Exploring the Process of Convergent Adaptation in Technology-Based Science Curriculum Construction

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Abstract: As a core complex systems process, understanding the dynamics of individual or group adaptation can provide valuable information for constructing professional development strategies that can increase chances of instructional success. This paper reports on an exploratory study that identifies indicators of convergent vs. non-convergent adaptation between two cases of teachers working together on a technology-based curriculum construction activity and explores the relationship between group characteristics and adaptation processes. We have used the complex systems concept of adaptation as a lens for understanding how and why some teachers are better able to adapt to the educational program requirements. The results show that processes of convergence and non-convergence influenced adaptive outcomes, and that the more similar the teaching characteristic index (TCI) number was between group members, the more likely it was that group dynamics would result in convergent adaptive outcomes.

Introduction
The recent focus on using complex systems approaches in educational research has spawned a number of programs, models and frameworks both for understanding how students learn about complex scientific topics (Hmelo, Holton, & Kolodner, 2000; Jacobson & Wilemsky, 2006; Yoon, 2008a) and for understanding the complexities inherent in educational systems for the purposes of professional development and educational reform (Fullan, 1993; Yoon & Klopfer, 2006). In this study, we follow on the latter line of research in using a complexity lens to investigate and document teachers’ social adaptive processes that help or hinder curriculum construction in the context of a technology-based high school science project. We introduce the concepts of convergent and non-convergent adaptation to assess and predict the outcomes of individual and group dynamics, collaborative products, and success of classroom implementation. As a core complex systems process, understanding the dynamics of individual or group adaptation can provide valuable information for constructing professional development strategies that can increase chances of instructional success. Reiser et al. (2000) for example, describe a study in which achieving mutual adaptation is the goal that drives the use of work circles for curriculum construction that consists of teachers and university researchers. They document constraints experienced by the group due to differing perceived work circle purposes. Whereas the researchers in the group were interested in understanding the process by which teachers came to produce the end product, teachers were less interested in articulating rationales and resolving or discussing how differences got resolved. Despite such challenges, the authors state that the team succeeded in creating a coherent curriculum. It appears then that adaptation did occur. However, missing from the discussion is an analysis of mechanisms that propelled the group to this state. Our study extends this work by investigating how processes of convergence and non-convergence can lead to more or less adaptive outcomes. As described in more detail below, convergence as a core collaborative mechanism has been addressed in processes that fuel conceptual change (Roschelle, 1992), knowledge-building (Scardamalia, 2002), and interactional construction of knowledge (Greeno et al., 1998). As we will demonstrate, convergent processes work well with a complex systems lens due to their implicit relational nature. This paper reports on an exploratory study that identifies indicators of convergent vs. non-convergent adaptation between two cases of teachers working together on a technology-based curriculum construction activity and explores the relationship between group characteristics and adaptation processes.

Theoretical Frameworks
Complex systems approaches have been used in the biological sciences since the 1940s when von Bertalanffy (1968) first introduced the study of Systems Theory. The utility and ubiquity of this seminal theory has since proven to be enormous as many more knowledge domains have used complex systems concepts to investigate how real world phenomena operate and exist as self-organized coherent structures. For example, this theory has been used to understand behavior in non-linear thermodynamic systems (Prigogine & Stengers, 1984), the evolution of cooperation in social systems (Axelrod, 1984; 2006), synchronization in natural systems (Strogatz, 2003), and the
dynamics in cognitive developmental systems (Thelen & Smith, 1994).

Despite variation in physical components or agents, complex systems can generally be defined as existing when any given number of interconnected elements, parts or individuals, communicate in non-linear ways. The patterns of interactions form a collective network of relationships that exhibit emergent properties that are not observable at subsystem levels. When perturbations occur, the network self-organizes often in unpredictable ways where new properties can emerge. In other words, the behavior of the system cannot be accurately determined by simply observing the behavior of the parts. The manner in which complex systems communicate, respond to perturbations and self-organize is understood by studying the dynamical processes through which they evolve over time. Acquiring information from their environment through feedback, complex systems identify regularities in that information and use this to modify behavior in the real world (Gell-Mann, 1994). In this way, they are said to be adaptive. The central interest in our study is investigating this process of adaptation.

**Complex Systems in Education**

In education, there have been two consistent lines of complex systems research. The first and more common in the learning sciences are studies that investigate how students learn complex scientific topics (Chi, 2005; Hmelo et al., 2007; Jacobson, 2001; Wilensky & Reisman, 2006; Yoon, 2008a; Yoon, 2008b). Results have shown that students typically have difficulties in understanding the complex nature of scientific and social phenomena due to inabilities to grasp core complex systems processes such as decentralization (Resnick, 1996), emergence (Penner, 2000), and complex causality (Grotzer, 2005). In order to assist student learning, computational modeling tools and corresponding curricula such as StarLogo, NetLogo, Connected Chemistry, Model-It, and handheld Participatory Simulations (Colella et al., 2001; Klopfer et al., 2005; Resnick, 1994; Soloway & Pryor, 1997; Stieff & Wilensky, 2003; Wilensky & Reisman, 2006) have been constructed primarily by learning sciences researchers to visualize the multiple levels, processes and patterns of interacting agents and events.

The second line of research investigates the complexity of implementing educational change. In his Change Forces series focused on educational reform, Fullan (1993; 1999; 2003) uses complex systems theory as an organizing framework to reveal core concepts such as non-linearity, unpredictability and multi-level agency that are important issues to contend with in real-world educational systems. Elmore (1996) writes about the difficulties experienced by nested clusters of innovation when trying to move from local to global contexts. He states that failures, historically, in generating successful large-scale reforms can be attributed to an “absence of practical theory that takes account of the institutional complexities that operate on changes in practice” (p. 21). Coburn (2003) reinforces the idea that educational reform and improvement are matters of complexity. She further contends that better research designs must be utilized to capture a more complex vision. Within the CSCL community, an influential body of research has sought to document impacts by educational and information technology programs on educational reform efforts (Dede et al., 2005; Fishman, 2004; Fishman & Pinkard, 2001). One common recommendation for reform strategies amongst these programs is to recognize and leverage the multiple variables and curricular goals of system constituents (Dede & Honan, 2005). Elsewhere we write about a professional development program for implementing one of the above computational modeling tools in a small urban school district. Using a complex systems lens for program construction and evaluation in which the variable of adaptation figured prominently, charting the changes in professional development activities such as workshop foci, facilitation structures, partnership roles and curriculum shifts assisted in coordinating and prioritizing needs as well as revealing important gaps in our professional development programming (Yoon & Klopfer, 2006). In biology, adaptation refers to the notion that organisms become suited to their habitats. It was one of the main concepts enabling Darwin to construct the theory of evolution. The theory can be briefly summed up in the following way. As environmental conditions change, pressures on populations to survive also change. Through the mechanism of inheritance, natural selection, which is the random emergence of new adaptive characteristics, dictates whether organisms survive or become extinct. Varela (1999) extends the idea of biological adaptation to human and social systems. He argues that humans always operate in some kind of immediacy in a given situation and contends that environments and identities are historically constituted. In other words, our ability to function organizes around recurrent patterns of embodied experience as we make transitions from one environment to the next. In cases where human experience cannot cope with a specific environment, we must carefully examine the parameters around which such a breakdown occurs in order to seek better strategies.

**Processes of Convergence**

What might the parameters that more or less affect adaptive outcomes look like? We found a number of interrelated processes in the learning sciences literature. Greeno et al. (1998) discuss a set of attunement variables that indicate
well-coordinated patterns of participation in interactive systems of activity where the group and its actions become the unit of analysis. Indicators of mutual construction of meaning include responses of acceptance, objections, affirmations, and repairing of interpretations. They also discuss from a systems perspective observing trajectories of discursive participation such as turn-taking patterns that can reveal the status of individuals in the group. Thus, one might perceive the dynamics in a group that does not exhibit responses of acceptance, objections etc., as not coordinating well and where convergence on shared meaning may be difficult to achieve. Where trajectories of turn-taking reveal hierarchical rather than decentralized patterns of communication, the differential status of group members may influence types of individual participation. In his seminal work on convergent conceptual change, Roschelle (1992) likewise reveals through patterns of conversational turn-taking, in addition to the content of those turns, that convergent conceptual change is achieved incrementally, interactively and socially through participation in joint activity. The content of turns is key here in that jointly constructed metaphors and progressively higher standards of evidence are necessary conditions for conceptual change to occur. In situations where metaphors are not jointly constructed and where the use of progressively higher standards of evidence does not occur, this might lead to non-convergent adaptation.

Another important set of processes discussed in the CSCL literature deal with the difference between collaborative and cooperative learning (Dillenbourg & Schneider, 1995; O'Donnell & O'Kelly, 1994). Dillenbourg and Schneider (1995) make a distinction between cooperative and collaborative learning in that cooperative learning is “… a protocol in which the task is in advance split into subtasks that the partners solve independently” (p. 8). Conversely, collaborative learning describes situations “… in which two or more subjects build synchronously and interactively a joint solution to some problem” (p. 8). We take the distinction between the two as indicators of convergent and non-convergent adaptation in that collaborative processes tend to lead more to convergence of shared meanings and higher levels of adaptation through joint activity.

Finally, Scardamalia (2002) describes a program of cognitive, pedagogical and technological affordances that lead groups of learners to achieve collective cognitive responsibility. This canonical process of knowledge-building also attributes success in such learning communities to a set of twelve determinants that include amongst others, epistemic agency—participants offer their ideas and negotiate a fit with the ideas of the group, democrizing knowledge—all participants contribute to community goals and take pride in knowledge advances of the group, and symmetric knowledge advancement—expertise is distributed amongst the group and knowledge is exchanged regularly between group members. Taken collectively, we draw from this literature, a set of indicators in joint activity that are hypothesized to lead to convergent and non-convergent adaptation. Convergent adaptation is described by conversational dynamics where: i) group members share approximately equal speaking time time; ii) turn-taking patterns that indicate a level of synergy as demarcated through group members finishing each other’s sentences; iii) members all contribute to the goals of the group collaboratively; iv) individual ideas are negotiated and decisions are made collectively; and v) group members distribute expertise across the group. Conversely, in non-convergent adaptation: i) group members do not share equal speaking time; ii) turn-taking patterns show that members rarely finish each other’s sentences; iii) members contribute to the goals in a cooperative manner; iv) individual ideas are not negotiated and decisions are made unilaterally; and v) expertise is localized and not distributed. We apply this convergent/non-convergent framework to small group participation data collected from a professional development activity of curriculum construction described below.

**Methods**

**Context**

This work is part of a comprehensive large-scale NSF-funded project under the program title *Innovative Technology Experiences for Students and Teachers (ITEST)*. The ITEST program is designed to increase opportunities for students and teachers in underserved schools to learn and apply information technology concepts and skills in the STEM content areas (science, technology, engineering and mathematics). Our project, entitled *Nanotechnology and Bioengineering in Philadelphia Public Schools* (ITEST-Nano) aims to achieve the broader ITEST goals through a curriculum and instruction framework premised on five component variables addressing content knowledge, pedagogical content knowledge and workforce development goals: i) real world science and engineering applications; ii) educational technologies to build content knowledge; iii) information technologies for communication, community-building and dissemination; iv) cognitively-rich pedagogical strategies; and v) STEM education and careers investigations.

There are two parts to the scope and sequence of project activities. The first part entails a three-week 75-hour teacher professional development workshop in the summer where teachers learn to construct and pilot curricular units based on the five component variables of the ITEST-Nano framework. These curricular units are
also aligned with school district standards for high science. The summer workshop is followed by the school-year implementation of these units in teachers’ classrooms. For this study, we focus on interactions of the teachers in the summer workshop activities conducted in August 2008.

Ten male and six female teachers participated in the workshop from 10 high schools and 1 middle school in the district. The ethnic breakdown of the teachers included 7 White, 6 African American and 3 Asian. Courses taught ranged from grades 8 – 12 in the content areas of physical science, biology, chemistry and physics. The average number of teaching years was 15.8 with a range of 1 to 39 years of experience.

Teachers self-organized into 7 curriculum unit construction groups in the second week of the summer workshop. Based on researcher field notes, we noted some variance amongst the groups in terms of adaptation dynamics, which led us to hypothesize that there were differing processes of convergence occurring. The dynamics of two groups are showcased as representative examples of how convergent and non-convergent adaptation occurred in the small groups and are presented as case studies in the results section.

Data Sources
Several data sources were used in our investigation to understand the processes involved in convergent and non-convergent adaptation. These sources included: (a) participants’ application forms in which participants’ teaching experiences were listed, (b) pre-workshop surveys from which teachers’ prior content and technological knowledge were gleaned, (c) audio-tapes of the interactions during the small group unit construction time (approximately 60 min) where the conversational dynamics were examined, (d) researcher field notes in which observations of pilot teaching in the third week of the workshop and anecdotal participant-researcher conversations were recorded, and (e) post workshop questionnaires from which feedback of their experiences were obtained.

Data Analyses
Several analyses were performed on the data collected. First, from the application form and pre-workshop surveys, a teaching characteristic index (TCI) was calculated for each teacher based on their teaching experiences and characteristics. These characteristics included, number of years of experience, formal leadership role within their school, amount of content knowledge as determined by number and kind(s) of post-secondary degree(s), generalized vs. specialized subjects taught, e.g., grade 8 general science vs. grade 11 chemistry, workshop experience in content domain, initial understanding of content domain, and experience with education and information and educational technologies. Codes for each of the characteristics were assigned 0-2 in most cases. For example, the category of number of years of experience was parsed into the following codes: <5 years = 0; 5-10 years = 1; >10 years = 2. In other cases, codes were assigned as 0 or 1, e.g., no formal leadership role = 0 and formal leadership role =1. An aggregate TCI score was calculated by summing all the assigned category codes for each teacher. We hypothesized that the TCI score could serve as a possible predictor of a groups’ adaptation processes in such technology-based science curriculum construction activities, i.e., the more similar the group members’ TCI scores were, the more convergent their adaptation processes within the group would be given that their experiences, knowledge and skills were similar.

Convergent and non-convergent processes in our representative groups were investigated using audio-taped discussions, which were transcribed and analyzed according to the set of convergence indicators outlined earlier in the Processes of Convergence section. Accordingly, group members’ proportional speaking time was determined. Turn-taking patterns in which group members finished each other’s sentences were quantified. For the three remaining categories of convergence indicators, instances in which individuals contributed to group goals, instances of idea negotiation, and instances of distributed expertise were noted and compared across the two groups. Other data sources were used to understand group-specific outcomes that contextualized the convergent/non-convergent analytical framework.

Results
Group A, which was comprised of two teachers who worked in the same school and taught different subjects and grade levels, demonstrated a higher level of collaboration from the outset. They were the first group to complete their unit construction and mentioned periodically how much they enjoyed the unit construction time. They co-taught their unit in mostly equal proportions to pilot summer school students in the third week. They followed the project template for their scope and sequence of unit activities and at the time of writing this paper, have also begun to implement the curriculum unit with similar motivation and interest in their regular school year classrooms. By contrast, Group B, which consisted of three teachers who taught at different schools and in different subject areas and grade levels, showed none of the collaborative qualities exhibited by Group A. One teacher in Group B
mentioned during informal discussions with one of the researchers that he did not like the unit construction time in the small group. This feeling was also corroborated in his post workshop survey. In addition, during the third week of the workshop, group members voiced concerns about unequal distribution of teaching time when their unit was being piloted with summer school students. Furthermore, their unit was the only one in which the scope and sequence of curricular activities differed from the sample unit templates provided to teachers. Instead, the group used an organization that was only familiar to one of the teachers in Group B. Finally, at the time of writing this paper, it is projected that only one teacher will successfully complete the implementation of their unit.

The analysis of the case groups’ characteristics and interactions confirmed our hypothesized difference in their adaptive processes. In Group A, the two teachers had similar TCI scores, which were very high amongst the group totaling 7. In contrast, TCI scores varied across members in Group B where Henry scored 6, Randy scored 5, and Jane scored 4 (see Table 1). For our participant population on the whole, the mean for the TCI score was 5.56, standard deviation, 1.46 and variance, 2.13. We discuss possible relationships of these scores to the respective adaptive processes exhibited in each group in the Discussion and implications section.

<table>
<thead>
<tr>
<th>Group</th>
<th>Teacher</th>
<th>Teaching Characteristics Index (TCI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Dana</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Angela</td>
<td>7</td>
</tr>
<tr>
<td>B</td>
<td>Randy</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Henry</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Jane</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>Cindy</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Lucy</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Nancy</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>Frank</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Perry</td>
<td>9</td>
</tr>
<tr>
<td>E</td>
<td>Manny</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Jake</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Jerry</td>
<td>5</td>
</tr>
<tr>
<td>F</td>
<td>Andy</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Zane</td>
<td>4</td>
</tr>
<tr>
<td>E</td>
<td>Mark</td>
<td>5</td>
</tr>
</tbody>
</table>

The sections that follow describe how these groups adapted differently during their co-construction of curriculum units in terms of group members’ proportion of speaking time, turn-taking patterns, contribution towards group goals, idea negotiation, and expertise distribution.

**Proportion of Speaking Time**

By calculating how much time a group member spoke in each group, we found that the percentage of members’ conversational participation varied across the two groups. In Group A, both teachers spent almost equal time speaking in their group, whereas teachers’ speaking time varied significantly in Group B (see Table 2).

<table>
<thead>
<tr>
<th>Proportion Speaking Time</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dana</td>
<td>51.26%</td>
<td>48.74%</td>
</tr>
<tr>
<td>Angela</td>
<td>60.60%</td>
<td>29.99%</td>
</tr>
<tr>
<td>Randy</td>
<td>60.60%</td>
<td>29.99%</td>
</tr>
<tr>
<td>Henry</td>
<td>9.41%</td>
<td>9.41%</td>
</tr>
</tbody>
</table>

**Turn-taking Patterns**

In order to identify turn-taking patterns, we particularly looked for turns when group members tried to finish each other’s sentences or ideas, which we believed was an indicator of convergent adaptation. The results showed that more such turns occurred in Group A’s conversation (a total of 26 instances) than appeared in Group B’s
conversation (a total 6 instances). Excerpt 1 demonstrates an example of the turn-taking pattern of Group A.

**Excerpt 1**

Angela: I'll just say 2 videos from err…
Dana: Right, “I know nano” and 2nd video, what was it?
Angela: Yes, video is err… she has it in here…

**Contributions Toward Group Goals**

Members in both groups contributed to achieve their respective group goals but did so in different ways. Specifically, teachers in Group A worked together in a more collaborative manner whereas teachers in Group B worked in a more cooperative manner. For example, Group A’s dynamics showed that Dana and Angela often evaluated each other’s contributed ideas and made decisions together. The following excerpt shows one example:

**Excerpt 2**

Angela: Before that, maybe we can start with a kind of video.
Dana: What kind of video?
Angela: Some kind of a nano… we have a …
Dana: Wait, this is our general. We can switch the sequence if you want…
Angela: So I…
Dana: Oh you mean put a video in? Ok. So which one do you want?
Angela: This is the one “take the nano-journey” (pointing to the computer screen). That’s the one…
Dana: Yeah.

The above excerpt shows an example of how Dana took Angela’s idea to insert a video into their unit and evaluated whether it was the right place to insert it. They showed a manner of collaborative work in which they treated their curriculum construction as a social action in which the group members worked together to produce a joint solution.

In Group B however, Randy, Henry and Jane contributed to the group work in an isolated way without much group interaction. The following excerpt demonstrates a typical way in which their group communicated:

**Excerpt 3**

Henry: Could we put this (a website Henry found) in now?
Randy: Yeah. What's that?
Henry: I just want to see if this could be put in before …, just so we have it. Put it right in.
Randy: Right. Where do you want to put it?
Henry: Or, it has to go under … medicine, right there.

In this excerpt, Henry makes a contribution by providing a website resource to the group. Instead of considering whether the content was appropriate or if it was the right place to insert, Randy took Henry’s idea without giving any feedback or evaluation. Throughout the transcript, group dynamics indicated similar instances of idea contribution without evaluation. Thus, Group B exemplifies what Dillenbourg and Schneider (1995) describe as cooperative action in which partners solve problems independently.

**Idea Negotiation and Decision Making Processes**

Another dynamic we investigated was how groups negotiated agreement on individual member’s contributions of ideas and processes of decision-making. Results showed that the two groups differed again in these fundamental idea negotiation dynamics. For Group A, both teachers individually contributed ideas but shared responsibility for decision-making. The following excerpt illustrates this dynamic:

**Excerpt 4**

Angela: And maybe we can ask them on day 3 at the end, we can ask them like what do they want to put in
their podcast. So write it down.

Dana: Right.

Angela: So at the end of day 3. So they write it down. So when they come… Thurs when they come in, when they prepare the …

Dana: (Flipping through her notes) Oh, we did, we have them for day 4… Discussions for pros and cons for podcasting. Let’s just put that at the end of day 4.

Angela: Day 4 is the day we do it. Well, that’s fine.

Dana: Oh ok. So I think we’re good.

This example shows the process of group negotiation before reaching an agreement. First, Angela proposed to have the students put down their thoughts for their podcast content on day 3. Dana then disagreed by showing Angela that they had planned to discuss pros and cons for podcasting on day 4. Angela changed her initial idea and agreed to move the activity to day 4. Although this excerpt does not demonstrate evidence of reasoning that might have convinced each other (the process of reasoning can actually be heard in earlier parts of their discussion), it does show that both teachers held equal responsibility in the group decision-making process.

In Group B, the group members did not show much individual idea negotiation during their group curriculum construction. The decision-making responsibility fell on the person who initiated an idea and the other group members did not provide feedback or alternative ideas. Thus there was no negotiating process before a decision was made, which we believe contributed to a dynamic of non-convergence within the group. For example in excerpt 3, we saw how Henry made an individual contribution in terms of including a web resource in their curriculum and also unilaterally decided where in the scope and sequence, the website should be placed.

Distribute Expertise

We believe that how teachers leveraged individuals’ expertise within their groups indicated their type of convergence. Analyzing the groups’ transcripts, we found the two groups differed in their approaches to expertise distribution. Specifically, Group A showed a collective expertise distribution, e.g., knowledge sharing or expertise was directed back and forth between members, while Group B illustrated a localized or compartmentalized approach, e.g., knowledge sharing or expertise occurred in only one direction. The following excerpt shows how Dana and Angela exchanged their respective expertise with each other.

Excerpt 5

Dana: What their knowledge content is before we move into this? Because how much do we really go into it… We can just give them a general…

Angela: Yeah, the general… like “What is matter?”

Dana: Right. Right.

Angela: What is the property? What are the physical properties…

Dana: Right. What is the difference between physical and … so basically the difference between the physical and chemical properties, right?

Angela: And then, the 3 phases of matter.

Dana: Right.

Angela: And how they change? … and we can talk a little bit about the pressure…

Dana: Ok right. So we are going to talk about pressure, and the needles. So what’s going to happen is we are going to talk about pressure. I’m going to give them balloons…

The above example shows that Dana first suggested that they should consider teaching the students some general content knowledge before their planned activities. Angela then brought into the conversation, her expertise on the topic of matter in physical science. At the same time, Dana also contributed her expertise based on her understanding even though her expertise fell in biology. This interaction augmented the group’s collective knowledge about the topic of matter and helped to make progress in the curriculum construction.

In contrast, Group B showed more of a unidirectional expertise distribution, which often led to a didactic process of transferring knowledge. In the excerpt below, Henry appeared to teach his fellow members about the concept rather than contributing to a collective discussion.

Excerpt 6
Henry: I just made my point again. If you take 50 milliliters of alcohol and 50 milliliters of water and put them together, we will have how many liters will show on.

Randy: Like 99 something like that.

Henry: Well, 97.

Randy: Ok.

Henry: Why?

Jane: Because some goes up in the air?

Henry: No. Because the m … they slip into each other.

Jane: The m?

Henry: The atoms of the alcohol rubbing alcohol, slip into … The way is this … with the scale, the weight remains the same between the two,

In this conversation, Henry acted like an instructor teaching the other two members about the alcohol and water experiment. After this exchange, the group went on to a different topic rather than continuing the discussion.

Discussion

Our study directly responds to calls for using reform strategies in technology-based educational programs that can account for the complexities that influence their successful implementation in practice (Coburn, 2003; Dede & Honan, 2005; Elmore, 1996). We take the view of Small Groups as Complex Systems theory (Arrow et al., 2000) that evolves from a social psychological heritage and considers group dynamics as emerging products from complex and adaptive systems. We have used the complex systems concept of adaptation as a lens for understanding how and why some teachers in such educational programs are better able to adapt to program requirements (Yoon & Klopfer, 2006). To investigate this, we constructed a framework that examines the parameters under which group dynamics can lead to more or less adaptive outcomes. Based on seminal CSCL research, we have hypothesized that processes of convergence exhibited in teacher group interactions can predict these adaptive outcomes and present two cases that illustrate instances where convergence and non-convergence occurred.

The analyses of the small group unit construction discussions showed differences in the two case groups’ convergence and non-convergence processes, which represent different types of adaptation of immediate individual feedback to the program requirement in a collaborative context. One major difference lies in whether the group communication structure was hierarchical or decentralized (Greeno et al., 1998). Teachers in Group A shared approximately equal speaking time and demonstrated turn-taking patterns where members were heard finishing each other’s sentences a comparatively higher proportion of the time. This communication structure can be understood as decentralized and may have, in part, led to convergent adaptation. In contrast, Randy in Group B led much of the communication, speaking for more than half of the discussion time and instances where members finished each other’s sentences represented less than one-fifth of the proportion found in Group A’s discussion. Thus, the communication pattern can be viewed as hierarchical rather than decentralized and may have led to non-convergent adaptation.

In addition, the two groups illustrated the distinction between collaborative (Group A) and cooperative (Group B) task completion (Dillenbourg & Schneider, 1995) and showed differences in how members contributed to group goals, idea negotiation and decision making processes. Group A again demonstrated higher level functioning in all these measures compared to Group B. These findings are similar to those found in other studies where consensually driven explanations (Roschelle, 1992) and knowledge-building through epistemic agency (Scardamalia, 2002) led to increases in shared meanings and collective responsibility of cognitive tasks. Finally, in order to complete the curriculum construction, teachers in Group A contributed their expertise in a distributed way as opposed to the unidirectional pattern found in Group B’s discourse. This is an example of what Scardamalia (2002) has called democratizing knowledge and symmetric knowledge advancement, both of which have been shown to lead to higher levels of knowledge building. When taken collectively, we can see how processes of convergence and non-convergence influenced differential adaptive outcomes that explain why Groups A and B experienced different levels of success in the curriculum construction activity as explained in the first paragraph of the Results section.

Human and social adaptation is influenced by individual characteristics including knowledge, goals, experience, preferences, interests, and surrounding environment (Brusilovsky, 2001). In this study, we examine the parameters that benefit teachers to collaboratively seek better strategies as they make transitions from one pedagogical paradigm to the next. With respect to the teaching characteristics index calculations presented in Table 1, we were interested in understanding whether we could in some way predict a priori which group configurations
based on their teaching experiences would lead to convergent adaptation. There is evidence to show that the more similar the TCI numbers were between group members, the more likely it was that the groups’ dynamics would result in convergent adaptive outcomes. While we showcased Group A in our analyses, Groups C and F also showed similar patterns and the opposite was true for Groups E and F in terms of non-convergent adaptation.

**Implications**

We are in the process of collecting data from all of our teacher participants’ implementations of the co-constructed curriculum units during the school year and expect to conduct further analyses to compare teachers’ classroom implementations as well as student learning outcomes where we hope to find correlations between teachers’ TCI scores and their groups’ adaptation patterns. We also intend to conduct similar analyses with new cohorts of teachers attending our summer workshops in 2009 and 2010. However, as reform-oriented professional development learning science researchers, we find value in taking a more microscopic approach to understanding group adaptation processes in order to structure curriculum construction activities that will maximize potential for future success. From the results of this study, we are now in the process of identifying group activities that teachers can participate in where convergent processes are **modeled** and **practiced** prior to working in their curriculum construction groups. Furthermore, rather than allowing teachers to self-organize into groups, we are considering pre-assigning members to specific groups based on similarities in TCI scores with the intention of collecting more robust evidence that can demonstrate the efficacy of this method and justify its application in constructing professional development activities.

**References**


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