroom 4 High School	60%	50%	46%	51%	64%	53%	61%	64%	53%
Student Norms	44%	46%	46%	54%	48%	51%	47%	41%	46%

Figure 3: Classroom Environment Survey CES Outcome Graph from Teacher Data

7. 2. Phase Two

A network analysis of the four classrooms was conducted with Gephi network software for the second phase of the research. Data was collected from half hour classroom observation sessions. Rescher (1998) pointed out that complex systems "can be more or less complex in substantially different ways" (p. 9). Applying Rescher's (1998) ontological modes of complexity to network analysis provides evidence on how a classroom system is simple and complex in varied ways.

Compositionally, the network graphs of the four classrooms (see Figures 4, 5, 6, & 7 below) showed how heterogeneous agents of teachers and students can be represented by teacher-student interactions, student-student interactions, and teacher-whole class interactions. There could also be variations of students in groups. The observations revealed only a few of the interactions were student initiated. Structurally, the teachers were at the top of the hierarchy initiating and controlling a vast majority of the interactions communication-wise. The four network graphs of classrooms displayed fairly simple compositional and structural components.

In contrast, the network graphs revealed functional complexity in varying degrees. Operationally, the dynamism in the temporal sequences of classroom processes fit into three separate networks (see Figures 4, 5, 6, & 7 above). The first graph on the left (of three) in each classroom network visualization includes teacher ⟶ individual student interactions and student ⟶ student interactions. The second middle graph in each classroom network visualization depicts the whole class responding to the teacher. The third graph on the right in each classroom network visualization shows the processes the teacher engaged in with the whole class.

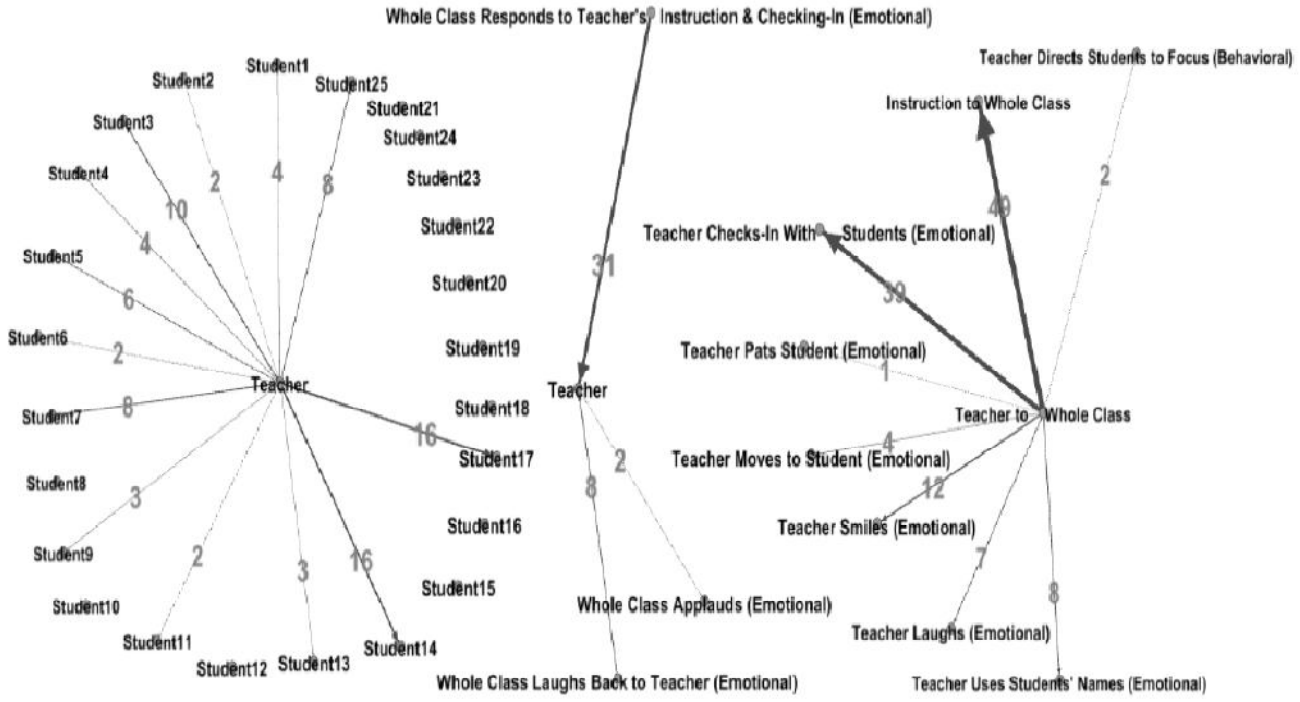


Figure 4: Classroom #2 Junior High Mathematics Classroom

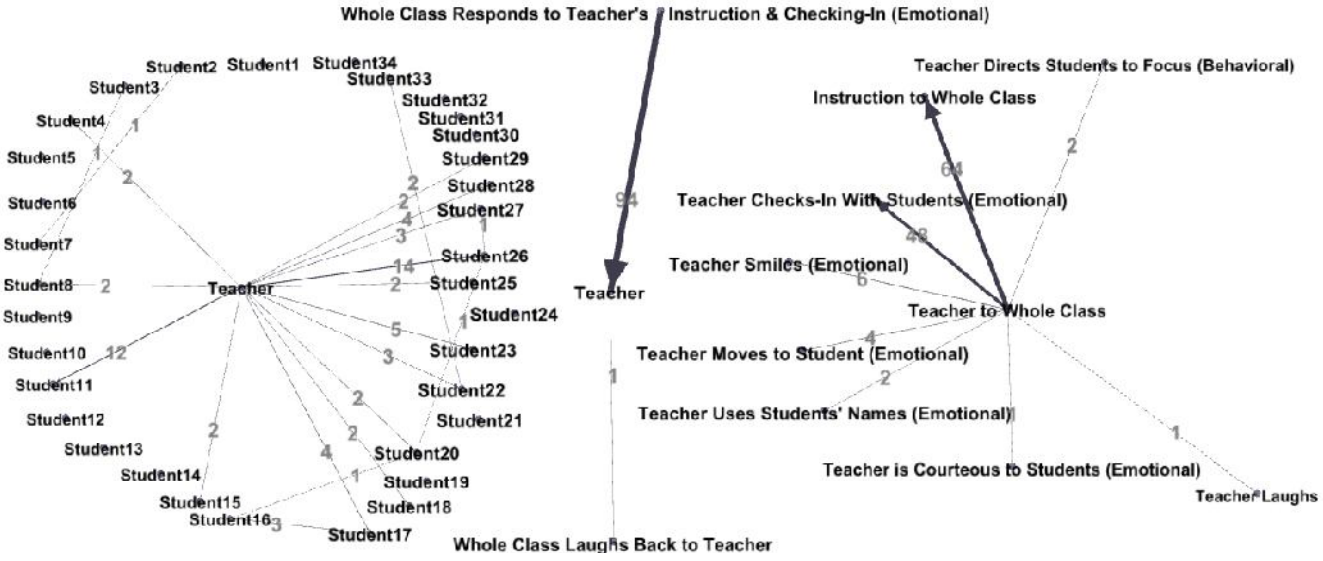


Figure 5: Classroom #5 Junior High Mathematics Classroom

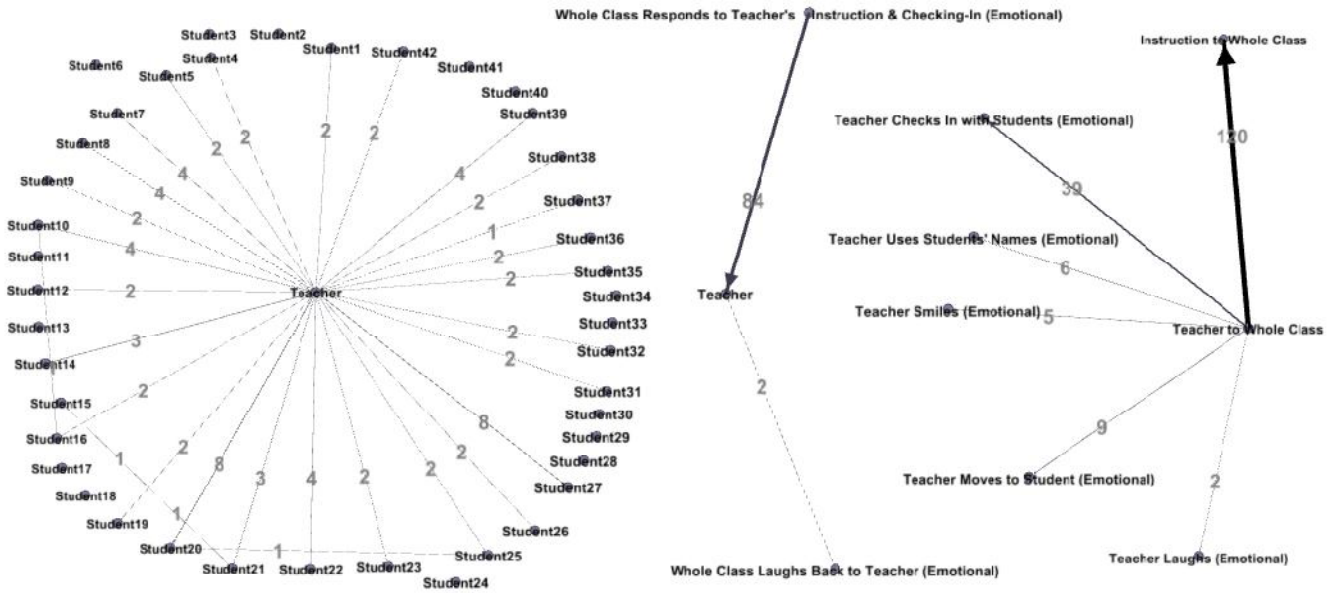


Figure 6: GephiNetwork Graph Classroom #1 High School Mathematics Classroom

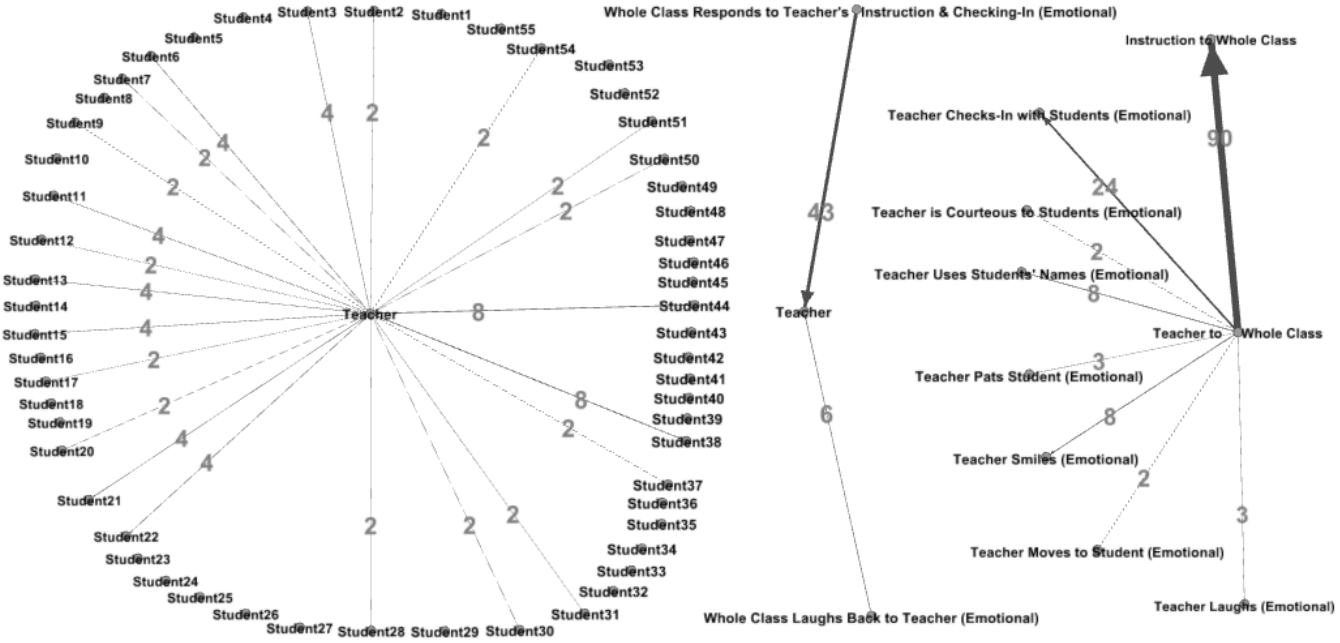


Figure 7: Gephi network graph Classroom #4 high school mathematics classroom

In the first graph on the left in Figures 4, 5, 6, and 7, the number of interactions between the teacher and one individual student range from 0 to 16.

In junior high classroom #2 48% of students had no one-on-one interactions with the teacher.
In junior high classroom #5 56% of students had no one-on-one interactions with the teacher.
In high school classroom #1 36% of students had no one-on-one interactions with the teacher.
In high school classroom #4 58% of students had no one-on-one interactions with the teacher.

Students that had no one-on-one interactions with the teacher tended to be seated in the back of the classroom and on the right hand side of the classroom from a teacher's vantage point. Only two of the classrooms had student-student interactions. They occurred when the teacher was writing on the board faced away from the class. There were limited number student-student interactions. They lasted briefly, seemed to be mostly focused on the instruction, and were not disruptive.

The middle graph shows the whole class' responses to the teacher, while the third graph on the right shows how the teacher interacted with the whole class. Teacher → whole class and whole class → teacher interactions fit into categories of instructional, emotional, and behavioral interactional processes. Teacher→whole class interactions include instructional, emotional, and behavioral management. The emotional processes in the teacher → whole class interactionsincluded checking-in with students by means of encouragement and affirmation, using courtesy, using student names, moving to a student's desk, smiling, laughing, and patting student on shoulder. Whole class teacher interactions include responses to the teacher's instruction and emotional checking-in, as well as clapping. There were not any additional observable group behaviors that showed any patterns.

Interaction types were weighted on the basis of the total number of interactions in a category in relation to all interactions. Overall, the graphs highlight the thickness of the weighted edges between teacher → whole class interactions of instruction and checking-in, as well as the edges between the whole class → teacher responses to teacher directed instruction and checking-in. Additionally, the network graphs reveal some glimpses into unraveling the functional complexity in relation to nomic complexity in the classrooms. At least during end of school review time period, the interrelationships showed:

1. High number of dynamic interactions.

Classroom #2 junior high had 245 total interactions.
Classroom #5 junior high had 289 total interactions.
Classroom #1 high school had 350 total interactions.
Classroom #4 high school had 263 total interactions.

2. Predominance of interactions were instructional from teacher to whole class.

Classroom #2 junior high had 49 teacher → whole class instructional interactions.
Classroom #5 junior high had 64 teacher → whole class instructional interactions.
Classroom #1 high school had 120 teacher→whole class instructional interactions.
Classroom #4 high school had 90 teacher→whole class instructional interactions.

3. High number of interactions were emotional checking-in from teacher → whole class.

Classroom #2 junior high had 24 teacher → whole class emotional support interactions.
Classroom #5 junior high had 48 teacher → whole class emotional support interactions.
Classroom #1 high school had 39 teacher→whole class emotional support interactions.
Classroom #4 high school had 24 teacher→whole class emotional support interactions.

4. High number of interactions were whole class→teacher responding to instructional andemotional checking-in.

Classroom #2 junior high had 31 whole class → teacher response interactions.
Classroom #5 junior high had 94 whole class → teacher response interactions.
Classroom #1 high school had 84 whole class→teacher response interactions.
Classroom #4 high school had 43 whole class → teacher response interactions.

Though the teachers exhibited a strict, serious almost militaristic style, they were highly enthusiastic about the review process and subjects of review. They provided numerous instructional opportunities and provided a proportionally high number of emotional interactions of encouragement and affirmations by checking-in. This is supported by the CES results and observations. The students knew what was required of them and were expected to respond individually or as a whole group when called upon. There were few behavioral disruptions from students. Teachers were effective in redirecting students to refocus. Additionally, the classrooms dynamics included interactions of laughing, smiling, clapping, patting, courtesy, use of student names, and teacher movement toward students. This demonstrates a positive climate with positive affect, positive communication, and respect, yet an environment that is highly competitive (Teachstone Training LLC, 2012).

7.3. Phase Three

A quantitative analysis of agent and process interactions from the Observation Mapping Checklist (see Appendix A) of classroom interactions was conducted for the third phase.

To further examine functional complexity, interaction typologies are reported in the form of instructional, emotional, behavioral management, and agent interactions (see Tables 1, 2, 3, & 4 below). Two classrooms had behavioral management issues but the interactions accounted for only 1% to 3% of the total interactions.

Two classrooms had student-student interactions ranging from 1% to 3% of total interactions. Teachers directed interactions for over half the 30- minute observation sessions from 55% to 69% of the time. Instructional interactions ranged from 67% to 85% of total interactions. Overall, the results demonstrate a predominant amount of classroom time in each classroom was devoted to instruction, support of instruction, and sustaining a positive classroom environment.

8. Discussion

Consideration of the working interrelationships between 1) the classroom environment results in phase one, 2) the network elements from phase two, and 3) quantitative and qualitative analysis of observations in phase three shows varying degrees of "complicatedness" and "entanglement," contributing to addressing nomic functional complexity (Rescher, 1998, p. 12). Similar to the periodic table, organizing and combining knowledge on agent interactions and process interactions (instructional, emotional, and behavioral) enables summarization of fundamental relational properties in learning environments to discern base repeating patterns, on which more complex patterns can adapt from. Yet even the instructional, emotional, and behavioral processes presented in the research can be further broken down into more specified and detailed types of interactions.

The interrelating environment and classroom network structures allowed for maximizing instructional time and active engagement by students. Content understanding is critical during review sessions. The teachers demonstrated communication of mathematical concepts and procedures, while providing opportunities to students for practicing procedures in written form and orally. Regard for adolescent perspectives was evidenced by teachers connecting mathematic concepts to real life examples and stressing the usefulness of the content for the forthcoming achievement test (Teachstone Training LLC, 2012). Observations of teachers' instruction did not provide evidence of poor quality of instruction as reported by Akyeampong and Ananga (2014) as a major problem contributing to student drop out. The quantity of students in the classrooms in the sample ranged from 25 to 56, which disputes national claims of overcrowding classrooms with 80 to 120 students (Akyeampong&Ananga, 2014).

However, the observed teachers rigidly provided all the structure for the class. Teachers did not provide adequate opportunities for student leadership and autonomy to meet and capitalize on the developmental and social needs of adolescents (Teachstone Training LLC, 2012). Students reported classrooms as highly competitive, which despite a positive climate can contribute to dropout (CASTLE, 2013). There is no evidence that the type of and level of instructional, emotional, and behavioral interactions positively impacted academic outcomes. Also, there were no measures on the depth of content understanding during review sessions. Achievement scores and educational outcome measures were not available, nor was past history of dropouts, in order to track interaction effectiveness and impacts over time. Of concern is 36% to up to 58% of the students in classrooms had no one-one one interactions with their teacher during the observed review session.

Yet, the observations showed that teachers had high expectations in relation to student engagement and content comprehension. The research revealed there were ample opportunities to learn from instruction and ask questions for clarification or further assistance. Though teachers directed most of the interactions, observations showed that teachers were very encouraging, affirming, supportive, and enthusiastic. This further disputes a claim of poor quality in instruction, at least in the observed classrooms. Overall, the research framework provided insight into how a network analysis in the context of compositional, structural, and functional complexity can add to the understanding of interdependencies of classroom environment, agent-level interactions, educational opportunities, and quality of teaching methods. Future research can build on this framework and context; in order to one day discover the nomics (laws) of dynamism that govern classroom networks.

9. Conclusions

In conclusion, there are a great number of challenges in Ghanaian classrooms to still be explored and solved. This research did not provide a definitive cure for the drop out problem or improvement of academic outcomes. The research was limited in sample size and generalizability. Network science has provided a foundation for increased understanding, by examining classroom relations in regard to compositional, structural, and functional complexity. Networks have properties hidden in their construction that enhance or limit teachers' ability to empower or influence students in productive ways (Barabasi, 2003).

Visual and simulation representations of networks can unhide some of the basic interrelationships between agents and processes, as demonstrated in this research (Johnson, 2015). But what are the critical thresholds and the means to create robustness in Ghanaian classrooms within various learning orientations, environments, and heterogeneous agent populations? Given everything is connected to everything else, how can educators build adaptive capacity in Ghanaian classroom interactions and sustain them so there is responsiveness to future needs? These questions await further exploration.

Barabasi (2003) argued everything is connected to everything else. Yet how can we use that knowledge and power to contribute to future opportunity and achievement for not only Ghanaian students, but also all students globally? The answer may be only one link away.

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Table 1: Classroom #2 Junior High, Agent and Process Interactions

INTERACTION TYPOLOGIES 25 Students Classroom #2 Jr. High Math	# Of Interactions In ½ Hour	% Of Total Interactions 245
INSTRUCTIONAL INTERACTIONS	164	67%
Teacher to all students INSTRUCTING	49	20%
All students RESPOND To Teacher	31	13%
Teacher to 1 student INSTRUCTING	44	20%
1 Student to Teacher REPSONDING	40	16%
EMOTIONAL INTERACTIONS	81	33%
Teacher checking-in with all students	39	16%
Teacher moving toward students	4	2%
Teacher pat student on shoulder	1	<1%
Teacher laughs	7	3%
Teacher smiles	12	5%
All students as group laugh	8	3%
All students as group clap	2	1%
Teacher use students names	8	3%
BEHAVIORAL MNG. INTERACTIONS by Teacher	0	0%
AGENT INTERACTIONS (no peer to peer interactions)	245	100%
Individual student to Teacher interactions	40	16%
All students as group interactions	41	17%
All teacher interactions	164	67%

Table 2: Classroom #5 Junior High, Agent and Process Interactions

INTERACTION TYPOLOGIES 36 Students Classroom #5 Jr. High Math	# Of Interactions In ½ Hour	% Of Total Interactions 289
INSTRUCTIONAL INTERACTIONS	217	85%
Teacher to all students INSTRUCTING	64	22%
All students RESPOND To Teacher	94	32%
Teacher to 1 student INSTRUCTING	34	12%
1 Student to Teacher REPSONDING	25	9%
EMOTIONAL INTERACTIONS	63	21%
Teacher checking-in with all students	48	15%
Teacher moving toward students	4	1%
Teacher laughs	1	<1%
Teacher smiles	6	2%
Teacher use students names	2	1%
Teacher uses courtesy	1	<1%
All students as group laugh	1	2%
BEHAVIORAL MNG. INTERACTIONS by Teacher	2	1%
AGENT INTERACTIONS	289	100%
Individual student to Teacher interactions	25	9%
All students as group to Teacher interactions	95	33%
Student to student interactions	7	3%
All teacher interactions	152	<55%

Table 3: Classroom #1 High School, Agent and Process Interactions

INTERACTION TYPOLOGIES 43 Students Classroom #1 Sr. High Math	# Of Interactions In ½ Hour	% Of Total Interactions 350
INSTRUCTIONAL INTERACTIONS	283	81%
Teacher to all students INSTRUCTING	120	34%
All students RESPOND To Teacher	84	24%
Teacher to 1 student INSTRUCTING	42	12%
1 Student to Teacher REPSONDING	37	10%
EMOTIONAL INTERACTIONS	63	18%
Teacher checking-in with all students	39	11%
Teacher moving toward students	9	2%
Teacher laughs	2	1%
Teacher smiles	5	1%
Teacher use students names	6	2%
All students as group laugh	2	1%
BEHAVIORAL MNG. INTERACTIONS by Teacher	0	0%
AGENT INTERACTIONS	346	100%
Individual student to Teacher interactions	37	14%
All students as group to Teacher interactions	86	24%
Student to student interactions	4	1%
All teacher interactions	223	61%

Table 4: Classroom #4 High School, Agent and Process Interactions

INTERACTION TYPOLOGIES 56 Students Classroom #4 Sr. High Math	# Of Interactions In ½ Hour	% Of Total Interactions 263
INSTRUCTIONAL INTERACTIONS	203	77%
Teacher to all students INSTRUCTING	90	34%
All students RESPOND To Teacher	43	16%
Teacher to 1 student INSTRUCTING	37	14%
1 Student to Teacher REPSONDING	33	13%
EMOTIONAL INTERACTIONS	56	21%
Teacher checking-in with all students	24	9%
Teacher moving toward students	2	1%
Teacher laughs	3	1%
Teacher smiles	8	3%
Teacher use students names	8	3%
Teacher pats student on shoulder	3	1%
Teacher uses courtesy	2	1%
All students as group laugh	6	2%
BEHAVIORAL MNG. INTERACTIONS by Teacher	4	2%
AGENT INTERACTIONS	263	100%
Individual student to Teacher Interactions	33	12%
All students as group to Teacher interactions	49	19%
All teacher interactions	181	69%

Appendix A

Observation Mapping Checklist

Date_____ School_____ Teacher_____ #Students_____

TEACHER	*STUDENTS*
Emotional Support	1.
Moves to/away from Student Smiling	2.
Laughing + Comments	3.
Respectful language: please, Thank-you Checks in with students: recognition & affirmation of effort	4.
Individual support Reassurance & assistance	5.
Behavioral Support	6.
Attention to positive Anticipates possible neg. behavior	7.
Irritability Anger	8.
Yelling Threats	9.
Punishment Physical control	10.
Teasing Bullying	11.
Humiliation/sarcasm Exclusionary behavior	12.
Inflammatory/discriminatory/derogatory Language or behavior	13.
Instructional Support	14.
Open-ended questions Follow-up questions	15.
Assistance Hints	16.
Prompting Expansion	17.
Clarification Specific feedback	18.
Encouragement of persistence	19.
Notes: on classroom context & time of day.	20.

Appendix B

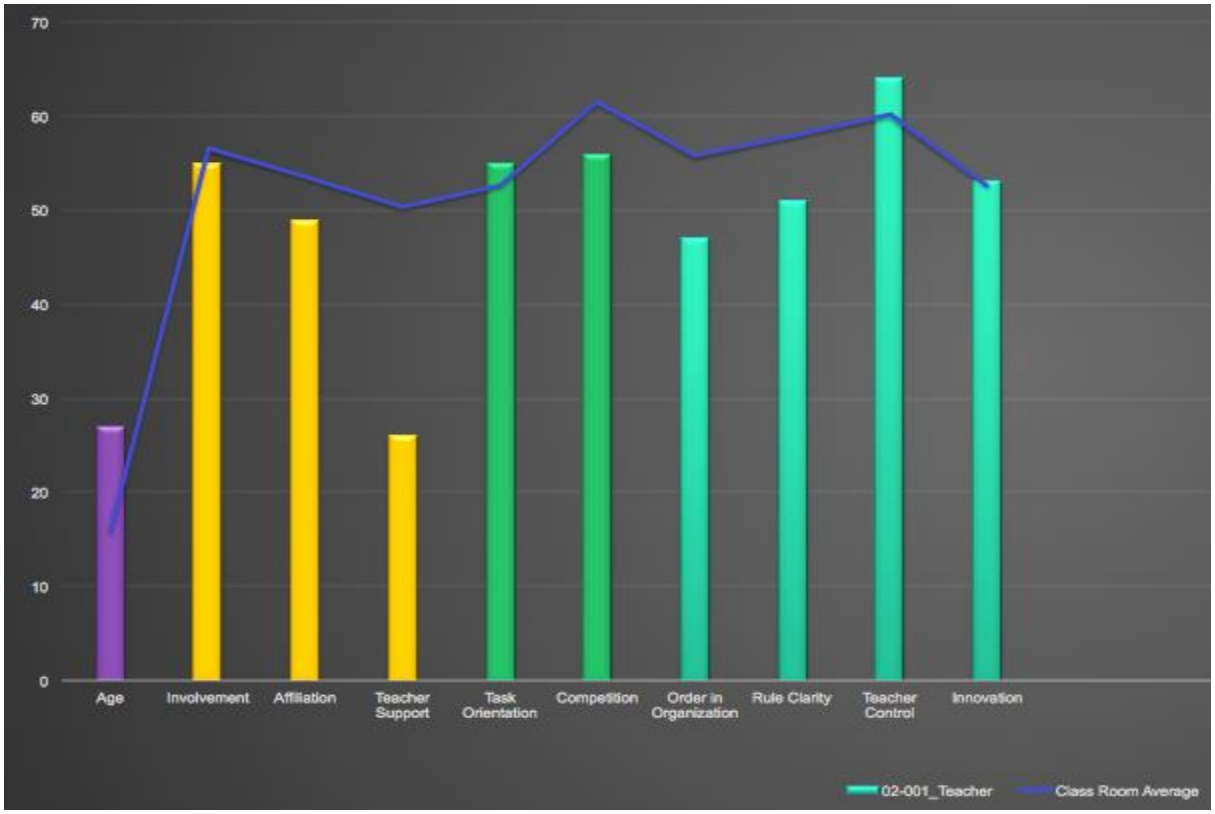


Figure 12: Classroom #2 junior high CES Classroom Environment Scale Profile

Appendix C

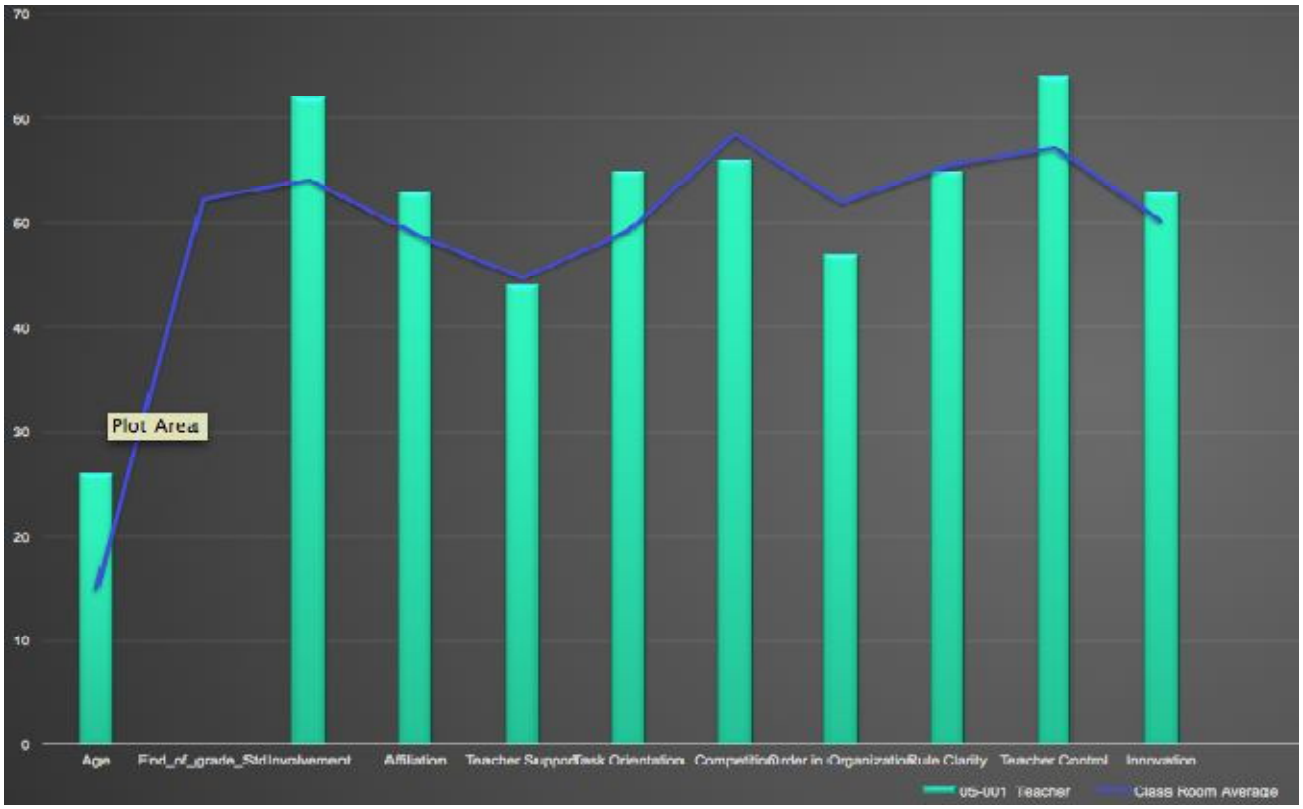


Figure 13: Classroom #5 junior high CES Classroom Environment Scale Profile

Appendix D

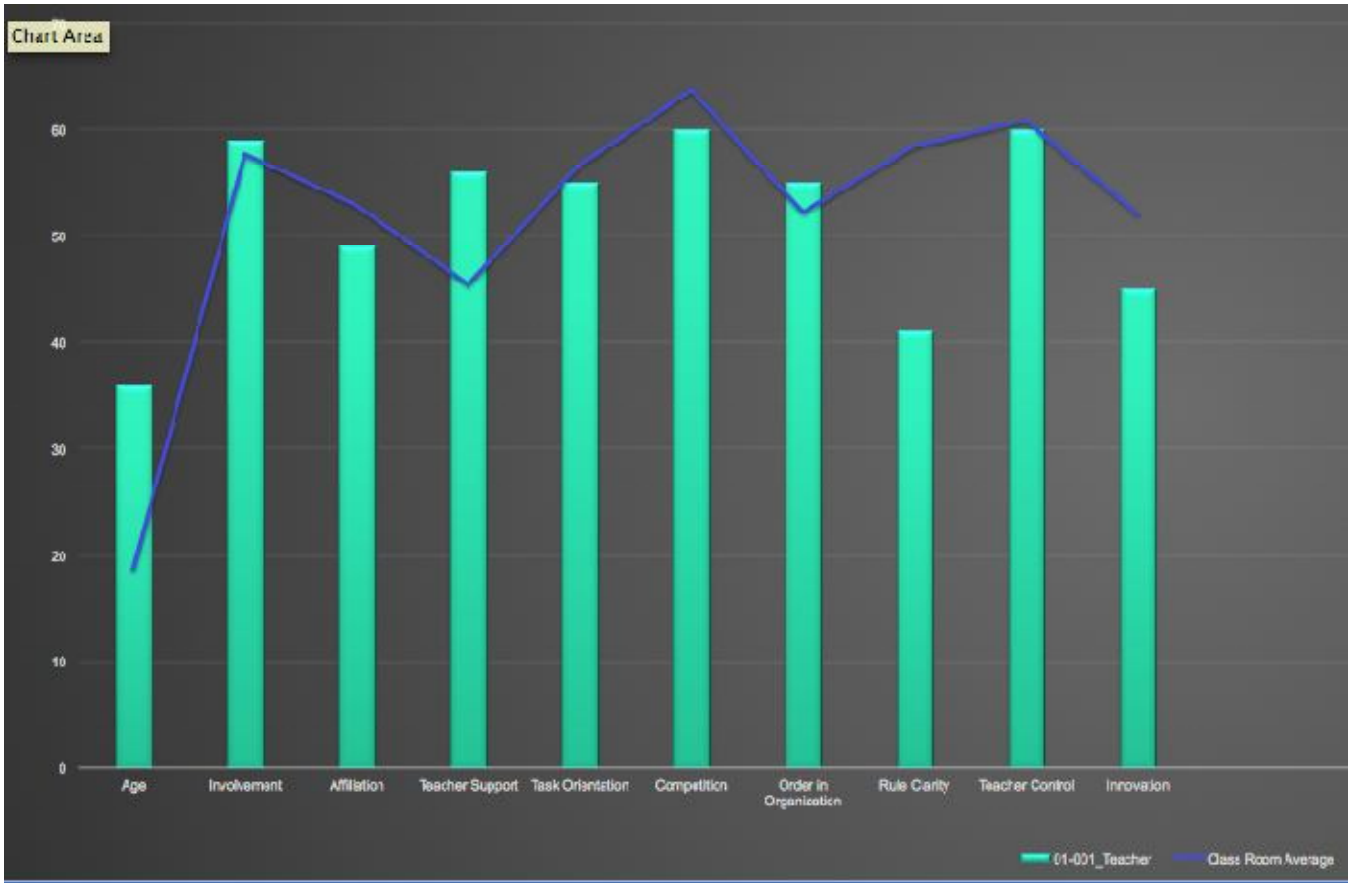


Figure 14: Classroom #1 high school CES Classroom Environment Scale Profile

Appendix E

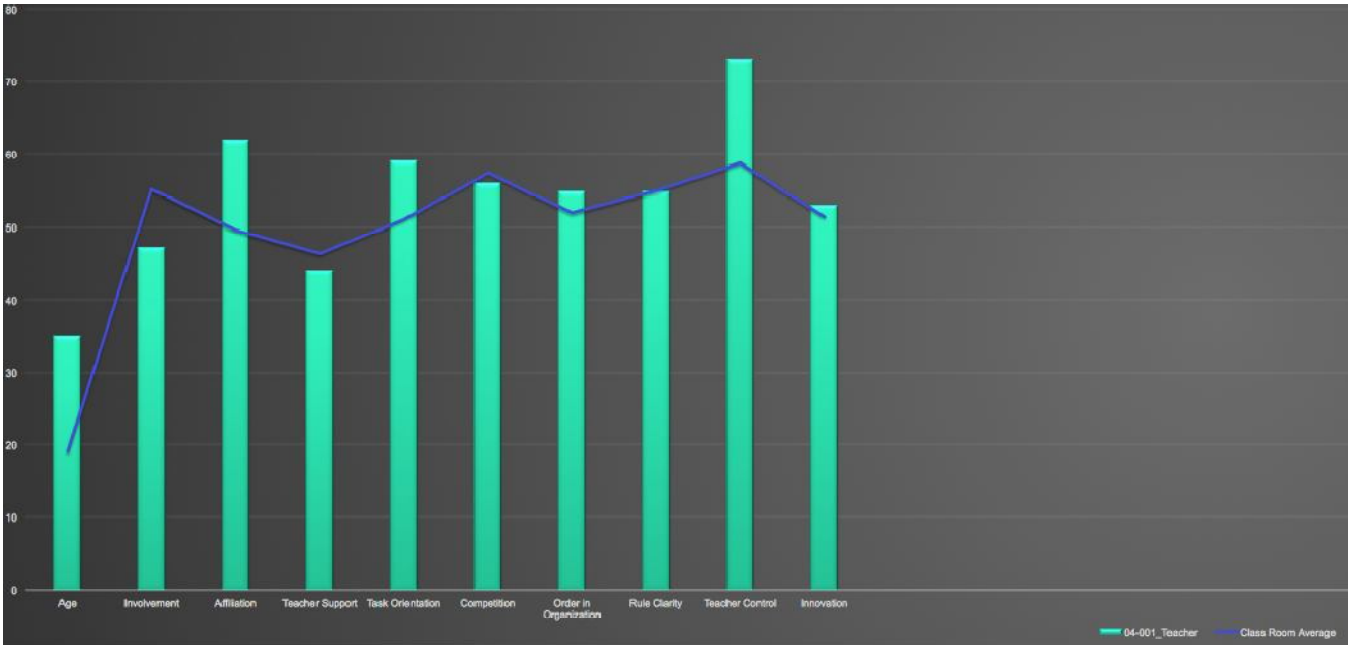
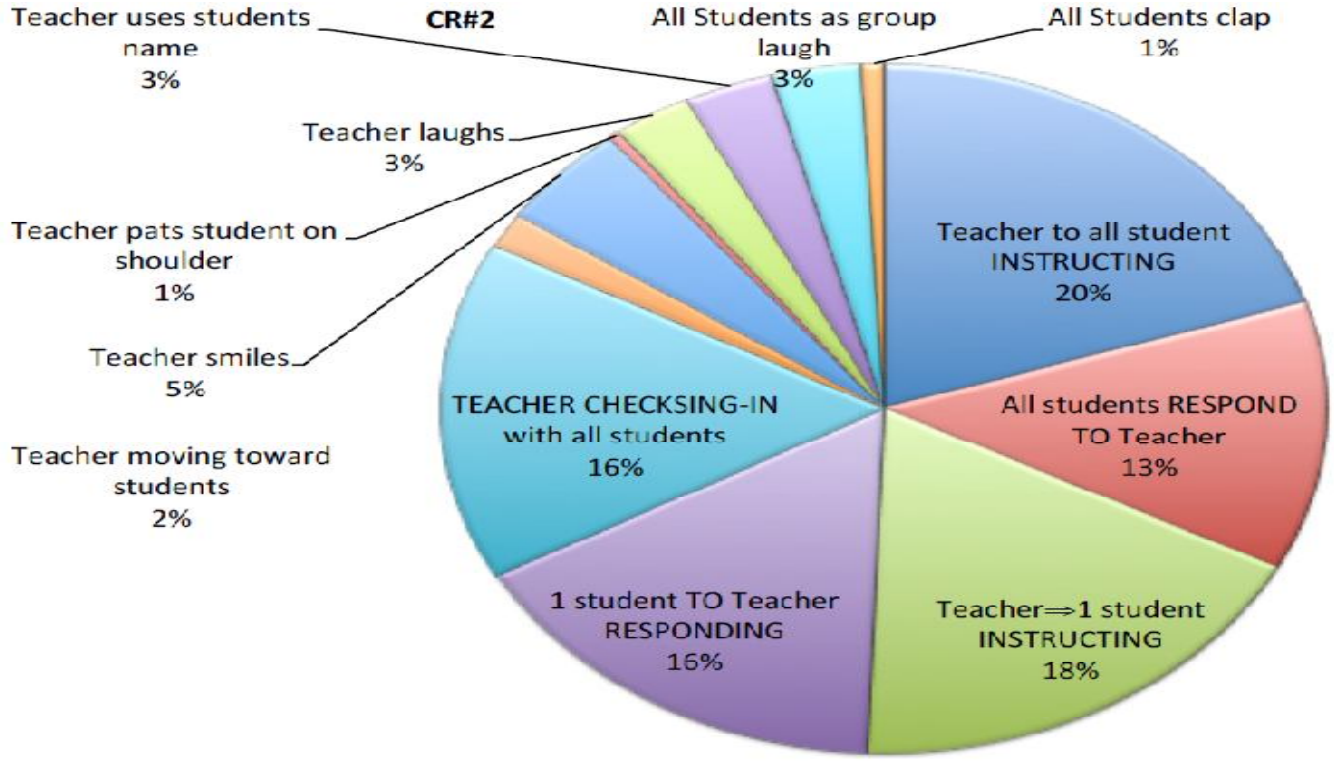
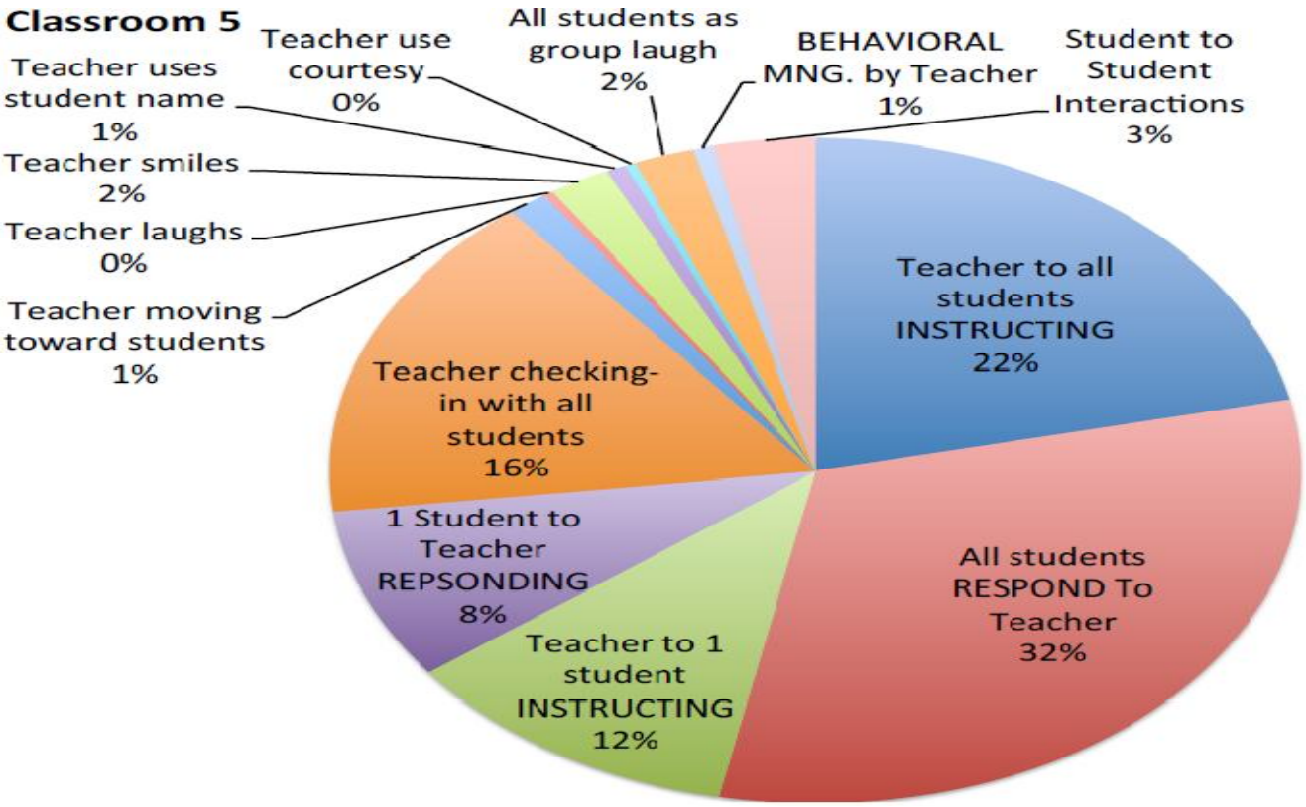


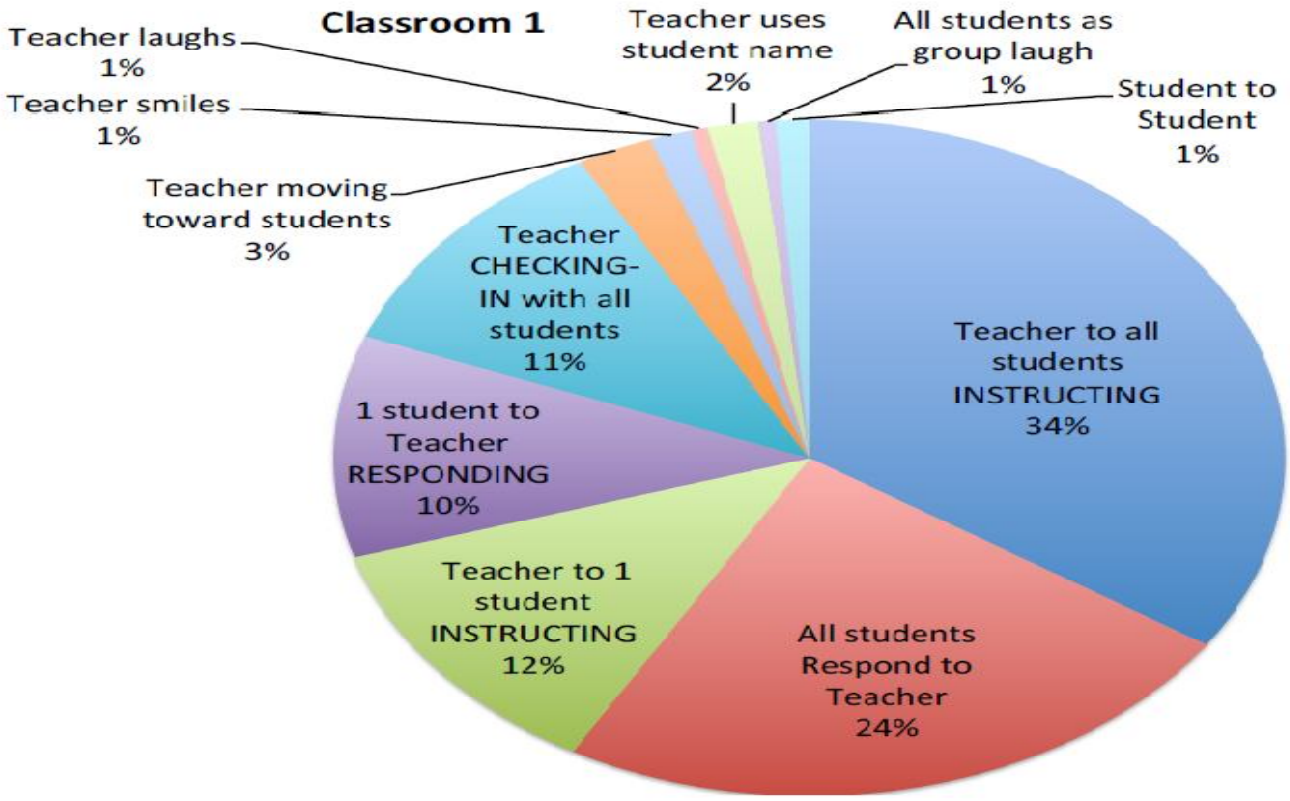
Figure 15: Classroom #4 high school CES Classroom Environment Scale Profile

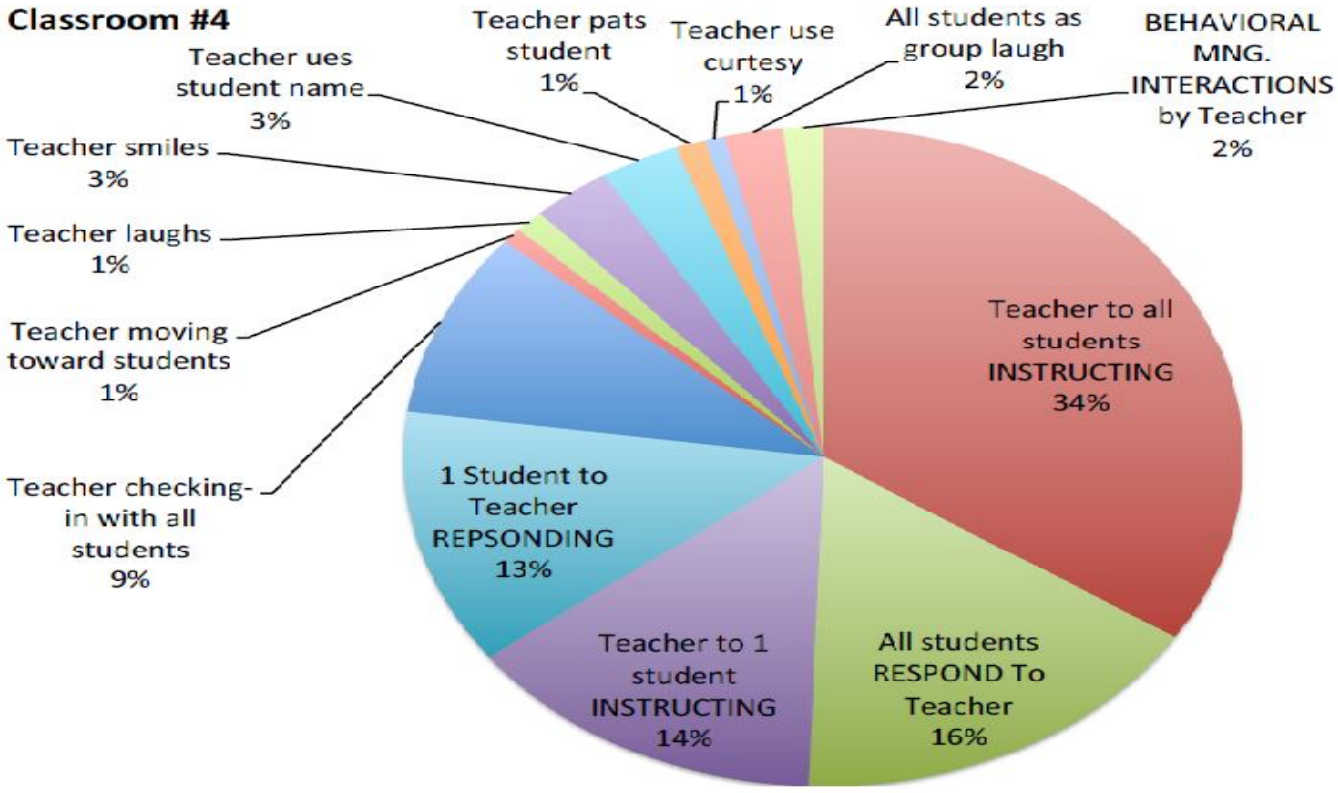
Appendix F

Classroom Interaction Percentages






Classroom 1
Teacher laughs 1%
Teacher smiles 1%
Teacher moving toward students 3%
Teacher uses student name 2%
All students as group laugh 1%
Student to Student 1%
Teacher CHECKING-IN with all students 11%
1 student to Teacher RESPONDING 10%
Teacher to all students INSTRUCTING 34%
Teacher to 1 student INSTRUCTING 12%
All students Respond to Teacher 24%


Classroom #4
Teacher ues student name 3%
Teacher pats student 1%
Teacher use curtesy 1%
All students as group laugh 2%
BEHAVIORAL MNG. INTERACTIONS by Teacher 2%
Teacher smiles 3%
Teacher laughs 1%
Teacher moving toward students 1%
Teacher checking-in with all students 9%
Teacher to all students INSTRUCTING 34%
1 Student to Teacher REPSONDING 13%
Teacher to 1 student INSTRUCTING 14%
All students RESPOND To Teacher 16%